Technologies
for water

1942 – 2007

Water Supply and Sanitation for All

Obligation of the water professionals for our common future

International Symposium
September 27 – 28, 2007
Berching – Germany

in cooperation with:

International Water Association

EWP
European Water Partnership

Water Supply and Sanitation for All

Obligation of the water professionals for our common future

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ISBN 13978-1-84339-514-0
ISSN 1476-1785

Printed by: M.W. Bauer, 92339 Beilngries

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Foreword

The supply of healthy drinking water and disposal of our wastewater is a central problem. Solving this problem is one of the claims of the UN Millennium Development Goals, and consequently an obligation for all those involved with water to join efforts in finding solutions. This applies to sanitary engineers, politicians, financiers, sociologists and many others.

In this symposium we want to examine the subject from different angles, mainly from the point of view of sanitary engineers. I am sure we will be able to provide a comprehensive overview since experts from all over the world have been invited to speak. We want to show the possibilities we see concerning the connections related to water and present an outlook on the future.

This includes, of course, proposals and solutions that need to be implemented. The outlook will also reveal that we have to abandon many a conventional technology and common concept if we want to achieve the UN Millennium Development Goals.

My thanks go to all who have added to the success of this conference, especially to all the speakers who have made a substantial contribution and took it upon themselves to travel all the way to Berching. Thanks also to the organizers Prof. Dr. Peter Wilderer, Dr. Stefania Paris and Prof. Dr Franz Bischof.

I also wish to thank IWA, EWP and Academia Scientarium et Artium Europaea for their cooperation.

For me personally, this symposium is a highlight in my professional career. For forty years I have been engaged in water engineering, of course from the perspective of a businessman. All the time, I have considered it very important that also business companies, through innovation, contribute their share to solving problems.

For it is innovation that makes companies fit for the future and strengthens their market position in the long run. Therefore, I feel it is important not to look back but to open new perspectives for the future with this symposium – of course also for the future of my company. I also would like to take this opportunity to thank all the institutions and universities that have provided me with ideas over the forty years of my working life and supported me in developing my ideas. And I hope that in cooperation with science institutions HUBER Technology will also in future remain a company with a great innovative ability.

Hans G. Huber

Berching, September 2007

Change of Paradigms !?

Climate change, population growth, migration and urban sprawl are factors forcing us to reconsider the traditional approach to urban water manage-ment. The water supply and sanitation infra-structure currently in use worldwide was developed in and for countries which are relatively wealthy, and which have access to plenty of water. Unfortunately, conditions like this are not common in other parts of the world, and they may become uncommon even in many of the industrialized countries.

Is it really wise to build the same kind of infrastructure and to apply the same methods and processes in regions with different climatic, ecological and economical conditions? Should we maintain our flush and discharge sanitation concepts while freshwater is becoming a limited resource? Aren't there smarter, more environ-mentally sound methods to use and safeguard our precious water resources? Are water authorities, city planners, architects, regulators and politicians ready to accept innovative solutions deviating from those described in text books?

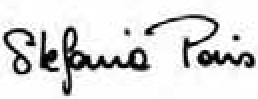
Questions like these will be raised during our symposium, and we will jointly search for answers. We, the organizers, encourage open and contro-versial discussions, although we admit to believe that wastewater should no longer be viewed and treated as waste, but as a valuable resource.

September 2007

Hans G. Huber

Prof. Dr. Peter Wilderer

Dr. Stefania Paris



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Introduction

Tom Vereijken*

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Mr. Tom Vereijken

Water is Life – Water from the Biblical and Theological Point of View

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Abstract: "Water is life": This expression sets forth a positive message, which can be found–and used–in a variety of contexts. This is demonstrated statistically by the fact that a well-known internet search engine specifies 168,000 "hits" for the expression "water is life" in English, and an additional 113,000 locations for "water is life" in German. "Water is life" means, above all, to commit oneself to a good and important cause.

The biblical point of view sees present reality through the eyes of people who view their life and the world as gift of God, people who enter into a relationship with God and who live in this relationship. For biblical people, their history is a history with God. Seen this way, it is salvation history, which received its good beginning from God, and God is also its good end, whatever form it takes. Yet this biblical viewpoint also very realistically perceives everything in this world that is bad and evil. In the primeval history of the book of Genesis (Gen 1-11), we find both the positive and the negative. Regarding the topic of "water is life", we learn about the life-giving aspects of water and about its life-threatening and deadly aspects as well.

The world from god: "god saw that it was good." (Gen 1:9, 12, 18, 21, 25)

Creation, coming as it does from God, is thoroughly good. A "house" for humans to live in is arranged. Potentially threatening aspects, like the waters, are within placed within limits:

- *... Darkness was upon the face of the deep; and the Spirit of God was moving over the face of the waters...*
- *... And God said, "Let there be a firmament in the midst of the waters, and let it separate the waters from the waters."*
- *And God made the firmament and separated the waters which were under the firmament from the waters which were above the firmament...And God called the firmament Heaven... And God said, "Let the waters under the heavens be gathered together into one place, and let the dry land appear." And it was so. God called the dry land Earth, and the waters that were gathered together he called Seas. And God saw that it was good. (Gen 1: 2, 6-10)* [1]

According to Erich Zenger *(Introduction to the Old Testament, 1995)* this theological expression of creation drew its inspiration from the image of an annually flooded river plain, such as the Nile in Egypt, or the Euphrates and Tigris Rivers in Mesopotamia. The surface of the earth emerged from the waters, vegetation likewise began to sprout, and, as habitable earth, it became populated by animals and human beings.

The first book of the Bible contains two creation narratives. In contrast, as "chaos before Creation", the second creation narrative (Gen 2-3) introduces completely dry fields where water sources from God will create a flowering paradise. This is expressed figuratively and anthropomorphically as follows:

"The LORD God took the man and put him in the Garden of Eden to till it and keep it." (Gen 2: 15)

Life, then, is dependant on water according to both creation stories. God's creative work places the gift of water into a system of order. This means, on the one hand, forcing back the waters, and on the other hand, fending off the deadly drought and laying out an irrigated garden that will become the garden of Paradise.

The world of human beings: god saw the earth, and, behold, it was corrupt. (Gen 6:12)

From the Biblical viewpoint, the negative development of life becoming adverse to creation and being fundamentally threatened is the work of man, who greedily and violently abuses his liberty and disturbs the order. It was through man that the world, of which it is said: *"and God saw that it was good"*, became a world of which it is said: *"God saw the earth, and, behold, it was corrupt."* What followed is something most people know, even without any profound knowledge of the Bible: the great flood and the rescue of Noah, along with all who found a place in the ark. Wherever man disturbs the order of creation, or completely destroys it, chaos returns in the figure of the primeval waters.

However, the history of mankind after the great flood never progresses back to the good. A return to Paradise does not take place. That is something recognized up to the present day. The realistic Biblical viewpoint of the condition of the world and the disposition of man is expressed as the word of God: "*... the LORD said in his heart, "I will never again curse the ground because of man, for the imagination of man's heart is evil from his youth..."* (Gen 8:21) God blesses these human beings, whose "imagination of heart" is bad, and gives them the commission again: *"Be fruitful and multiply, bring forth abundantly on the earth and multiply in it."* (Gen 9:7) – Creation was placed once again into man's hands up to the present day.

Water in salvation history: reference to the mystery of baptism

"Water" in the Bible is not, of itself, a symbol of life. It requires integration into the totality of creation; it must be allotted a place in the order of creation. Then it is not only the cradle of earthly life anymore, but rather the image of the divine life, in which man receives a share. In the Biblical perspective, creation is never merely an earthly quantity. It cannot be adequately described in measure, number or weight. Creation has a referential character, meaning that it refers to something, to someone greater than itself. It refers to God. Water, which is the cradle of life, receives special attention in the Bible. Water becomes the sign of the deeper meaning of earthly life, and of the dimension of God. Thus, in the Bible we encounter again and again the image of God as the source of life; and the image of dew, and of the river. One who turns his life over to Christ and places it, through faith, into the dimension of God, is in need of baptism. At the dawn of Christianity, as the act of incorporating the believer into God, baptism was administered at a river by immersion in the flowing water. People attached great importance to baptizing with flowing water, that is, with living water, because the new life of God, into which the newly baptized person was incorporated, should be adequately expressed in the procedure of baptism. Just as all creation emerged from the waters, so the new life of God, the new creation of man emerges from the water of baptism. This remained in the consciousness of Christianity, even after the administration of Baptism was relocated within ecclesiastical architecture, into the baptistry. This baptistry contained a large basin of water, into which the candidate for baptism climbed and was immersed three times. The water of baptism, and faith in Christ, give us the life of God. Even today, baptism is administered by pouring at least a small quantity of water three times.

The conversation of Jesus with the Samaritan woman at Jacob's well provides the basis for such an understanding: "*Whoever drinks of the water that I shall give him will never thirst; the water that I shall give him will become in him a spring of water welling up to eternal life.*" (John 4, 13-14) The sacrament of baptism opens this way to us.

Particularly in the Easter night, the biblical and theological view of water enters profoundly into the language. In "*praising and invoking God to bless the water of baptism*" we find, to a certain extent, a summary of this salvation history:

"...In a variety of ways, you have chosen to make water a sign of the mystery of Baptism:

At the very dawn of creation, your Spirit was moving over the waters, and granted them the power to save and to make holy.

Even the Great Flood was a sign of baptism, for the water defeated sin and made a new beginning for holiness of life.

As the children of Abraham were liberated from enslavement to the Pharaoh and passed on dry ground through the waters of the Red Sea, they were a sign of your faithful ones who, through the water of baptism, are liberated from evil.

Almighty, eternal God, your beloved Son was baptized by John in the Jordan and anointed by you with the Holy Spirit.

As he hung upon the cross, water and blood flowed from his side.

After his resurrection he commanded his disciples:

"Go forth and teach all nations and baptize them in the name of the Father,
and of the Son, and of the Holy Spirit."
Almighty, eternal God, look mercifully upon your Church,
and open to her the well of baptism.

By the power of the Holy Spirit, may this water receive the grace of your only begotten Son, so that man, created in your own likeness, may be cleansed from sin through the sacrament of baptism, and, through water and the Holy Spirit, rise to the new life lived by your children.

Through your beloved Son, may the power of the Holy Spirit descend upon this water, so that all, who through baptism, are buried with Christ in his death, may also, through baptism, rise again with Christ to new life. [2]"

In this baptism, the goal of humanity and of all creation, "the eternal life in community with God" is constituted–which we call, among other things, the heavenly "wedding feast", "light", "peace". John's book of Revelation describes this blissfulness of heaven in an inviting, vivid image of the "water of life", which can give us, too, hope and courage in our time:

"They shall hunger no more, neither thirst any more; the sun shall not strike them, nor any scorching heat. For the Lamb in the midst of the throne will be their shepherd, and he will guide them to springs of living water; and God will wipe away every tear from their eyes." (Rev 7:16-17)

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[1] All Bible quotations are taken from the Ignatius Press Catholic Bible-RSV, National Council of Churches of Christ in the USA, San Francisco 2003 –TRANSLATOR

[2] The official English text of this Easter Vigil prayer, **Blessing of the Water**, translated by the International Committee on English in the Liturgy (ICEL) and currently used in the English language liturgy, differs significantly from the German translation. Therefore, the text above is an original translation from the German liturgical text, to avoid losing important parallels between the quoted liturgical text and the previous points made in this lecture. –TRANSLATOR

Dr. Gregor Maria Hanke

Each One of Us Can Contribute

Hans Hermann Hahn*

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Abstract: "Water is a heritage that must be protected and treated with great care. Water is to be used reasonably, in solidarity with others and in a sustainable way. – We, as members of the community of water specialists, demand that the essential resource water is made available to all and that the resources itself as well as the aqueous ecosystem is treated wisely and with great care; we will teach others to do so and we will oppose any abuse of this resource."

Urban water management, i.e. water supply and sanitation is a task with long tradition

There are numerous historical testimonies in all civilizations to a successful solution for the task of supplying safe potable water and to a safe and sanitary removal of rainfall and solid and liquid wastes from settlements. - However the industrial revolution in the past as well as societal changes witnessed today, leading to an urbanization of unforetold rapidity, have led us beyond those classical solutions. Even those concepts that were developed in the Western hemisphere in the wake of the first wave of industrialization, which helped to restore some of the aqueous environments to a liveable quality, seem to be no longer the most promising solutions for tomorrow.

The problems resulting from intensive urbanization are manifest in many parts of the world. They hinder in particular the development of healthy societies and societal structures in areas where the rate of industrialization and urbanization is higher than the financial and organisatorial capacities of society. Statistics of United Nations agencies document that alto many people are without hygienic water supply and sanitation. They also report the sad consequences of such lack of urban infrastructure: diseases, epidemics and high mortality, in particular children's mortality. The world leaders' millennium declaration, in part repeated at the Johannesburg summit and the Kyoto meeting echoes this recognized lack of development and sets the stage for developing new concepts, new activities and improved solutions.

It is the aim of these short introductory remarks to fathom the limits and possibilities of past and present concepts as well as new ideas based on new technologies for the solution of those future tasks (where it must be said that the future has already begun). It is of particular interest to identify the possible contribution of each one of us in our own environment, may we be water specialists or may we only be water users.

Providing water supply and sanitation and generating new problems

Let us briefly recapitulate the 'historical' challenges and the concepts developed for the solutions of water supply and sanitation tasks and also the subsequent problems resulting from these concepts: with increasing population density many cities in the Western hemisphere faced (and face) in the 19th and 20th century the nearly impossible task of providing large amounts of safe drinking water at all times, mostly through large and ever growing centralized systems; and this even for less demanding purposes such as transport of household wastes that do not necessarily require high quality water. The consequence of such sprawling distribution systems is the need for collecting all that water again - mostly together with the urban precipitation. This leads to the establishment of yet another large infrastructure system, the sewerage system. - Today, more than one hundred years after the first conception of such very centralized urban water management one might say that the immediate task of supplying water and then collecting it again, was mastered successfully in particular also in hygienic terms. And what is more, the comfort to each user was and is very high, making everyday life easier. To re-evaluate this solution also means to re-evaluate the degree of comfort offered. To possible step down in degrees is a decision that must be supported by each individual user.

Yet the effect upon the aqueous environment, not only close to such urban centres, was a disastrous one: significant diminishing of the local natural water cycle where abstraction took place and very heavy pollution where the used waters were re-introduced. - Thus, it became very soon obvious that on top of centralized distribution and collection a very intensive purification of raw waters for the production of potable water and treatment of wastewater prior to discharge into natural systems were needed.

Much time and finances needed for traditional infrastructure and still no perfect solution

Expenditures for distribution and collection were very large. Purification and treatment demanded large financial efforts as well. Seen in comparison, the mere transport expenditures, i.e. the cost for distribution and collection, are by far outweighing those of water purification. On top of this the time requirement for planning and building such large network systems is very large, in effect prohibiting fast solutions for of water supply and disposal task if solved with such concepts of ´centralized infrastructure´. This historical solution, has had its merits in alleviating the then observed problems of industrialization and urbanization in the late 19th and up to the 20th century. However, in saying this, one has to remember that there actually was sufficient time and apparently sufficient financial supply to construct these infrastructure systems.

This not unsuccessful concept, however, has in the course of further development led to significant problems, in particular where it was extended or misappropriated to include the collection and removal of substances other than domestic, mostly biodegradable substances of natural origin. Such ´foreign´ matter is for instance industrial waste containing anthropogenic and very often harmful substances.

Both, the mixing of diverse wastewater streams, beginning with urban storm water runoff and domestic sewerage and the inclusion of priority pollutants, foremost from industrial sources, caused a failure of these solutions. Again, it was the argument of expediency and the decision of individuals that led to such failures. To correct this in existing systems requires, alongside with a re-writing of the water management framework, the cooperation of individual decision makers.

Contribution of each individual needed in addition to that of national or international bodies

How does the contribution of each individual complement national or international efforts? It is the argument of this discussion that the effect or the reach of such efforts of individuals are largely underestimated. And furthermore individuals´ actions are much more readily put into effect than those that need national or international agreement and financing.

For most Europeans the basis for such much needed unselfish contributions might still be a certain awe or reverence for our globe and its population, or in other words for creation. Amongst the suggestions for individual action are a careful and saving (in modern terminology "sustainable") consumption of water in its everyday use even in water-abundant regions. In this way the possibilities of attaining or maintaining a satisfactory standard of life at reduced resources consumption can be developed and demonstrated. Very much included into this sustainable use of water is the reduced demand for goods produced with water, whether it is food products or items for everyday´s life. We should ask ourselves more and more whether we really need what we consume today along with all the water used for its production.

There is a special obligation for each one of us who has understood this, be she or he a water specialist or an enlightened water user: We must alert all around us to these problems. The present discussion on limiting or reducing carbon dioxide production is a good example of the necessary rethinking of our way of life – also needed in terms of direct and indirect water usage. It should be a consequence of increased public awareness and the resulting public pressure that for once the necessary financing instruments are set up more readily by national and international institutions and second that more and more qualified young persons decide to enter professional fields that alleviate problems in water supply and sanitation for all. Finally it is to be expected that such a "grass root movement" develops a momentum that leads older and possibly retired professionals to volunteer part of their time and effort for the solution of these "millennium problems".

How to decide what needs to be done tomorrow?

Historians tell us, that we can understand what is coming to us, if we analyze our past, that we are fit to solve future problems, if we have understood yesterdays developments and faults. Extrapolating from what we have identified as our past problems and achievements we can formulate three `imperatives`:

1. We need a HOLISTIC approach to all supply and sanitation concepts.
2. Our water use must be governed by the principle of SAVING.
3. We must SHARE finances, technical know-how and operational experience.

Let us look at the implications of these imperatives, again with a particular focus on what that means for each one of us, what each individual can or must do.

First, a holistic approach

Conceiving urban water management systems in a holistic way implies foremost that we do not separate water supply and wastewater collection, be it in construction, or in operation or in organization. Our former separation of supply and sanitation, for instance also in developmental strategies, is no longer acceptable. We have to analyze and optimize the overall municipal water cycle as is demanded for instance by the European Water Frame Work Directive. Furthermore the former `domination` of all water management decisions by water supply requirements and the concurrent primate of the protection of man is no longer acceptable. As can be seen from the changes in the German Water Law (WHG - Wasserhaushaltsgesetz) in its fourth and fifth amendments in 1976 and 1986; the changed wording puts the protection of the overall aquatic ecosystem as highest goal and is the right approach to future oriented holistic water management. These arguments appear at first glance to be more directed at official and government agencies. However, it is you and me who in the developed regions need to show that in using potable water we must already think of its possible re-use in fishery, in leisure activities and in particular for its ecological function.

Second, to use water sparingly

Resources-aware municipal water management, even in regions where there is no immediate scarcity, is not readily agreed upon by everyone. There are various aspects to be analysed in following this imperative. Domestic water demand, as we are discussing it, is frequently more a problem of infrastructure and less a problem of overall water availability. In this instance we should rather think of saving water transport, i.e. making use of technological developments that allow reliable supply and sanitation of subcenters avoiding expensive transport networks. Industrial water management demonstrates possibilities and limitations of such short-cuts or closing of water cycles. On the other hand agricultural use of water will most likely show the largest increase. Thus, in this area there is not only the largest potential for savings but also the highest demand to be saving. What is needed is a development of agricultural production schemes such that we can survive without "strawberries in winter", i.e. without growing, exporting and transporting such goods from mostly water scarce areas to others that are luxurious not only in water but also in financial terms. Again, without realizing it, you and me as individuals will decide to what degree this call for more awareness, this call for intelligent water resources use is heard and leads to the necessary re-orientation.

Thus, the goal for urban water management of tomorrow, the saving use of water, is accomplished by reducing (a) unnecessary import/export activities of water intensive agricultural products between areas of uneven water resources and (b) by lowering financial and other efforts for water and wastewater collection and transport in particular in areas of water scarcity and lack of (urban) infrastructure. There are numerous options today for this last-mentioned strategy, that can be illustrated by a spectrum of possibilities that surely will be analysed in detail by many of the subsequent papers. Naturally there are all kinds of variations and combinations of such `moving towards more closed water cycles` in domestic or urban water management. And to explore these various options, to demonstrate their feasibility and their robustness in practical solutions is again a challenge for each individual water user, where ever such new solutions are proposed.

Third, sharing know-how, experience and finances

The lack of wholesome water globally seen, i.e. resources and infra-structure, is immense. And solving this problem is dictated by moral and economic considerations. This is agreed upon internationally. It is not easy to accomplish all of this, in regions or by nations that are in the middle of developing all of their resources and all those attempts to answer all citizens' needs of their growing population. These ambitious goals can only be reached by a sharing of finances, technical know-how and operational experience. For, in many `water-management-problem-regions` there is a lack of finances, technical know-how and operational experience.

These resources are available elsewhere. In addition other countries have shown that the aqueous environment and thus, human health can be protected even under conditions of intensive use.

The aspect of sharing can be illustrated in many ways. One demonstration of possibilities and challenges of sharing all types of resources in urban water management is the identification of all actors in this field as there are (a) the water user, and by this also the wastewater producer, (b) the authorities protecting water resources and (c) the planning, constructing and operating agencies. In a global urban water management in the best sense of the word, the here identified ´actors` must not necessarily come from within one region, one organization or one country. There can or should be cooperation across borders and across cultures of any kind.

Concluding remarks

It has been the object of this brief discussion to show how we can and must learn from past experiences - good and bad ones - in urban water management. Three imperatives or directives can be defined for our future decisions on urban water management. Of these the first one, the request for a holistic solution to water supply and sanitation is the most immediate one. This imperative also encompasses the other ones. All three notions of successful water supply and sanitation require the cooperation, the co-financing and the joint responsibility not only of water authorities but of all water users.

Many recommendations as to how to attain such new views of sustainable and moral use of water resources in urban systems have been formulated. One might even cite the publications of the Club of Rome. And many of these manifests address individuals, begging them to accept these challenges. I want to conclude this introductory discussion by listing some of these recommendations or demands that I believe can be fulfilled realistically.

- All of us, even in those regions of Europe that do not suffer from water scarcity should use these resources as sparingly as possible, partly because of our responsibility to creation at large and partly in order to demonstrate that one can lead a very acceptable life style at reduced resources input.
- Saving water in general includes in a more advanced sense that we do analyse our daily diet and our daily use of industrial products. We do have to ask ourselves and can easily do this in any stage of our daily routines whether what we do helps save water here or abroad.
- Since many of us have a rather secured material existence, it might be possible that this new life style of a higher consciousness sets free some financial means that could easily be re-routed into funds for the solution of problems abroad.
- And finally those of us who have been retired, who have stopped earning their support for life by their active work, might think of a part-time continuation of their work – not only as water specialists but also as teachers and managers – in areas where technical know-how, public education and improved management is needed.

The European Parliament has formulated a preamble for the very ambitious European Water Framework Directive which the German Water Association (DWA) has re-written and amplified as a mandate for all of its members:

„Wasser ist ein ererbtes Gut, das geschützt und entsprechend behandelt werden muss. Wasser soll von den Menschen vernünftig, solidarisch und nachhaltig genutzt werden. – Wir in der Wasserwirtschaft Tätigen treten dafür ein das lebensnotwendige Wasser sicher zur Verfügung zu stellen, die Wasserressourcen sowie den Lebensraum Wasser weise und sorgsam zu behandeln und andere dazu anzuleiten und dem Missbrauch des Wasser und der Ressourcen entgegen zu treten."

(Water is a heritage that must be protected and treated with great care. Water is to be used reasonably, in solidarity with others and in a sustainable way. – We, as members of the community of water specialists, demand that the essential resource water is made available to all and that the resources itself as well as the aqueous ecosystem is treated wisely and with great care; we will teach others to do so and we will oppose any abuse of this resource.)

Prof. Dr. Hans Hermann Hahn

Realisation of the MDGs

Paul Reiter*

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Mr. Paul Reiter

Welcome Address Water Supply and Sanitation for All

State Secretary Dr. Otmar Bernhard*, Minister Dr. Werner Schnappauf

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A hearty welcome!

- Ladies and Gentlemen!

Minister's greetings

On behalf of the Bavarian Ministry of the Environment and especially State Minister **Dr. Werner Schnappauf**, I should like to welcome you most cordially to the international symposium "Water Supply and Sanitation for All". The symposium has been organised by "Huber – Technologies for Water" in cooperation with the "International Water Association", the "European Water Partnership", and the "Academia Scientiarum et Atrium Europaea".

The challenge of a deep historical change in awareness

"Water Supply and Sanitation for All" is a claim and a challenge that is clearly forcing itself into the foreground!

Because linked directly with it is the greatest challenge of the twenty-first century and the first natural hazard to currently threaten the whole of mankind: the climate change.

Since Spring this year at the latest the discussion about the urgent need to tackle climate change on a global scale has become a politically explosive issue on an unprecedented scale.

With the 4th IPCC Climate Report we are witnessing a deep historical change in awareness.

Never before in the history of the world has climate change topped the world political agenda.

Never before have we had such binding commitments:

Common goals

The goal is to restrict the global rise in temperature to 2° Celsius.

To achieve this, the EU Member States decided in March this year

- to drastically cut greenhouse gas emissions: by 20 % by 2020,
- to increase the share of renewable energies to 20 % by 2020,
- and to increase the share of biofuels to 10 % by 2020.

Trailblazer in climate protection

Internationally this makes the EU a trailblazer in climate protection.

It demonstrates to emerging countries like China and India that it is possible to disengage economic growth from energy supply.

But even an immediate stop in emissions will still give rise to a global temperature increase of 0.6°C.

Forecasts for southern Germany

Not only the international climate report makes this clear. The forecasts of the climate research project KLIWA are also unmistakable:

Studies initiated by our Ministry and the Ministry of the Environment of Baden-Württemberg clearly show

- that Southern Bavaria will gradually become warmer and wetter,
- we will even have to expect up to 35 % more precipitation in winter months,
- there will be an increase in torrential rain,
- and in the number of "floods of the century".

Summary of forecasts

In short, extreme events such as floods and drought will occur more often.

This will have an overwhelming impact, especially on the hydrologic cycle!

Response of the state government

The Bavarian State Government is therefore pursuing a double strategy:

- this includes **precautionary** measures,
- as well as **adjustment** to the unavoidable consequences of climate change.

Reducing CO_2 emissions

A **precautionary** climate protection policy means the consistent reduction of greenhouse gas emissions.

It is our goal to reduce CO_2 emissions in Bavaria from the level of 92 million tons in 1998 to 80 million tons in 2010.

Current emissions amount to approximately 83 million tons: this means we are well on track, but we will have to increase efforts over the coming years and decades to reach the national and international targets.

Precautionary contributions of water management

And what about water management?

Urban water management must also make a contribution to reducing CO_2 emissions:

- The energy saving potential from the modernisation of sewage treatment plants can amount to as much as 40 %.
- In sewage sludge digestion the amount of generated gas can be increased substantially through operational measures. The CO_2-neutral gas can subsequently be used in blocktype thermal power stations for cogeneration of electricity and heat.
- Heat recovery from sewage using heat pumps is another potential energy source that is still not used enough.

Adaptations in water management

But all climate-sensitive sectors must prepare for the inevitable outcomes of the climate change as well.

Required here are **adaptation strategies**:

- For sewage disposal this will necessitate intensified adjustment to lowwater situations.
  ⇨ The efficiency of sewage treatment plants must be checked and, if necessary, modified.
- Drainage systems also need to be examined owing to the impact of both drought and heavy precipitation.
- Similarly, the water supply must be made fit for changes in water availability.
- Groundwater resources that are suitable for drinking water must be secured sustainably through water protection areas and instruments of regional planning.
- The existing infrastructure of the drinking water supply must be safeguarded through greater networking among plants and alternative extraction methods.
- The option of above-ground drinking water reservoirs will gain in importance.

Climate protection versus environmental protection?

Describing precautionary measures contributed by water management and adaptations as necessary responses to the climate change does not mean that we are finished yet.

We also need to reexamine the measures we are taking for the protection of the climate:

Our ground water as the largest drinking water reservoir must not be endangered through measures required for reducing CO_2 emissions!

- In turn, with an increased use of geothermal energy resources, it is essential that water management regulations are observed to prevent damage to protecting strata layers.
- With an increase in oil crop planting it is important to reduce the input of fertilizer and pesticide pollutants in our groundwater to a minimum.

Climate protection and protection of water bodies

It is now the task for us all to harmonise climate protection and the protection of water bodies at the required high level!

We can control the impact of climate change on waters **in Bavaria** if we act conscientiously and in time.

Global context

On a global scale, however, climate change is intensifying the water crisis throughout the world:

- Six children die every minute due to water problems!
- It is the set goal to connect 1.4 billion people to a drinking water supply and
- 2.4 billion people to a controlled sewage system by the year 2015.

Mammoth task

This international water crisis, this mammoth task

- **can only be solved if there is a leap forward in technology,**
- **a new technological revolution.**

TTW supports companies

With the project "Technology Transfer Water" the Bavarian Ministry of the Environment is helping **Bavarian companies** to tackle this task.

Environment clusters

For example, in 2004 the Bavarian Council of Ministers set in motion a cluster initiative which is now also pursuing developments in various directions in the field of "environmental technology":

- For instance, along with a high-tech project on climate protection
- it addresses the issue of innovative water technology from Bavaria for Bavaria and the international water market.

The ideal **cluster spokesman** in the field of environmental technology is Mr. Hans Huber. As the recipient of the prestigious "German Environment Award", Mr. Huber is certainly an excellent representative of the cluster initiative.

With his company, he has shown how systematic developments may be implemented within a relational network between science, industry and government.

And this is exactly the aim of the cluster concept.

So the climate change is not only a great challenge for water management.

Climate change is also an opportunity for **companies** facing up to these with pioneering spirit and innovative ideas!

The pioneering spirit of Huber

Such is the pioneering spirit at "Huber Technologies for Water".

So it is not surprising that this company is the place where the initiative for today's symposium originates.

Thanks

I thank you, for your commitment, Mr. Huber, that makes it possible for us to continue to think things out together here.

And I wish you all as participants innovative ideas and a pioneering spirit of a special quality for today and tomorrow. After all, the challenges of which I have been speaking also have a new, special quality to them!

Dr. Otmar Bernhard

Session II – Enabling Framework
Introduction

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The Relevance of Water Resources for the Economic Development of Emerging Nations: The Case of India

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Abstract: At the start of 21st Century, a growing number of countries find themselves confronted with the challenge of providing an adequate supply of water, in sufficient volume and quality, to support dynamic economic development. In addition to many other Asian countries, this applies to India. Continued economic expansion – both in the agricultural as well as in the industrial sector – depends to a large extent on the availability of the factors of production, specifically in this case, water. It may safely be said that the need for water in both sectors will continue to rise.

At the same time, the demand for water in private homes is on the increase. Besides having a sufficient volume, private home use also demands an appropriate water quality. According to UN estimates, 80% of all illnesses and more than one third of all deaths in the developing nations are related, directly and indirectly, to a polluted water supply. An adequate quantity of clean drinking water as well as sanitary facilities and waste water disposal systems are key starting points in the effort to improve the level of health among the population and also an important condition for the development of human capital.

In India, this equates to competing requirements for water. Many regions of India today are already experiencing a shortage of water or, a water crisis. This is equivalent, assuming that no adequate effort has been made until now to improve the water supply in India, to a negative influence on economic growth and the development of the national economy overall.

Keywords: Economic Development, Economic Growth, Environmental Pollution, Industrial Sector, Water Consumption, Water Pollution, Water Resources.

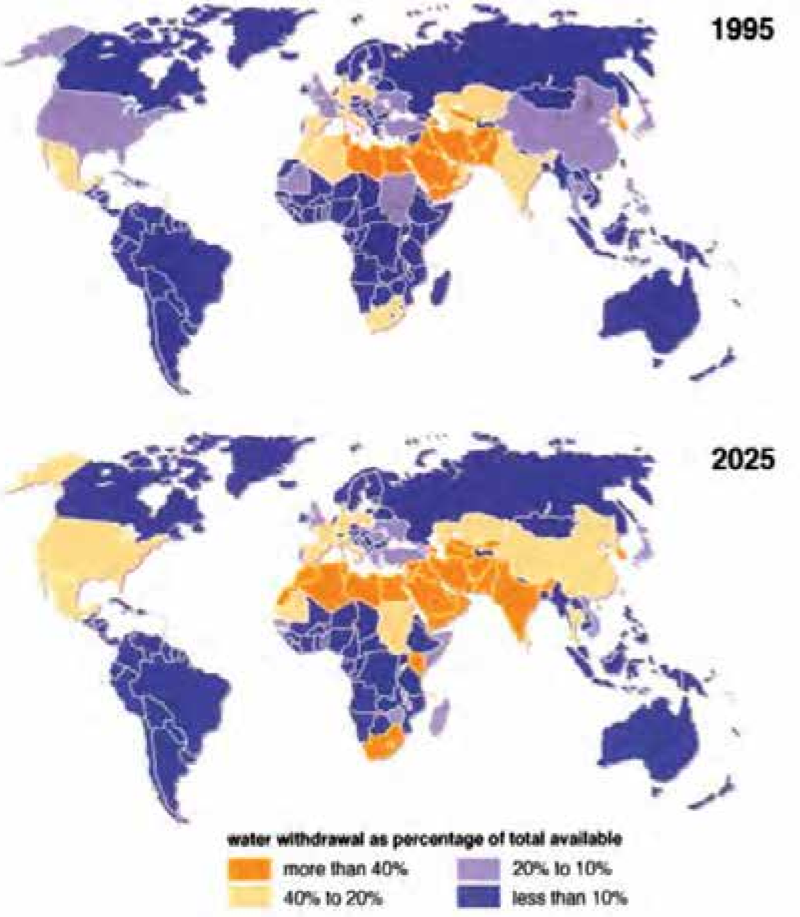
Introduction

In the 1990s in particular, as well as at the beginning of the new decade, India's economic performance was marked by a considerable, continuous dynamism. During this phase, economic growth was more than 5%. This economic dynamism can be expected to continue over the next few years, too. There continues to be remarkable growth in the secondary (industrial) sector, both in absolute and real terms. In the view of many experts, this trend will also continue in the future: India's industrialization has not yet peaked.

Since the beginning of the 1990s, India has also been able to significantly improve its attractiveness as an economic location for foreign investors. Here, too, a positive trend can be seen in the influx of foreign capital, and this will also continue in the future. Moreover, the federal states have increasingly discovered their responsibility, and especially their opportunities, for structuring and promoting their own economic development. This is leading to increasing competition between the regions, not least for foreign capital, and is also encouraging the process of decentralization in India. There are, therefore, many economic indicators that can be quoted as evidence for India's extremely positive economic development, and which suggest that its economic outlook is good.

Over the same period, however, the quality of the environment has deteriorated considerably. In principle, therefore, India corroborates the "ecological Kuznets curve", which shows that, in dynamically developing countries, environmental pollution increases as economic activity grows. One particularly significant factor here is the decreasing availability of water.

Agarwal and Narain, for example, estimate that the amount of water available per inhabitant fell by 50% in the period between 1947 and 2001 (Agarwal, Narain 1999). This progressive loss of water resources is made even worse by the high level of contaminated water supplies. The industrial sector plays a significant part in the scarcity and pollution of water. It is reasonable to assume that this problem will persist into the future. Figure 1 provides an overview of the availability of fresh water in the year 1995 and a forecast of what the availability will be in 2025. One possible scenario of the situation in the year 2025 was developed by Alcamo/Heinrichs/Rösch (2000) in a report to the World Commission on Water. The presentation makes a clear case for the coming change in the regional availability of water for the period from 1995-2005.



Source: UNEP (1999), p. 55.

Figure 1: Estimated change in the availability of fresh water, 1995 to 2025

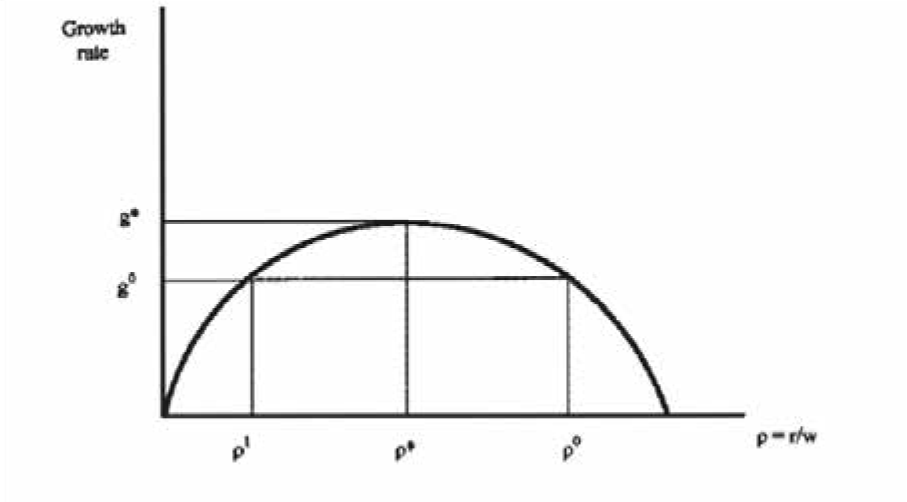
In the future, however, while water is expected to become even scarcer, demand for water is expected to increase still further. The main reasons for this are population growth, combined with rising income levels and greater demand for water in both industry and agriculture. Current forecasts estimate that the demand for water in India will double in the next 25 years. At the same time, water supplies in India are limited by climatic and geographical factors. This suggests a clear relationship between economic development and water resources in India. The present article is based on the thesis that economic development depends on water resources. This relationship will be discussed both from the point of view of economic theory and empirically.

The following section explains the theoretical relationship between water resources and economic development. Section 3 provides a general discussion of the situation concerning water availabilty in India. The discussion in section 4 turns to the relationship between industrial expansion and water consumption in India, in consideration of the fact that economic development in the industrial sector is of major importance for the overall economy of India. However, consideration must also be given to the agricultural sector in India as that is where water consumption is the greatest. So, there is also a direct relationship between economic growth and the availability of water in the agricultural sector .

The theoretical explanation linking water resources to economic growth

The availability of a sufficient quantity and quality of water can have a decisive effect on the growth of an economy. In this way, water takes on the role of an ecological factor for a location's attractiveness. Empirical studies such as the one conducted by Barbier (2002) for an economy where water scarcity is not a hard and fast fact, show the relationship between growth and water utilization describes an inverse U curve. In other words, when water utilization in an economy increases, economic growth initially rises, then stagnates, and may eventually decline.

In his model, Barbier assumes that the abstraction and usage of water [1] displays the character of a publicly provided good in an economy. On the one hand, the water provided by public authorities is a direct input for the production of private goods, and on the other hand, the government constructs the dams, irrigation systems, water mains, pumping stations, etc. to provide upstream services for industrial companies. When the water usage in an economy increases relative to the water resources available, more capital will be invested in increasing the water supply, as difficult to access freshwater reservoirs will also have to be exploited.Figure 2 shows the relationship of water utilization and available water resources to the economic growth of a national economy.



Source: Barbier (2002), p. 30

Figure 2: Growth rates and water utilization

The degree of utilization of water in an economy (p) is the total amount of renewable freshwater (w) divided by the amount of freshwater (r) drawn from it. If the socially optimum rate of water utilization (p*) is achieved, then it is also ensured that the optimum rate of growth (g*) is achieved. Both over-exploitation and under-exploitation of the existing freshwater reserves result in a sub-optimum rate of growth. Barbier tests the U-curve hypothesis in a cross-sectional study involving 163 countries. The regression model chosen confirmed the hypothesis of an inverse U curve in economies with water scarcity.

It may be concluded from the Barbier model that the rate of growth stops when the supply of water available to manufacturers is sufficient to raise the net capital productivity. In the case of an economy where water scarcity is prevalent, the relationship between the degree of water utilization and growth is not explicit.

Although optimal for the public sector, providing the maximal attainable volume of fresh water does not necessarily lead to a more robust economic development. Growth in this model is tied to two conditions. First, the net marginal productivity of the invested capital must be greater than the negative effects of water scarcity on the economy. Second, there must be an adequate volume of fresh water resources. The question arises: what happens when the second condition is not satisfied.

In this context, advances in environmental engineering as discussed in various models of the endogenous growth theory are relevant (v. Hauff 2005). The literature on this topic tends to take a differentiated view of environmental technologies – presenting them either as additive or "end-of-pipe" technologies, or as integrated environmental engineering. The distinctions can be categorized as follows:

- Additive environmental technologies are defined as any approach to environmental engineering which is concerned with the end of a production process (desulfurization, nitrogen removal, filter- and catalyst technology, waste water purification). Such approaches are analyzed as output oriented solutions.
- Integrated environmental engineering focuses on the sources of potential environmental strains. This includes process and product innovations that reduce the consumption of materials, substances, and energy or strive to eliminate the use of particularly harmful substances. These approaches are analyzed as input oriented solutions.

There is little doubt, from both an economic as well as an ecologic efficiency standpoint, that the preferred method is the development and application of integrated environmental engineering, i.e., the application of technologies that reduce water usage or the production of waste water. This is always the case at least, whenever an integrated technology can be substituted for an additive one. However, because the production of waste water is fundamentally not entirely avoidable, only the optimal combination of additive and integrated technologies can produce an ecologically and economically satisfying solution.

Availability and distribution of water in India

India is home to approximately 16% of the world's population. However, only approximately 4% of the world's water reserves are available to this population (Amezaga et al, 2003, p. 4). Nearly 226 million people in India haven no access to clean drinking water and almost 10% of the entire population have no access to sanitary facilities (Ramachandraiah 2004, p. 1).

Water scarcity or water stress are defined in terms of the availability of water per capita or as the relative demand for water, whereas for the purposes of this paper, the relationship between water usage and available water resources is used. The original index for water scarcity or water stress can be traced back to Falkenmark. According to Falkenmark (1989), water stress exists in a country whenever the annual supply of renewable fresh water is less than 1,700 m^3 per resident.

In 2000, the per capita supply was still 1,882m^3 p.a. in India. According to the definition of Falkenmark mentioned above, water stress currently does not exist there. Nevertheless, on the basis of the estimates of Engelmann/Dye (2000), the population of India will have grown to 1.2 - 1.4 billion people in the year 2025. By that time, the water scarcity that we see today in some regions will be more extreme and a major portion of the population will no longer be supplied with an adequate amount of water (Engelmann/Dye 2000, p. 96).

India is a land with heavy rainfall. However, the showers are concentrated during the time of the monsoons and fall unevenly across the country. For example, the average annual rainfall can be anywhere from 100 mm in western Rajasthan to 9000 mm in the north eastern state of Meghalaya (Government of India 2002, p. 16). The ground is unable to absorb such extreme concentrations of precipitation in a short period of time, and correspondingly, much is lost to surface runoff. This creates periods of water scarcity and periods of water abundance (Büttner 2001, p. 64).

The greatest demand for water is attributed to agriculture. The uneven distribution of water discussed above has lead the government of India to subsidize the expansion of the irrigation industry, giving the agricultural sector claim to between 70% and 90% of the utilized surface and ground water. The area of irrigated agricultural land has nearly quadrupled in the period since 1951 – from 23 million hectares to 90 million hectares in 1997. The remainder is divided between industry and private homes (Rao/Mamatha 2004, p. 942).

The requirements for water for home use and industrial production are concentrated primarily in large cities. The rural areas were neglected in the planning for adequate water supplies (Kathpalia/Kapoor 2002, S. 8). The demand for water is increasing among the private households and in the industrial sector with the increasing levels of urbanization, population growth, personal incomes and advanced industrialization (Government of India 2002, p. 8). The growing need for water by the manufacturing industry, especially in the field of energy production but also in the other sectors as well, highlights the need for an efficient supply of water and the considerate exploitation of a scarce resource in the future (Kathpalia/Kapoor 2002, p. 8). However, only limited reserves are available to meet the growing demand. Efficient water management is essential.

An important consideration in addition to the availability of sufficient water, is the quality of the water. The water pollution in India is a significant problem and estimates are that approximately 70% of the surface water is contaminated. The pollution of surface and ground water is greatest in the cities, where large concentrations of waste products are released into small areas (Rao/Mamatha 2004, p. 942). The necessary conditions for industrial production and for securing the private requirements are associated with high costs, that are not always assigned to the actual cause of the pollution. The protection of water quality must be given a special importance in a national water policy.

Industrial development and water consumption

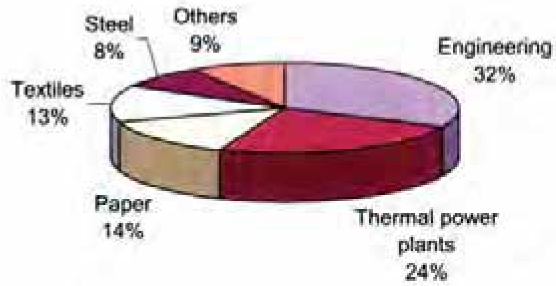
In the 1990s, as mentioned briefly at the beginning of this article, the Indian economy recorded average annual growth of more than 5%. In the present decade, the industrial sector is growing at an even higher rate. Furthermore, the industrial sector has clearly increased in size in India. This explains why the industrial sector in particular has played a significant role in the pollution of the environment. As early as 1995, a conservative estimate by the World Bank assumed that this cost India an average of 9.7 billion US dollars every year, or 4.5% of GDP (at 1992 prices). Of this figure, 7 billion US dollars alone are due to air and water pollution (see USAID 2001, p. 2). Both in absolute and relative terms, the cost caused by pollution has continued to increase.

At present, the Indian industrial sector is responsible for just 3% of the water drawn, but this need will increase further as growth continues. Above all, inadequate treatment of industrial sewage presents a considerable problem for water quality. Table 1 shows the water consumption and wastewater discharge of the individual branches of Indian industry.

Table 1: Wastewater and consumption (1990-2001)

Industrial sector	Annual wastewater (million cubic meters)	Annual consumption (million cubic meters)	Proportion of water consumed in industry
Thermal power plants	27000.9	35157.4	87.87
Engineering	1551.3	2019.9	5.05
Pulp and paper	695.7	905.8	2.26
Textiles	637.3	829.8	2.07
Steel	396.8	516.6	1.29
Sugar	149.7	194.9	0.49
Fertilizer	56.4	73.5	0.18
Others	241.3	314.2	0.78
Total	**30729.2**	**40012.0**	**100**
Source: CSE (2004), p. 1			

Every year, some 30,729 million m^3 of wastewater is produced in industrial enterprises, of which approx. 68.5 million m^3 per day is discharged directly, and without any treatment, into rivers and lakes. Wastewater treatment in particular displays some considerable shortcomings. Only a small share – roughly 12% - of the water used goes directly into the production process. The rest is mainly used as coolant in combined heat and power stations, and is not significantly polluted. Figure 3 shows the use of process water by branch of industry.



Source: Central Pollution Control Board (2003), p. 19

Figure 3: Use of process water by industrial sector

Nevertheless, the discharge of industrial wastewater is a serious problem, due to its greater hazardous potential and more complex composition.[2] In India, roughly 70% of the surface water and increasingly more of the ground water reservoir is contaminated with biological, organic and inorganic substances. A distinction can be made between industrial wastewater from individual industrial plants and wastewater from wastewater treatment plants, as well as pollution from the pesticides or fertilizers used in agriculture. A further source of ground water pollution are contaminants such as halides, arsenic or salts (see Sudhakar/Mamatha 2004, p. 942f.). The pollution caused by industrial enterprises can be subdivided into organic and inorganic and dissolved and undissolved substances. Table 2 shows the amount of biochemical oxygen demand (BOD) – one of the most important measures of pollutants in wastewater – by industrial source.

Table 2: Water Pollution before and after Treatment

Branch of industry	Pollution Load Generated in Tonnes/day		Pollution Load Generated in Milligrams/litre	
	Before Treatment	After Treatment	Before Treatment	After Treatment
Distillery	5773	503	45102	3930
Pulp & Paper (large mills)	646	36	650	36
Pulp & Paper (small mills)	864	118	974	133
Oil Refinery	19	0.8	253	11
Steel	109	90	100	83
Sugar	266	20	649	49
Tanneries	64	46	1829	1314
Petrochemical	101	33	1485	485
Pesticides	29	13	2231	1000
Textile	829	460	475	263
Dye & Dye Intermediate	30	22	508	373
Paint & Varnish	0.7	0.5	2333	1667
Edible Oil & Vanaspati	62	38	4429	2714
Pharmaceutical	34	16	400	188
Viscose Rayon	22.5	7.3	250	81
Soap & Detergent	24	18	1714	1286
Engineering	360	263	85	62
Organic Chemical	245	91	2450	910
Total	**9,478**	**1,776**	**65,917**	**14,585**

Source: Central Pollution Control Board (2003), p. 16f.

The table shows that distilleries cause the most organic pollution – 60% - prior to wastewater treatment. After wastewater treatment, this contribution falls to 28%. It is followed in second place by the paper industry, which causes 16% and 9% of organic pollution prior to and following treatment respectively. However, the level of wastewater treatment technology used depends to a great extent on the size of the company. While most large-scale enterprises comply with the wastewater treatment stipulations set out in the *Water Prevention and Control of Pollution ACT (WPA) and Environmental Protection Act* (EPA), this cannot be said of the small and medium-sized enterprises. According to estimates, only 20-25% of these companies comply with the rules currently in force. The reasons for this are to be found in obsolete production processes, insufficient capital resources, and the lack of qualified personnel in this sector (see for example Shankar 2001, p. 14).

Having said that, these medium-sized enterprises contribute significantly to economic growth, to industrial production and to employment and exports. Some 40% of industrial production and 35% of total exports are generated in this sector. Almost 27.3 million employees work in the roughly 11.5 million corporate entities (see Government of India 2004, p. 153, and see also Ministry of Small-Scale Industries 2002 p 1). It can be observed that grave water pollution is caused by these small and medium-sized enterprises whenever they occur in clusters. Smaller rivers in particular, such as the Pali, Balotra and Jodphur in Rajasthan, the Jetpur in Gujarat and the Tiruppur in Tamil Nadu, have been especially badly affected by the textiles companies located there. So far, government environment policy has failed to have any significant impact on the water pollution caused by small and medium-sized enterprises (Agarwal 2001, p. 10f). Not only these companies' remoteness makes it difficult to implement these regulations. There is also their sheer number, the number of employees working there and their economic significance for the national economy.

According to DOWNS's theory of vote maximization (Downs 1969, p. 51), politicians strive solely to assume ruling power. The players – government and voters – behave rationally, and try to maximize their benefit. In this process, the political programme of a party is simply a means to an end, being intended to secure re-election for the (ruling) party, and thus being determined by the distribution of voters' preferences. In a democracy such as India, therefore, environmental regulations for small and medium-sized enterprises may be thwarted by the loss of votes as a result of environmental policy actions. Should the political parties feel that they stand to lose more votes as a result of strict environmental regulations than they stand to gain from better-off voters, they will not include these actions in their programmes.

Water pollution by industrial enterprises may be reduced as a result of industry increasingly using non-polluting production processes. There is a possibility that technological progress will mean a reduction in demand for water as a resource, and that the existing (environmental) technological gap will be closed. Estimates relating to this topic assume that more than 80% of the industry production capacity that will exist in

2010 was not yet in existence in 1996 (USAID 2001, p. 7). Should these estimates prove correct, then pollution (and in particular water pollution) should be reduced considerably as a result of the advances in environmental protection that this new plant offers.

In order to increase the efficiency of water utilization, the water used might also be re-used elsewhere, depending on how badly contaminated it is. For example, most of the water consumed is used solely as coolant in combined heat and power stations, after which it is discharged as wastewater without being re-used, despite the existence of possibilities for further use. An integrated approach aimed at re-cycling and re-using process water may reduce the consumption of this resource. The technology for encouraging recycling, re-use of the water consumed and reduction of water consumption is available, and falling prices in this segment ought to make their use more likely in the future (CSE 2004b, p. 1).

Conclusions

The relationship between water and economic growth has been proved in theory by Barbier. In an economy with non-compulsory water scarcity, the connection between economic growth and water utilization describes an inverse U curve. This is also the case in India. In this respect, water scarcity is in principle an obstacle to the long-term generation of economic growth. What this theory does not consider is progress in environmental technology, and more particularly in wastewater treatment. Wastewater treatment and closed cycles can reduce or remedy the problem of water scarcity, and thus remove the problem of water scarcity as an obstacle to growth. India's industrial development and its prospects for economic growth have to be seen against this background.

India's positive economic development, including that of its industrial sector, has led to a huge increase in demand for water, as well as in the amount of wastewater. This development will continue in the next few years. The requirements of Indian water protection policy should take increasing account of this new situation. Specific obstacles, such as the structure of the industrial sector with its many small and medium-sized enterprises, run counter to an effective implementation of water policy measures that help bring about more effective utilization. These obstacles also make themselves felt when it comes to checking and monitoring compliance with the regulations that already apply.

In the past, water was regarded in India solely from the point of view of supply: instead of efficiently managing this scarce resource, politics concentrated on extending and tapping existing and new sources of water. At first, only insufficient action was taken to counter the increasing scarcity, unequal regional distribution and increasing pollution of existing water resources, not least due to the absolute and relative increase in industrialization.

Three strategies can be mentioned that provide the most effective means of combating the problem of water scarcity in India. From the point of view of wastewater treatment, the "integrated water resources management" approach deserves special attention:

- *Demand Management:* Ecologically and financially, irrigation systems must be sustainable. In this approach, a demand-managing policy and irrigation strategies have to be pursued.
- *Integrated Water Resources Management:* Irrigation is carried out according to the integrated water management approach, i.e. water is used several times in more than one sector as the quality of water decreases. This allows cycles to be closed, and water and energy to be saved.
- *Rainwater Harvesting:* Apart from irrigation management, the potential of rain-based farming has to be exploited in full. Wherever suitable, water from precipitation and from the soil above the water table should be used for agriculture, in order to reduce the need for irrigation. The reason why this is significant from the point of view of industrial development is that it should be attempted to avoid increasing competition for water between agriculture and industry, both of which are sectors that intensively use water.

The use of water several times over calls for institutional reforms and cross-sectoral regulatory mechanisms. Apart from irrigation-based agriculture, the management of water for habitation and the industrial sector must also be involved. However, the investments needed for a conversion to a system of water use several times over must not be underestimated, because when irrigating with only partially treated wastewater, separate networks of water pipes are needed for certain areas. If the various sectors of the economy are not to be over-taxed, it may be necessary here for the government to provide additional pipelines.

Equally, the price charged for water used must be geared to actual scarcity and the parties competing for use, and a corresponding regulation must be made. A price system scaled according to quality might also increase the incentive to convert to a system of water use several times over. In principle, there already exist enough concepts in India for efficient water utilization. Nevertheless, water continues to be used highly inefficiently even today. Some rainwater still runs off without being used, in this way impeding the formation of new groundwater, and the possibilities of recycling water are neglected. Overcoming the problem is not a question of technology, but mainly one of institutional obstacles, of the need for political initiatives, and of the lack of institutional acceptance.

Solutions have already been discussed at international water conferences, but binding decisions have not yet been implemented on the national level. The need for reform focuses among other things on reducing water price subsidies, on scaling the prices for water according to quality and on promoting flexible forms of cooperation. The creation of land and water rights can also advance the sustainable utilization of water resources. It should also be noted that close cooperation between private players and the public sector can contribute to greater efficiency of water utilization. Nevertheless, there has to be adequate, enforceable regulation before private players are involved, to ensure that they give sufficient attention to social and ecological aspects when making their decisions (DIE 2002, p.1). To conclude, then, the availability of sufficient water resources, as a precondition for industrial growth, has not yet been secured.

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[1] The difference between the utilization and consumption of water is that utilized water is returned to its original source after use. Water consumption, by contrast, means that water is irretrievably lost after utilization, and no economically meaningful reuse is possible. It is estimated that approx. 3,800 km^3 of water were abstracted and used worldwide in 1995, of which 2,100 km^3 were consumed (see Barbier (2002), p. 8).

[2] As concerns these pollutants, two different groups have to be distinguished. On the one hand, there are those pollutants that are emitted above all as a result of combustive processes. These include sulphur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds and solids (dust). On the other hand there are all the other inorganic and organic pollutants, including dioxins and furans. (Görner/Hübner 2002, N-1).

Prof. Dr. Michael von Hauff

Good Governance and What Bavarian Administration Can Contribute to This

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No doubt: Good Governance (GG) is worldwide accepted to be an absolutely essential key to solutions for the challenges of the Millennium Development Goals. So, GG is on the worldwide agenda for poverty reducing as well as for public health, welfare and special in the complete field of the water sector.
GG is defined as the interaction between state governance, communities, civil society including all groups and private responsibility. The original use of GG meant the balanced influence of state and civil society, including democracy aspects and social equity (MKANDAWIRE, 2004), meanwhile enhanced to the idea of an activating state. The „Bonn Conference for Sweetwater" wrote 2001: "*The primary responsibility for ensuring the sustainable and equitable management of water resources rests with the governments. Each country should have in place applicable arrangements for the governance of water affairs at all levels and, where appropriate, accelerate water sector reforms. We urge the private sector to join with government and civil society to contribute to bringing water and sanitation services to the unserved and to strengthen investment and management capabilities. Privately managed service delivery should not imply private ownership of water resources. Service providers should be subject to effective regulation and monitoring.*"

A Bavarian contribution to the search of GG could be quite simple: To be a good example and to help to transform knowledge about GG.

Why should Bavaria be able to give a good example?

Some arguments:

Most people say that the living quality here in Bavaria is very well. There are many reasons for that, the people, the scenery. But let's have in this context a closer look to the water sector: Even though Bavaria has a high density population and industries, particularly the standard of environmental protection measures and as a result of that the quality of surface and groundwater is high. Even so, with the integrated flood protection program 2020 the natural hazard mitigation is on a top level. Also the connected sectors of waste, hazard waste and natural protection are well organized. Last but not least, the remaining problems are well known, with the help of a high quality monitoring especially in the water sector. All in all, Bavaria seems to be near to this "sustainable water management", which is the aim of the state of the art water management and also the reason for claiming GG. This probably has to do also with GG.

What and where is GG in Bavaria?

No question that this success has to do a lot with the EU and the federal German environmental policy and the corresponding legal framework. But this seems to be only a part of the solution, because in the EU the implementation of action in the water sector differs between the states, the same may be said in the graduate of sustainable water management. So, what are the additional reasons for success?
We know today: GG is more, it is

- the complex interaction between all state levels from EU up to the communities,
- the legal frame,
- corresponding with technical ability,
- in the sense of general public interests the defined responsibility of the government as a guarantor (not only an enabler!) for basic environmental needs and the
- administrative capacity on all levels for putting things to action,
- the ideas of regional responsibility and
- the corresponding role of the civil society as NGO, group or individual.

Only if this mixture is well, including some external factors, success can happen.

Additional reasons lay in the implementation of ethical and cultural issues into decisions and in the information, communication and decision making processes on all levels from the participation of public interest groups to the single civilian. Also governance has an at least indirect role as an enabler for the invention power of the science and the companies and by its education system for the quality of trained employees in the handling and maintenance.

Especially on side of the government – this includes the community level – a good working organisation and partially administration is a main tool for success. In other words, governance is not only a political principle, realized in the constitution and the laws, it is also flesh and blood man-made (Goethe: "menschlich – allzumenschlich"). A simple example: the legal frame in the environmental sector in different countries worldwide normally is quite well; the differences lie predominant in the implementation of these rules. Furthermore it is clear, that not only the politicians but also the administration is the link between the law and its implementation, is actually the tool for the "enabling" and the "guaranteeing" role of the state.

The theoretical and practical approach of god governance

Bavaria has a long history in environmental issues. In Munich worldwide the first Environmental Ministry was founded in 1970. The water sector, until that with about

185 years institutional history, was incorporated there in 1990, you may say, about 200 years practical experience in the search of GG.

In 1998, the Project Technology Transfer Water (TTW) was founded as part of the State Water Administration, as an institution for technology transfer in the water sector. In the frame of TTW tools for handling GG in international projects have been developed in cooperation with **bfz Hof** (Berufliche Fortbildungszentren der Bayerischen Wirtschaft, Internationaler Bereich) – together with partners from consultants, supplying industry and universities. With the help of TTW today it is possible to accompany international projects of Bavarian enterprises in the water sector if it is needed with the know-how of the state and communities of Bavaria to help them to tackle challenges in the field of GG.

The theoretical idea of GG is described in a lot of sources, first of all the papers of the World Bank, the Global Water Partnership (GWP) and other. Worldwide in the water sector the best approach for water policy is defined with the Integrated Water Resources Management (IWRM), by that part of GG. TTW tried to understand this approaches and to develop them (GRAMBOW 2005). As one of the main arguments came out, that by its interaction and feed back character the complete state system is complex in a mathematic meaning (KÜPPERS 1996). In consequence, in any kind of discussion, development and transformation of the GG- system or parts of it you need special approaches for example from the Chaos-Theory (CT). Most important is, to mix theoretical understanding with practical examples, e.g. to use the "self coordinating and organizing power" of complex systems by working like a catalyst, or to stay in the nomenclature of the CT, working like a "strange attractor" (KLAUS 2003).

The approach for implementing GG:

As a result of the analysis of the practical experiences and the theoretical findings, TTW created step by step a practical approach for supporting sustainable, integrated projects or in other words to take IWRM from vision to action. The solution is as simple as evident:
1) Come together, 2) build a network, 3) use examples and 4) create and live a vision.

Come together:

TTW uses the experience that our administration had made over years in its day to day business. One experience is, that we try to learn from the best and try to stay in a continuous "benchmark" with worldwide water administrations. As a important example, there is nothing like a "simple advise to do things right or even better" in this complex water sector, but it is possible to communicate problems together with experts at home and from abroad to find complex solutions. We do this with our neighbours in Germany and Europe in many ways since many years (WIEBEKING, 1811). So, in the frame of international projects too, we support the high quality contacts and communication between water experts.

Consequently in projects, which include challenges in the sector of GG, we organize meetings between experts of GO's and NGO's, stakeholders and consultants, both, in between the partner region and with Bavarian counterparts. In these groups, it's possible to talk about challenges and solutions. In the background, in those groups it is possible to "build up the chain". That means, – in the ideal case – the decision makers of governmental, stakeholders and involved enterprises meet together and start to work together in a partially informal and personal way, building a necessary network.

By the way we are convinced, that this is in any way a win-win because the water sector is standing in front of the biggest challenge ever and we will only have a chance to solve those problems by a intense worldwide cooperation between the whole water sector.

Talking about networks:

To explain it in the theoretic way, networks can model the integral, transsectoral connecting points of the real complex (water) world. They are a very common and important way of working together between people. Networks can work crosswise the hierarchic, sectoral or institutional structures or be part of them. GG has to be aware of them and has to use them.

In practice, they appear in different ways, as organized expert groups like the German Water Association (DWA) or as informal group of people with common interests, like the water family. They are self-help organisations like the Bavarian network of waste water and drinking water neighbourhoods, which meanwhile are important part of the overall quality management of water infrastructure in Bavaria - at the same time a good example for active society and communal self responsibility.

Networks are an important part of the Bavarian philosophy of GG. They are a matter of course of the national and international work. For that, in international projects TTW supports deliberately the implementation or strengthening of networks. Also, every contact in the frame of TTW is a new knot in the network of the Bavarian State Government and makes the participants including us stronger. A very new and important network is the Cluster of Environmental Technology, which is chaired by Hans Huber.

For the partner enterprises of TTW this means, that they become part of and have the full access to the Bavarian water network, which includes the state and communal administration, the cooperating enterprises, scientific institutes and more.

Good and bad examples:

"Seeing is believing", an old Japanese saying. Indeed, good examples have more power than any explanation. They are important in all scales. Sometimes, the "big deals" like complete legal solutions or ambitious management plans are of interest. But more often, the little, small approaches and solutions are the secret of success, as well as they are very often the reason for wash outs (failures).

Good examples are probative for the feasibility of solutions. Some may be worry that the world water problems are – depending of different environmental, society and economic reasons - to different for taking advantage from special Bavarian solutions. In fact, an astonishing big part of environmental challenges are quite similar or even comparable over the world. There are typical patterns of difficult and problems. Think about

- principle questions like sustainability,
- the connection between water usage and water shortage,
- floods and droughts,
- treatment of industrial and public waste and waste water,
- all organization questions from stuff development to TQM,
- planning scale problems from the project area to river basin management,
- "simple" things like ergonomic and complex like integrated planning.

We worldwide have developed numbers of solutions for that, and some of the best-working are made in Bavaria. Most of them are assembled from technical and management components in a more or less complex way and they are quite often more or less woven in a legal, political or governmental background.

Of course, normally such solutions cannot be taken 1 to 1 to another region. But it makes sense to compare the solutions with that in the partner land and start a creative discussion: why did you do that this way? What were the problems, what the main results? Where are differences in between the local situations, where are comparabilities?

By discussing long enough, it will be possible to find out the complex interaction, the technical, legal and management background. This makes you ready to transmit the idea of solutions. Now it can be made a choice, which parts of the solution can be taken over and what the requirements or the framework of these solutions are.

A typical example is the requirement of trained and motivated stuff for running the facilities. Or in the sector of good governance the well tempered design of monitoring, law, fees and taxes, which produces the framework for environmental protection and common weal.

At the latest, when these legal and fiscal questions appear, GG comes to the scene. Most of the solutions in the area of infrastructure are in a wide range dependent from the governmental framework. Knowing the interactions, the reasons for the chosen administrative design you can contribute helpful points in the discussion. This, so the experience, is quite often the "missing link" between technical solutions and success.

The longing for the sea – visions and missions

Tsar Peter the Great is cited "If you want to build up a new naval power it is necessary to teach the people building ships and navigate. But more important is to wake up the love and longing to the sea"

In this sense maybe the most important thing the Governance and all the people in Bavaria can contribute to our international partners is to show them a wonderful, country, prosperity with a rich nature and well protected environment. The nearer we are to sustainability approaches including all three arguments of the Agenda 21 triangular – economy, ecology and social aspects, the more intensive will be the vision and the longing for a good environment in the home countries of our guests. We simple have to prove here, that a good environment, that sustainability is possible.

Conclusion

That is, what Bavaria can offer in international projects and contribute to the aim of GG: a good example of sustainable water management, a network of know-how, a lot of good and bad experience, the feeling of responsibility, the consciousness to act in a complex system, ideas about appropriate technical and organisational solutions and a lot of motivated people keen in contact and discussion with experts from abroad.

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Building Competence for Health and Wealth through Integrated Capacity Development on Water and Sanitation

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Why am I here?

There are two good reasons for being here.

The first one comes from my professional experience and my work in the WHO:

This enterprise, and the work delivered by Hans Huber and his worldwide operating teams, is a place of hope. Namely, a place of hope for many people, who are longing for safe water and adequate sanitation services.

The second reason comes from a very private perspective:

The mayors and civil servants of my home town Bremerhaven, Germany, had applied their competence to re-establish, within very short time after World-War II, the water supply system of their city, from which my father could take safe tap water, which he was competent to handle safely during my delivery in 1949.

Therefore, due to the application of individual and institutional competence in handling water safely, I am lucky to be here and I am happy to present a speech about building competence.

It is my firm belief, that there a no circumstances in the world, that hinder competent people to provide safe water for healthy use. Neither post World War II, nor today's conflict scenarios across the world would automatically hinder competent people to exercise their competence. However, people may be hindered actively and aggressively to apply their competence. This seems to be the case in far too many places around the world, regardless whether its peace there, or formal war.

Today we wish to highlight the fact that water and sanitation problems have many solutions, each of which will need specific competence for effective application. The simple and strongest motive to apply the most appropriate one of these in the best suitable way is: The will to survive, the wish to provide healthy living conditions for our children.

It is as simple as that: No water – no future – no life.

The MDG – progress chart – target 10 not expected to be met

Provision of safe water and sanitation to the poor has been carried by good intentions of highly motivated people working in charitable and development organizations. They have done a tremendously good job. Supply with safe water is reaching the vast majority of all people in the world, the "last billion" of underserved people will be halved by 2015.

However, the world community is confronting the risk of failure due to **lack of progress in providing adequate sanitation services to some 2-3 billion people.**

The major source of water (and food) contamination has been, and will continue to be, the unsafe handling of excreta or sewage. At small scale at the family level, as well as at large scale conditions at community or megacity level, only safe handling of sewage and excreta will guarantee healthy living conditions, and will help to control water related diseases.

Comprehensive understanding of the water system, rather than the suspicious look at the water in the kettle, will be an essential element for building Health competence and combating poverty on the basis of Safe Water for All

The decade for action "water for life 2005 - 2015" – fresh impulses

The world community is facing a new challenge. Moving the agenda from a charitable activity towards an investment strategy within a framework of institutional and legal responsibilities will change the global interaction, north – south , rich – poor, east – west, within and among countries.

Providing water and sanitation to more than 2 billion competent customers is a global business opportunity. A pre-condition for being an active and productive customer is Health. And health is the precondition to combating poverty. Combating poverty will release human and financial resources, which will be freed for continuously improving water-, sanitation-, energy- and education - services. This cycle has been understood and needs wide application.

Essential tools are at hand, and their application has been widely communicated through the WWAP, and its comprehensive Volumes of the WWDReport. The present situation in many countries is characterized by lack of progress in implementing at local and regional scale, what has been tested e.g. in pilot studies for IWRM. Appropriate technologies and systems, like ECOSAN, DEWATS and others, have been developed for all kind of human and environmental conditions, and wait for wider application. However, this needs human capacity and competence in the widest sense. Whith this intention in mind, UN – Water agreed, to overcome this implementation gap by a boost towards integrated capacity development. The Federal Government of Germany offered in June 2006, to host a new institution, in close connection with the UNU-EHS, based at the UN Campus in Bonn. This **UN-Water Decade Programme on Capacity**

Development (UNW-DPC) has been opened officially a few weeks ago, and will become the essential tool for upgrading human capacity and competence in many countries across the world.

Cooperation between enterprises, academia, governments and their various supporting networks needs to be enhanced. Their activities can be more focussed, and investment can be directed more effectively, towards sustainable water and sanitation systems. This will not happen by itself, but needs a new balance between those who offer technology, intelligence and services on one hand, and those in urgent needs, on the other side. With that in mind, the Federal Governmant has decided to establish a **„Water Strategy Initiative Office"** which is meant to strengthen communication and interaction of the many players on the german water market, with their counterparts in other countries.

1. Integrating capacity development will include:

Water resources management	(Local authorities, Business/Industry, Agriculture)
Water technology	(Industry, SMEs, Customers, Research and Development)
Water legislation and its enforcement!	(local, regional and national authorities Business, NGOs, Civil Society)
Water valuation and pricing	Banking and Microfinance Raising financial resources ("creative channels")

2. Integrating Capacity development will support to understand cycles:

Close the cycles of	Water Nutrients Energy Money
Disconnect the cycles of contaminants e.g.	Pathogenic bacteria, viruses, parasites Toxic or hazardous compounds

3. Intergrating Capacity will help to establish a system of

	Construction, maintenance and pricing, Individual Responsibility Corporate Responsibility

Thus, water and sanitation services will become an essential tool for, and a very quick and informative indicator of, establishment and maintenance of Good Governance at local, regional and national level.

More than 2 billion customers are willing to pay the price for good and reliable services

As presented in the WWDR 1 in 2003 (table 13.6, headlined: "The poor pay more"), far too many poor people pay a high price for bad service! The poorest are spending an amount equivalent to something between 30 and 60 Billion USD every year for low quality water, in many cases sold without any reliable service and quality control, in some cases with hazardous consequences for the health esp. of young children.

This market can be developed, and has to be developed, in a human and sustainable way. Experience can be shared, demonstrating the stability and potential productivity of societies, who have agreed to care for all their people, and therefore, as part of Good Governance, take responsibility for reliable and sustainable water and sanitation services.

The necessary tools are at hand:

All over the world,

- appropriate technologies and strategies have been tested and wait for wider application,
- highly motivated and capable people take responsibility for their and their families health and safety, and
- many of them have built and maintained small businesses for their and their neighbours supply with water, sanitation, energy.

And:

- Investors are looking for new opportunities to invest their billions in a sustainable, human and reliable manner.

To expand this and to reach out to the unserved billions of people, is a challenge to all scientific, technical and institutional partners. There is no need to worry about competion: all technical, managerial and construction capacities around the world are needed and welcome to close the huge implementation gap.

Lets Get the order right:

Health is the precondition to everything.

There will be no wealth without good Health.

There will be no Health without provision of safe water.

There will be no safe water without the competence in managing and handling water and sanitation in an integrated manner – at individual and institutional level.

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Sanitation Planning – A Tool to Achieve Sustainable Sanitation?

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Abstract: The global sanitation crisis and its importance to the Millennium Development Goals (MDGs) is reflected in the specific sanitation target adopted in 2002. An enormous amount of funds will need to be invested in sanitation over the coming years in order to meet the MDGs. It is important that these funds are invested in sustainable sanitation systems, since providing sanitation systems that are not sustained is a very costly short-term solution that may contribute to long-term problems. The authors strongly believe that sanitation planning is one key to sustainable sanitation. Recent planning frameworks for sustainable sanitation systems suggest the utilization of a number of steps: (i) recognizing the existence of different domains across the city, (ii) analysis of the interests driving desire for the sanitation system and services for the stakeholders across the domains, (iii) analysis of external drivers and context that impact behaviour in each domain (iv) analysis of technical options, in relation to findings on context and criteria, (v) analysis of management requirements for proposed technical options, (vi) critical assessment whether the proposed system is fit for the purpose. This paper will discuss the merits and challenges of these planning methodologies in reference to experience from West Africa and Sweden. The intent is to illustrate the potential of these methods for increasing sustainable sanitation, but also to raise some key questions that may be missing from the frameworks.

Introduction

Improvement in sanitation coverage has been targeted by the United Nations Millennium Development Goals (MDGs) because of its strong link to issues of environmental and public health, economy, and human dignity. Achieving the goal of halving the percent of people without access to sanitation by 2015 will require a dramatic increase in investment and efficiency of bringing sanitation systems to scale. Yet, the challenge of the MDGs is not only to achieve statistical improvements on paper, but to do it in a sustainable manner that will lead to lasting positive change in the field. Sustainable sanitation systems can be defined as those that protect and promote human health, do not contribute to environmental degradation or depletion of the resource base, are technically and institutionally appropriate, economically viable and socially acceptable (Bracken et al, 2005).

The pressure for increased construction must be balanced against the lessons learned from past interventions. Historically, international water and sanitation projects have had low sustainability rates. Of the water supply and sanitation projects evaluated by the World Bank in 2001, only 50-66% was deemed to be satisfactory and less than half were rated likely to be sustainable (World Bank, 2003). Project assessments consistently report cultural constraints, behavioural change, prohibitive costs, lack of political and managerial support, or low community demand as reasons for failure. These constraints span a wide range of political, cultural, and economic issues that need to be overcome if sanitation is to be brought to scale in a sustainable manner.

Participatory and holistic approaches to sanitation planning can increase the potential for a sustainable system through better management of the numerous risk-factors and capacity development within the local domains for successful operation and maintenance of the systems. In recognition of this a number of organizations have developed/are promoting planning frameworks for sanitation based on the assessment of user priorities at different levels of decision-making within the urban environment (Eawag, 2005; IWA, 2006; Kvarnström and af Petersens, 2004). Users of these methods can then select appropriate technology that will satisfy the functional requirement of the various stakeholders. This paper will highlight the similarities between several of these frameworks and their application in case studies taken from Sweden and Ghana. The intent is to illustrate the potential of these methods for increasing sustainable sanitation, but also to identify the challenges of using these frameworks alone or in combination with other development tools.

Planning Frameworks

There have been numerous support tools and frameworks designed to aid in planning processes for sanitation/wastewater planning and management. While methodologies vary in their emphasis on top-down or bottom-up planning techniques, there is a growing consensus on the need to include stakeholder opinions. One such framework is the Open Planning of Sanitation Systems that is recommended by the EcoSanRes Programme (Kvarnström and af Petersens, 2004) and is based on the Open Comparative Consequence Analysis (OCCA) methodology that was developed in Sweden by WRS Uppsala AB (Ridderstolpe, 2000). This planning process is performed in five steps: (i) Problem identification, (ii) Identification of boundary conditions, (iii) Terms of requirement, (iv) Analysis of possible solutions, and (v) Choice of the most appropriate solution. The first step requires identification of the stakeholder groups and their roles. Sanitation is an issue that by its diverse nature demands cross-disciplinary work between administrations within the municipality. This process does not happen by itself, and the identification of stakeholders and their involvement in the planning process is one way of achieving the necessary cross-disciplinary work within the municipality. The problem identification process can then be performed using participative methods such as the Participatory Hygiene And Sanitation Transformation (PHAST). Identification of the boundary conditions should define the technical limits of the sanitation system (geographical limits, communities served, links to water supply and agriculture), but also potentially limiting socio-economic patterns, natural environments, and political conditions. After the first two steps, planners and stakeholders should be able to develop the terms of requirement (ToR) (i.e. criteria or functions the sanitation system shall comply to) for the sanitation system. The ToR should be comprehensive and include factors on health, water and natural resource protection, costs, technical reliability, user satisfaction, and management issues. The analysis of possible solutions is then based on how well potential technologies meet the ToR. At least three options should be presented to the stakeholders for evaluation and selection of the most appropriate solution.

Another bottom-up planning approach to sanitation is Household-Centred Environmental Sanitation (HCES), which has been developed by the Swiss Federal Institute of Aquatic Science and Technology (Eawag, 2005). HCES recognizes the importance of management zones and different stakeholder domains within the urban environment. The ten step HCES process follows a project cycle framework, from project identification, pre-planning and preparation, to implementation and monitoring. The process is built on identification and assessment of sanitation needs by the local stakeholders. Steps 1-4 establish the participatory communication channels and define local sanitation priorities based on an understanding of the current situation and system boundaries. Steps 5-6 identify and assess the feasibility of a wide range of technologies, as well as, the institutions and financial arrangements for providing these technologies. The final steps of the HCES process involve the stakeholder in the selection of appropriate solutions and the development of an implementation program, complete with methods for monitoring and evaluation. Eawag also emphasizes that the successful application of this planning approach is dependent on the preconditions of an enabling environment which includes government support, a legal framework, institutional arrangements, effective training and communication, credit and other financial arrangements, and a system for information and knowledge management.

More recently, the International Water Association specialist group, Sanitation 21, has incorporated many of these ideas into developing their own framework for the analysis and selection of appropriate sanitation systems (IWA, 2006). This framework defines three parts to effective sanitation planning: (i) defining the context, (ii) identifying technical options, and (iii) determining the feasibility of the options. Analysis of the context recognizes that different domains exist within a city and that the stakeholders in each of these domains will have different objectives with regards to sanitation. The domains can be broken down into household, neighbourhood, district, city, and beyond city. The context within each domain will include a set of interests, external drivers, and management capacity that are identified through a participatory process with the stakeholders. During the second step, a range of technical options is identified and listed according to their treatment capacity and level of management required. At this stage a generic list of sanitation system types can be used that include both on-site and centralized systems. The purpose here is more to look at the functionality, operation, maintenance, and basic management requirement of the systems than to outline specific costs and design requirements. The key step in the framework is finally to select a system based on its ability to meet the objectives and management capacity defined by the stakeholders. At this stage the important questions are to determine if the management requirements match the community capacity; basically will the system work? It is important to realize that it is possible to apply different technical options at different domains within the city in order to adequately meet the needs and institutional realities of everyone.

Table 1: Common steps in the planning frameworks and specific recommended actions within each framework

Common Step	Open Planning	HCES	IWA Sanitation 21
Recognition of Planning Domains	• Identification of affected stakeholders	• Differentiate zones within urban environment • Problems should be solved close to their source	• Identify key actors in each decision-making domain
Analysis of Objectives/ Interests	• Stakeholder participation in problem identification • Terms of Requirement	• Stakeholder participation in determination of needs and priorities	• Identify the interests of key groups
Analysis of External Drivers	• Identification of boundary conditions	• Assessment of current situation • Enabling environment	• Understand external factors
Analysis of Technical Options	• Define sanitation system boundaries • Terms of Requirement	Define system boundaries and current capacities • Identify a wider range of options	• Analysis of existing systems and new systems
Assessment of Management Requirements	• Terms of Requirement	• Assess current capacities and responsibilities of organizations • Need to ensure support from municipalities	• Identify the capacities within each domain for implementation and long-term management of a system • Identify the management requirements for the technical systems
Critical Assessment of Feasibility	• Choice of most appropriate solution based on Terms of Requirement (Stakeholder participation)	• Evaluation of feasibility of service combinations (Stakeholder participation)	• Assess whether systems meet the objectives in each domain • Assess whether systems can be managed in each domain

Comparison of these frameworks yields a number of common steps: (i) recognizing the existence of different domains across the city, (ii) analysis of the interests driving desire for the sanitation system and services for the stakeholders across the domains, (iii) analysis of external drivers and context that impact behaviour in each domain (iv) analysis of technical options, in relation to findings on context and criteria, (v) analysis of management requirements for proposed technical options, (vi) critical assessment whether the proposed system is fit for the purpose. Table 1 shows the common themes in each of these planning frameworks and the terminology used in each specific framework. The frameworks highlight the need for inclusion of a variety of stakeholders in the planning process, as well as a focus on the technical and managerial requirements of the systems. In each framework, the planners recognize that different zones of interest groups or economic domains may exist within the planning area. Stakeholder input is then solicited through surveys, interviews, or other participatory tools. Through recognition of different stakeholder and planning zones, the frameworks emphasize that successful sanitation strategies may have to apply different technologies at different levels within the city.

All of these frameworks also recognize the need to consider a wide range of possible solutions to sanitation problems. The focus of all these frameworks is on functionality and managerial requirements for sanitation systems instead on purely on the technology itself. This approach allows decision-makers the flexibility to consider many options that have the potential to meet the requirements defined by the stakeholders. The wider perspectives provided through the application of these frameworks can lead to innovative solutions to the complexities of insuring proper sanitation coverage.

Swedish case study: the island of Lambarö

A case study from Sweden illustrates how use of the Open Planning of Sanitation Systems framework led the municipality to explore a wider range of solutions to problems with the water supply and sanitation services in a small area within Stockholm municipality. Lambarö is an island located in Lake Mälaren just offshore (175 m) from mainland Stockholm. The 57 households (17 for year-round residency and 40 summer houses) currently rely on on-site water and sanitation facilities. Forty-seven households have in-house water connections, either using non-treated groundwater (9 households) or non-treated lake water. The households without groundwater connections haul drinking water from a Stockholm Water Company standpipe on the main land and use water from the lake for other purposes. Both the well water and the lake water have shown quality problems. All 57 households rely on on-site sanitation, seven households using water closets and the remaining 50 households using dry sanitation. Only 13 of the 57of households have a permit for their on-site sanitation. The local environmental authority demanded improvement in the sanitation situation on Lambarö. Since the island was not included in the jurisdiction of the Stockholm Water Company, a consultant was engaged to investigate a number of different options to improve on the water and sanitation situation for the inhabitants.

The Open Planning process requires the involvement of authorities, service providers and users to identify sanitary options that fulfil their needs. The project management group was lead by the local environmental and public health authority within the municipality. The other municipal bodies within the project management group were the land development department, the city planning department, the district council, and the solid waste department. The stakeholder group also included a user representative group of ten people and the Stockholm Water Company. The group participated in several meetings, with the consultant guiding the process. As a result of these meeting, the following terms of requirement/criteria/functions for any future water and sanitation system were identified:

- The sanitation system shall comply with treatment requirements as stated by Swedish EPA for on-site sanitation located in environmentally sensitive areas.
- The sanitation system shall be economically sustainable, with O&M costs that are reasonable in comparison to treatment level achieved by the system.
- The water supply shall be of high quality.
- The water supply shall satisfy the current water demand and that of the projected future growth.
- Other criteria that were considered include flexibility, site-specific adaptation, nutrient recirculation, reliability and robustness, user aspects, environmental consideration, organizational and legal issues.

According to phase four of the planning framework, the following technical options were evaluated for their ability to meet the criteria defined by the stakeholders:

1. On-site water and sanitation, using lake water/private wells and urine diverting dry toilets.
2. On-site water and sanitation, using lake water/private wells and water closets.
3. Municipal water and sanitation, by establishing a community-owned network for water and wastewater for the island with connection to closest connection point within existing water and wastewater jurisdiction (on the main land).
4. Municipal water and sanitation, through enlargement of the Stockholm municipal water and wastewater jurisdiction to serve the island.

The project management group recommended that alternative 4 was best able to fulfil the criteria stated above. This recommendation was based heavily on the wishes and concerns expressed by the user representative group among the stakeholders. The environmental authority officially approved the results of the study, and the recommendations has passed through the Environmental and Health Committee and will now be considered in the municipal council who will decide whether Stockholm Water Company will extend its water and wastewater jurisdiction to include Lambarö. The motivation from the environmental authority was based on (i) the recommendation from the users in the stakeholder group, (ii) the difficulty of on-site sanitation systems to meet the high effluent standards needed in the given setting (rocky terrain and limited areas available for wastewater infiltration and recirculation of nutrients), (iii) low willingness from the households to run a semi-decentralized wastewater collection system for the island, and (iv) the difficulty to find reliable on-site water supply.

Stockholm Water Company, on the other hand, remain in favour of a community-owned and operated water and wastewater network on the island (alternative 3), which could be connected to the closest connection point available within the existing water and wastewater jurisdiction. This view was expressed officially from Stockholm Water Company in their reply to the circulation round for comments by concerned parties, which preceeds the decision in the question by the municipal council. The motivation from Stockholm Water to recommend this approach is that alternative 3 represents praxis for other small islands in Sweden, and that it allows for a more flexible approach for connection to the system time-wise than would be the case if the water and wastewater jurisdiction was enlarged. Stockholm Water Company has decided that it will execute its rights to charge a higher connection cost to Lambarö residents, if the water and wastewater jurisdiction is enlarged. If the enlargement is executed, the connection cost for those on Lambarö will be more than double the connection costs to the system for those already within the water and wastewater jurisdiction. This was communicated to the Lambarö population during the commentary period and was not well received by the user group. A decision will be taken by the municipal council during the fall of 2007.

Use of the Open Planning process did not manage to arrive at a consensus among all stakeholders on the issue as of date. However, the involvement of the users, the municipal departments involved in sanitation issues, and service providers in such a cooperative process has provided insights on the situation that will facilitate the final decision making. The users, the project management group, and the environmental authority have expressed their view in favour of enlargement water and wastewater jurisdiction. Although they are not happy with the corresponding increased connection cost, the users have a greater understanding of the consequences of their decision through this participatory process than would have been the case if they had not been involved in the decision making. It is also possible, that when faced with the doubling of connection costs (information available only after the proposal was passed through the environmental and health committee), that the users will instead opt for alternative 3 as proposed by Stockholm Water. This situation highlights the necessity of having all relevant information on the table during the planning process, but also the potential need for iteration of the process prior to decision-making.

Although Stockholm Water Company does not agree with the conclusions of the environmental authority, they stressed during an interview, that they still believe the participatory approaches to be very useful in decision-making, and welcome the use of processes such as the Open Planning of Sanitation Systems. The process as such, inducing cooperation between the municipal departments, serves as a mean to address general service delivery questions (roads, electricity, school transportation, etc.) in an integrated way for inhabitants in areas outside the detailed plan. This is especially important in areas of urban sprawl, where increasing populations (e.g. the development of old summerhouse areas into year-round housing around cities in Sweden) and corresponding increases in demand for infrastructural and service delivery are occurring in areas outside the detailed plan.

Challenges for planning frameworks

Although planning frameworks can yield useful insights and increase the likelihood for sustainable solutions, there are still a few challenges to overcome. The inclusion of stakeholder perspectives and focus on functionality provides additional insights, but planners must still define how the process and information gathered are to be used. There remains the question of who is using these tools, what they get out of the process and in what context it is applied. In the Lambarö case, the main objective of the planning process was to gather more information for the decision-making process and to foster mutual understanding between stakeholders in a difficult planning situation. However, in some situations (particularly international development work) participatory planning tools are also promoted as a means to achieve a more democratic process through changing roles in planning and decision-making.

Even if the participatory planning process is strictly used to gather stakeholder input, the challenge remains on how to obtain this information. This can be especially difficult in areas with a long history of top-down decision-making. If stakeholders are not used to being consulted it can be difficult for them to express their opinions or offer constructive solutions. In general, people are good at identifying problems, but not as good at offering solutions. The democratic process of equal participation and discussion on ideas can also conflict with socio-cultural traditions and politics. In Mali, for example, soliciting stakeholder feedback during a town meeting can be difficult as it is considered impolite to criticize someone's ideas in public. Careful consideration of local customs and social structures is needed to insure that information gathered from stakeholders is relevant to the context. Fostering socio-cultural respect within the stakeholder group can also help all parties to understand the potential bias in the opinions of both stakeholders and planners.

Often the aim of participatory planning is to change the planning process itself through stakeholder ownership in the process. This in itself can increase the challenge. In practice, planning is generally performed by top-down management organizations rather than at a grass-roots level. In the experience of the authors top-down planning is the rule more than the exception, in both developed and developing countries. So, there is a paradox created between the desire for bottom-up, home-grown solutions to local problems, as advocated by the frameworks, and the traditional top-down decision-making processes that exist in most municipalities. In developing countries, the problem is accentuated where the local authorities lack the experience, resources, and manpower capacity for planning. In this situation the planning process is generally done with the help of outside consultants who are even further removed from the realities in the field than the municipal leaders. Therefore, in developing countries the challenge is not only to reform how planning is done, but to establish a functional planning system. Both reformation of the planning system and solicitation of stakeholder input can involve behavioural change on behalf of the participants.

Financing and managing participatory planning is another challenge. In the case of Lambarö the process was run by a consultant, and financed by the environmental authority through access to an environmental fund ("The Environment Billion") to improve the environment of Stockholm. If this type of planning processes is to be repeated on a large-scale, there will either have to be funds available within the municipal budgets to hire consultants to lead these processes, or the municipalities will have to develop their own capacity of running participatory planning processes. However, although these planning processes can be time and resource demanding, they can also be used to build local capacity and ownership in order to overcome other management and accountability problems that are inherent in many projects. It is possible to build the results of participatory planning processes into management systems of accountability that clearly defines the objectives and responsibilities that each party has for achieving results. Thus, the investment into a participatory sanitation planning process resulting in a sustained sanitation system with a high degree of ownership will most possibly prove to be, in the long run, cheaper than the traditional planning approach.

The common cause underlying all of these challenges is that planning for sanitation improvements requires behavioural changes in addition to infrastructure development. Traditional planning tools work well for infrastructure and urban development, but tackling behaviour change requires additional participatory tools and social marketing. Since many new planning frameworks are already encouraging participatory methods, it is interesting to explore how more of these tools could be utilised to overcome the challenges in sanitation planning. The next section will explore some of these methods and present a case study on how they can be integrated into an existing planning framework.

Participatory tools

Since the 1980s, many international development organizations have embraced participatory methods for incorporating local knowledge and values into project planning and development. There are a range of methodologies based on a participatory approach to evaluate development needs; for example, Rapid Rural Appraisal (RRA), Participatory Rural Appraisal (PRA), and Participatory Analysis for Community Action (PACA). In general, they aim to identify community problems and to plan solutions with the active participation of the community members (Selener et al., 1999). A wide range of participatory training and advocacy materials exist to assist the locals in analyzing the characteristics of their community (community map, social calendars), identifying problems (problem lists, priority analysis), and developing possible solutions (solution brainstorming, feasibility matrix). Several of these tools have been specifically adapted for water and sanitation issues, such as the Participatory Health And Sanitation Training (PHAST). PHAST is a series of interactive activities designed to help villagers identify sanitation issues in their village. It mixes traditional needs assessment tools with educational information on waterborne disease and transmission routes. The activities are community directed and allow the participants to arrive at conclusions themselves.

Another participatory sanitation tool is Community-Led Total Sanitation (CLTS), which was initiated in Bangladesh in 1999, as an innovative methodology for eliminating open defecation (Kar, 2005). CLTS uses a participatory approach to empower local communities to stop open defecation and promote the building and use of latrines through community-lead action instead of subsidies. The program uses PRA tools to help community member analyze their own sanitation practices and the potential for spread of fecal-oral diseases within the village. The CLTS approach works through the creation of a sense of shame within the community, which triggers collective action to improve the sanitation situation. The idea is to use peer-pressure through public recognition of the problem to induce behavior change. Facilitators trained in the CLTS methodology guide a community through five roughly defined steps: (i) introduction/rapport building during which the facilitator physically examines the village, focusing on areas of open-defecation. (ii) participatory Analysis of sanitation habits in the community using PRA tools, (iii) ignition Movement, where the facilitator steps out of conversation and lets community self-motivate to change, (iv) action planning by community with a focus on immediate positive action, (v) follow-up, including the identification of leaders and advertising of results. The method has proved successful in Bangladesh and has since been applied in other South and Southeast Asian countries, as well as several African countries.

Programs such as CLTS recognize that achieving the behavior changes necessary for improved sanitation requires stimulating a demand and motivation for change. A useful tool to achieving these results is social marketing. Similar to modern advertising science, social marketing techniques use the approaches of economics to advance social change. This is accomplished by offering affordable technology, but also by increasing the social desirability of sanitation systems. Studies have shown that the reasons people want improved sanitation facilities are less for health concerns than for social status, privacy, comfort and convenience (WHO, 2000). It should therefore, be the goal of any sanitation program to foster these feelings to increase the social demand for sanitation. Since social status is one of the driving factors in demand, it is important to recruit prominent people and community leaders to the cause of sanitation. Sanitation promotion by these leaders will increase the acceptability of the sanitation solutions (Ikin, 1994). While the role of community leaders may be important, so is the participation of the average community member. Community-based efforts have been shown to be more effective than external intervention (WHO, 2000). Sanitation programs can learn much from a marketing approach that selects key populations within the community to act as agents of change and uses appropriate channels of communication to reach the target audience.

Another recommendation for increasing bottom-up development has been to use participatory methods in project evaluation. Participatory Monitoring and Evaluation (PM&E) is a tested participatory methodology that has been applied in development programmes in many parts of the world. It engages participants (citizens, communities, social groups) in monitoring and evaluation, and creates ownership over evaluation results and of development project interventions. Using PM&E approaches increases consensus on project goals, objectives and activities as well as providing timely, reliable, and valid information for management decision-making. Additionally, the use of PM&E contributes to increased learning, skills transfer and confidence of local groups in water resources management and sanitation. This creates an atmosphere where local knowledge is better understood and utilized. Therefore, use of PM&E tools can increase project sustainability by improved management and accountability strategies.

West african case study: Ghana three town water supply and sanitation project

The Three Town Water Supply and Sanitation Project in Ghana is presented here as one possible solution to overcoming challenges in planning frameworks by integrating methods used in rural development work and social marketing. Although the project is still in the planning phase without secured funding for implementation, it is interesting to look at because the consultants behind the project proposal are trying to draw on many popular themes in international development literature and merge them into a workable plan. In order to increase the sustainability of their efforts, the project planners are exploring innovative sanitation planning methods by combining sanitation planning frameworks with participatory learning activities.

The Ghana Three Town Water Supply and Sanitation Project was initiated in 2006 by the Ministry of Water Resources, Works and Housing. In addition to provide designs for upgrading in water supply, the project aims to make suggestions for improvement of the environmental sanitation conditions in three towns in northern Ghana (Wa, Damongo, and Yendi). Current sanitation conditions in these towns are cited as poor due to the high frequency of open defecation, lack of solid waste disposal, and dumping of greywater into the street. The objectives of the proposed 3-year sanitation project are (i) changed attitudes and behaviour among targeted population, (ii) improved sanitary and social environment in homes/households, and (iii) improved environment in public places.

The project proposes the application of the IWA Sanitation 21 framework throughout the project, but complimented with participatory tools and social marketing (Table 2). It is envisaged that the sanitation project is implemented in four phases, as follows:

(i) Strategic project planning
(ii) Initial advocacy and social marketing
(iii) Capacity development, demonstration and mid term evaluation
(iv) Scaling-up throughout the three towns & final evaluation

The strategic planning phase will be completed over a 3-day workshop using LFA as a management tool. The project will solicit the involvement of individuals, groups, and institution with interest in the sanitation project. These stakeholders will offer their analysis of the problem and the specific project objectives to be achieved. Additional PRA activities and tools will be used during the workshop to facilitate the discussion and generate information for a SWOT analysis. Following the definition of objectives and strategic planning phase, the initial advocacy and marketing phase will lay the foundation for subsequent work to reach the set goals of the sanitation project. A number of social marketing campaigns will be undertaken in order to stress the need for communal responsibility and to encourage citizens to evaluate their immediate environment in order to identify and take action in areas of poor sanitation and hygiene.

Based on the interest generated through sanitation advocacy, the third phase will implement a program for capacity development and refinement of the planning process through use of demonstration projects (initially serving 2.5% of the population in each town). The aim of this phase is to test the appropriateness of proposed planning methodologies and technical interventions, continue promotion of behavioural change, and increase management capacity that will sustain the system. The capacity development will be geared towards local authorities, local artisans, entrepreneurs, trainers, and planners. A PM&E procedure will be used to collect feedback from the demonstration areas throughout this phase, and the information will be used to inform decisions on the final phase of scaling-up (where 25% of the population in each town will be addressed). The feedback loops during the last two phases will be connected to local and regional Learning Alliances. Such alliances aim to break down barriers to both horizontal and vertical learning and information sharing through partnerships between organizations with complementary capabilities in such areas as implementation, regulation, policy and legislation, research, learning, documentation and dissemination. Through collective information sharing this project envisions impacting sanitation development beyond the three towns.

Table 2: Ghana Three Town Sanitation Plan

	Assessment	IWA Sanitation 21		Additional Tools
Awareness Raising	Demand Creation	0	---	Adapted-CLTS, PHAST, and social-marketing
Context Definition	Institutional Mapping	1	Identify the Key Actors in each Domain	PRA tools: community/social mapping, stakeholder analysis
	Interests/ Objectives	2	Identify the interests of the key groups	PRA tools, problem analysis through stakeholder consultation, workshops, questionnaires
	External Factors	3	Understand the external factors driving decisions on sanitation	LFA, SWOT
	Capacity	4	Identify the capacities which exist for implementation and long-term management of any system	Demonstration planning areas, institutional surveys, survey of existing systems management
Sanitation System	Sanitation Elements	5	Analysis of existing systems and potential new systems	Survey of existing systems and management practices
	Management	6	Identify in detail the management requirements for the systems	User and experts consultations
Decision-making	Does it meet Objectives?	7	Assess whether the proposed/existing system meets the objectives in each domain	User consultations, discussion groups, demonstration sites
	Do Management requirements match?	8	Assess whether the system can be managed based on the capacities of each domain	User consultations, discussion groups, demonstration sites
	Will it work?	9	Taking into account all the previous steps and technical considerations, ask the question 'will it work?'	User consultations, discussion groups, demonstration sites
Implementation	System costing, design and construction	-	---	User consultations in design stage, demonstration sites
	Management & Accountability	-	---	PM&E

Some initial information available from the project planning phase has helped in the identification of risk-factors and challenges to be addressed during project implementation. The most important external issues contributing to poor sanitation in the towns are:

- *Attitudes leading to widespread open defecation*
- *Poor hygienic behaviour*
- *Traditional beliefs regarding use of public toilets*
- *Sanitary functions performed by the Assemblies are sometimes sabotaged by citizens for political reasons*
- *Perception that sanitation shall be provided for the citizens by the Assembly or central government.*

Since many of these issues will require attitude and behavioural changes, it has been suggested that social marketing tools be employed in conjunction with the planning process.

The project planning phase also yielded some insights into the terms of requirement/criteria/function for a new sanitation system. A group of invited stakeholders in one workshop identified the following preferences:

- *For location: accessibility is the most highly regarded criteria.*
- *For construction: good ventilation, affordability, lighted, easy to construct/well constructed, disability-friendly, gender-based and absence of flies.*
- *For function: hygienic, clean, odor-free, safe and easy to use.*
- *For operation and maintenance: easy to desludge, easy to manage and maintain.*

This ambitious approach to sanitation planning and implementation will be a challenge in itself. However, the authors believe that this kind of merged approach, where more traditional sanitation planning is coupled with participatory approaches, is one key to achieve the implementation of more sustainable sanitation systems in the future. Another challenge is the funding for implementation of this project and its replicability in the Ghanaian context. The project proposal is constructed with the aim that on-site systems will be financed by the house owners. Nevertheless, as the number of household sanitation facilities increases, financing will also be necessary to meet the demand for management of faecal sludge and other end-products generated by the systems (services that are malfunctioning or non-existing in all three towns today). According to the National Environmental Sanitation Policy the responsibility for such waste management systems falls upon the district/municipal assembly. It is reasonable to assume that O&M of the sanitation management system could be covered through emptying fees and/or surcharges on the water bill. However, it is equally reasonable to recognize, in analogy with the investments in water supply systems, that full cost-recovery of hardware investments (such as faecal sludge treatment plants, suction trucks etc for the sanitation case) will be more difficult to address through fees/surcharges, and thus will need external national or international funding.

Conclusions

Sanitation planning frameworks developed for use by municipal authorities often overlook important issues within the household domain (affordability, comfort, prestige), as well as fail to address issues of low demand for sanitation in general. However, many participatory rural development tools are designed to work in areas without centralized regulations on health and the environment. Neither set of tools can truly stand alone when addressing the sanitation needs to meet the MDGs. This paper suggests that a combination of planning frameworks, participatory rural appraisal, and social marketing as one method for improving the sustainability of sanitation intervention. Yet, even with improved sanitation planning methods, the challenges of financing and capacity development necessary for execution of these plans remain. The authors recognize that the disciple of sanitation planning is evolving and intimately connected with a variety of cross-disciplinary issues. New planning methods need testing and critical evaluation to that continued progress can be made. The entire process of planning and management needs to remain flexible so that changes and improvements can be made as new information becomes available. One way of doing so is to focus the planning process on terms of requirements/criteria/function of the sanitation system rather than on technologies. Sanitation planners need to start experimenting with different methodologies and critically evaluating them to find out what works in their specific setting.

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The 7th Framework Programme and the Promotion of Innovation in the Water Sector

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Abstract: The debate for the preparation of the 7th Framework Programme (2007-2013) was mainly characterised by the recognition of the fundamental role of research to promote innovation, and consequently the competitiveness of European industry. Along with the ambitious target of reaching an average of research investments of 3% of GDP by 2010, and with the objective of promoting private R&D investments, a group of industry-led Technology Platforms were promoted, among which the Water Supply and Sanitation Technology Platform (WSSTP).

Its launch in April 2004 was also connected with the Environmental Technologies Action Plan (ETAP). The final goal of WSSTP is to strengthen the potential for technological innovation and competitiveness of the European water industry, of water professionals and research institutions through the development of a common strategic and visionary science and technological research agenda and a suitable implementation plan.

Its ambition is to promote step changes in the technological capacity of the European Water industry, consolidating and strengthening its position in the world market, while contributing to the global challenge of reaching the Millennium Development Goals of ensuring safe and secure water supply for different uses and sanitation services through the development of sustainable technologies and of appropriate institutional frameworks.

The WSSTP strategic research agenda identified:

- 4 main challenges (Increasing water stress and water costs, Urbanisation, Extreme events, and Rural and under-developed areas)
- 5 research areas (Balancing Demand and Supply, Ensuring Appropriate Quality and Security, Reducing Negative Environmental Impacts, Novel Approaches to the Design, Constructioin and Operation of Water Infrastructure Assets, and Establishment of an Enabling Framework)

- and the integration of them through the concept of pilot programmes, articulated in 6 specific "pilots", each one associated to a number of test sites in Europe and beyond, where to carry out targeted and prioritized research defined by and tested in real-life applications, covering generic research, enabling technologies development and full scale demonstration in the various implementation case and mobilising different sources of funds – beyond solely FP7 resources – through a solid public/private partnership. The 6 pilots are:
  - Mitigation of water stress in coastal zones
  - Sustainable water management inside and around large urban areas
  - Sustainable water management for industry
  - Reclamation of degraded water zones (surface & groundwater)
  - Proactive and corrective management of extreme hydro-climatic events

The European Commission has well taken into account the research strategy proposed by the WSSTP in the formulation of the FP7 programmes, and the activities are now in the phase of implementation.

European water policies – and in particular the Water Framework Directive - are deeply embedded in all the above mentioned research subjects and pilot projects, which are and will become subject of FP7 funding throughout the seven years of the programme.

FP7 water research will however span also beyond the subjects of more "industrial" interest, in particular with the objective of better understanding the potential impact of global and climate changes on water resources and, consequently, on EU water policies.

FP5 and FP6 research projects have provided important knowledge and policy insights of the role water plays in our environmental and socio-economic welfare.

The application of results from those projects will certainly help the implementation of short-term water policy requirements as well as long-term adaptation to global change and progress towards sustainable development.

In view of the increasing complexity of water problems the use of models in policy formulation and the need to understand and assess uncertainties associated with these models will become a fundamental issue in the future.

Research will continue in FP7, with more focus on the development of solutions to water problems (in connection with the Water Supply and Sanitation Technology Platform), and looking at the impact of climate change on water systems

All interested stakeholders, from industries to professionals and to regulators, have the possibility to access and make use, through European research results, of the most advanced available methodologies, technologies and tools in order to implement the Water Framework and other Directives, minimising the costs of implementation. However, a higher participation of Water companies in the research consortia would be extremely beneficial, allowing for a closer participation of "problem owners" in the definition of research projects, and associating them in the evaluation of research results through case studies and pilot implementation tests. More and more, the most efficient companies are those who are more able to introduce innovative technologies and management methods.

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Appropriate Technology for Wastewater Treatment and Reuse in Developing Countries[1]

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Abstract: In developing countries the order of priority of investment in the water sector is first water supply, then sewerage and only then wastewater treatment. In view of the water sector institutional problems and financing restrictions, in most developing countries the percentage of wastewater that undergoes any type of treatment is very low, usually less than 10%. Population growth forecasts indicate that most of the world's growth will take place in developing countries. This will further reduce the perspectives of expanding the coverage of wastewater treatment in these countries, unless innovative affordable wastewater treatment technologies will be made available. Wastewater treatment needs in developing countries are different than those of industrialized countries and therefore guidelines for good practice of wastewater management in developing countries and the strategy for achieving adequate wastewater disposal are different. The paper advocates that the key to expanding wastewater treatment in developing countries is the use of appropriate technologies based on simple processes which are less costly than conventional processes in terms of investment as well as operation and maintenance, simple to operate, and have the capacity of yielding any required effluent quality. The paper then presents a series of appropriate treatment technologies which are recommended for use in developing countries, and which can be used in industrialized countries as well.

Global water supply and wastewater disposal issues

World's Population growth forecasts indicate that: (i) the world population will reach 9 billion in 2050; (ii) practically all the growth will take place in developing countries; and (iii) a strong migration from rural to urban areas will take place, mostly in developing countries. The implications of the trends of population growth and urbanization are: (i) increased urban water demand; (ii) increased generation of municipal wastewater; and (iii) increased irrigated land and increased demand of water for agriculture to generate sufficient food for the growing population.

Provision of adequate wastewater disposal is an act aimed at protecting public health, controlling contamination of water sources and protecting the environment. One of the water and sanitation sector's deficiencies in developing countries is the inadequate disposal of wastewater. In most developing countries the percentage of wastewater that undergoes any type of treatment (in relation to total wastewater produced) is very low, usually not more than 10% and in many cases less. However, in view of the prevailing water and sanitation sector problems, it is considered that for most developing countries increasing the provision of safe drinking water and sewerage coverage are of a higher priority than providing sewage treatment.

Considering the expected population growth and the order of priorities in the development of the water and sanitation sector, it is difficult to assume that the current low percentage of treated wastewater in developing countries will increase in the future, unless innovative affordable wastewater treatment options will be used. Application of appropriate wastewater treatment technologies is a key component in any strategy aimed at increasing the coverage of wastewater treatment in developing countries.

The appropriate technology concept

Developing countries cannot afford expensive and difficult to operate wastewater treatment installation. Experience shows that mechanical biological processes are usually out of operation in developing countries a short while after their commissioning due to high operation costs or lack of capacity to operate them adequately. It is therefore necessary to use in developing countries simple treatment processes, otherwise known as processes based on appropriate technologies.

Appropriate technologies for wastewater treatment means simple treatment processes of proved technology, of low investment costs and especially of low Operation and Maintenance costs (much less costly than conventional processes), simple to operate and with the capacity of yielding any required effluent quality. Such processes do exist and are especially fitted for countries of warm climates, as most developing countries are, since biological processes perform better at higher temperatures. Appropriate technology processes are often ignored, certainly in industrialized countries, and also in developing countries, due to lack of understanding of environmental authorities and politicians (decision makers and even professional do not understand the concept), fashion (the drive to install cutting edge technologies even when not necessary and not affordable), corruption or combination of the above. Also, since appropriate technology processes do not consist of sophisticated equipment and in most cases do not include equipment at all; just local construction materials, there are no equipment manufacturers to push these processes, while a lot of manufacturers and consultants promote sophisticated process based on complicated equipment, and convince decision makers to stay away from appropriate technologies.

Not all the appropriate technology processes achieve the same effluent quality, i.e., each process yields an effluent of different quality, and some do not achieve a high quality effluents, however, this does not present any impediment for the use of these processes since: (i) not always is a high quality required, and (ii) high quality can be achieved by combining various appropriate technology processes into one treatment plant.

One of the main problems of using in development countries conventional technology based on aerobic processes is the high cost of energy required for supply of oxygen to such processes and the difficulty in ensuring proper operation of the oxygen supply equipment (the aeration equipment) over a long time horizon. It is therefore good practice to avoid in developing countries the use of aerobic processes and base wastewater treatment, to the extent possible, on anaerobic processes. Aerobic processes which utilize mechanical air supply should not be considered appropriate technology processes.

Appropriate treatment technologies

Condominial sewerage systems

Sewerage systems are not wastewater treatment systems (although there are opinions that some treatment takes place in the sewerage and conveyance systems); however, sewerage and treatment systems are coupled in the sense that sewage treatment cannot take place without the existence of the sewerage network which collects the sewage and conveys it to the treatment plant. For a municipality, the investment in wastewater management includes investment in sewerage networks, wastewater conveyance and wastewater treatment. Reducing the investment in sewerage networks is as important as reducing treatment investments.

The condominial sewerage technology –also called "shallow sewerage"- is different from the denominated "small bore technology" or "simplified sewerage" because there is no retention of solids in the condominial systems. Consequently, there is no need to construct household retention boxes and no need for periodic sludge removal. Detailed information on the condominial technology is provided by Vargas-Ramirez and Lampoglia (2006) and can be found also in the report of the World Bank Water and Sanitation Program (2002).

From the technical standpoint, the condominial technology simplifies the design and characteristics of pipelines, making it physically easier to connect households. Condominial sewerage considers that the network is divided into a private part (the condominial lines) and a public part (the main sewers). The condominial lines are built in areas with no road traffic, such as gardens, sidewalks, etc., and are laid at a shallow depth. The diameter of these lines is usually 100 mm and it uses much smaller inspection chambers.

Conominial systems provide a series of benefits, including: (i) financial benefits (ii) adaptable layout - the flexible condominial layout allows working in irregular urban layout settlements, very steep slopes and rocky terrains; and (iii) better hydraulic functioning - the use of the shear stress boundary concept for design instead of the minimum velocity, allows the use of lower minimum slopes. Similarly and counter intuitively, smaller diameters allow greater buoyancy and more efficient transportation of solids, especially in densely populated areas.

The financial benefits, manifested by capital cost savings, is one of its more appealing characteristics of condominial systems, since it allows the provision of services to significantly more people with the same financial resources. Cost reductions stem mainly from (a) lower excavation volumes due to more shallow location of the pipes; (b) use of simplified inspection chambers instead of costly manholes; (c) reduced pipe diameters and layout length; and (d) easiness of construction that result in less need for heavy machinery. The financial benefits are also manifested by reduction of O&M costs since the accessibility of the system at depths varying from 60 to 150 cm. allows for easier access for manual maintenance. In case of breakage, system components are much easier and cheaper to replace.

The overall cost savings of implementing the condominial technology, when compared to conventional technology, are well documented, reaching 40 – 50%. Fig. 1 demonstrates the reasons for cost saving. In the condominial system, most of the network consists of lower cost condominial sewers, while in the conventional system all the network consists of higher cost conventional sewers.

Condominial systems have been utilized in Brazil since the 80´s where they were first employed in the city of Natal. By 2000, 13.6% of the sewerage connections in Brazil were condominial. In the capital of Brazil, the city of Brasilia, since 1995 the condominial technology was adopted by CAESB, the local utility, as the only option for sewage collection. The system is also employed in parts of El Alto, Bolivia and parts of Lima, Peru.

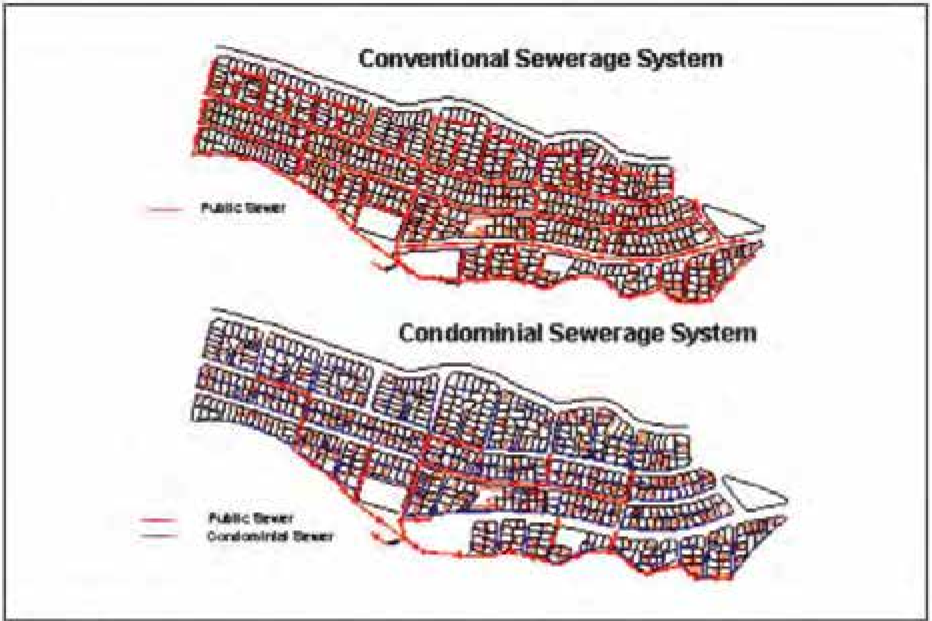

Figure 1: Comparison between Condominial and Conventional Sewerage Systems

Preliminary treatment in rotating fine screens (RFS)

Preliminary treatment is aimed at removing from the wastewater coarse materials, grit and floating materials, mostly to protect equipment in subsequent treatment units of a treatment plant. Preliminary treatment is usually not the sole treatment unit in a plant but rather the first in a train of units; however, in certain cases it might be sufficient to have only preliminary treatment. Conventional preliminary treatment usually consists of coarse screens followed by a grit chamber, in most cases an aerated grit chamber. Recently, innovative, automatic and efficient equipment for preliminary treatment has been developed in Germany by the Huber Technology Group. The coarse screens have been replaced by rotating fine screens (RFS) and the conventional grit chambers by compact vortex grit chambers.

The concept of rotating fine screen manufactured by the Huber Group of Germany is presented in Fig. 2 (Courtesy Huber). The operation principle is self explanatory. Screen opening is offered in the range of 0.2-1.5 mm according to requirement. The screened material is compacted by a press which forms part of the unit and is discharged to a container, from which it is removed to a solid wastes deposit site (sanitary landfill or alike). Reductions of up to 50% of particulate COD and up to 30% of total COD have been achieved for the lower range of screen opening.

The smaller the screen opening, the higher is the quantity of the removed solids which need to be properly disposed. The rotating screen units are manufactured in a variety of diameters up to 2.6 meters. The flow handling capacity of each unit depends on the unit's diameter and on the screen opening. If the flow of sewage to be treated is larger than the capacity of the largest unit, a plant consisting of several units needs to be installed. The rotating fine screen technology is suitable to serve cities of any size, from small to large.

Investment costs in preliminary treatment based on rotating fine screen unit are in the range 3-10 US$/Habitant, depending on the unit size and level of plant finishing (outdoor plants are of lower cost than indoor plants with elaborated site development). Operation and maintenance costs are low, estimated at 0.1-0.15 US$/Year/Habitant.

It is the author's opinion that a preliminary treatment unit consisting of at least rotating fine screens should be the first unit in any type of wastewater treatment plant. It removes coarse and floating materials from the raw wastewater in a reliable and cost effective manner, and it is an exemplary appropriate technology treatment unit.

Figure 2: Preliminary Treatment by Rotating Fine Screens

Anaerobic treatment

Introduction

The most commonly used method for decomposing the organic matter present in wastewater is aerobic decomposition, which requires supply of oxygen usually by injection of air, and presence of aerobic bacteria. Another path of decomposition of the wastewater organic matter is anaerobic decomposition, which takes place in an oxygen void environment in presence of anaerobic bacteria. The anaerobic biochemical pathway is different than the aerobic pathway and its final products are: (i) a biogas which contains a large portion of methane, in addition to lower quantities of CO2; and (ii) sludge composed of new cells of anaerobic bacteria. The sludge quantities produces in the anaerobic process are much smaller than the aerobic sludge quantity formed while decomposing the same amount of organic matter in an aerobic pathway. This is a result of the fact that only about 5-15% of the organic carbon is converted to biomass during anaerobic decomposition of organic matter, while in aerobic decomposition; the equivalent number is about 50-60%. Anaerobic decomposition is a two-stage process, each stage being carried out by a different group of bacteria, with the second stage bacteria being more sensitive than the first to environmental conditions such as pH. The anaerobic process is sensitive to low temperatures and its rate declines strongly at temperatures lower than 120C (in the liquid, not in the air), however, it is well functioning at higher temperatures and therefore appropriate for developing countries, which are usually located in hot climate zones.

In industrialized countries, the anaerobic process is mainly used for digestion of excess secondary sludge in activated sludge plants. All over the world it is considered a slow rate process adequate mainly for digestion of sludge. Only in recent years the anaerobic process started to be considered a process suitable also for municipal wastewater treatment, not only for sludge treatment. The capacity and rate of decomposition of organic matter in raw wastewater under anaerobic conditions at temperatures higher than 120C are similar to those of aerobic processes (as evidenced by the fact that the hydraulic detention time in anaerobic reactors treating wastewater are similar to those of detention times in activated sludge aerobic reactors), so an anaerobic process can work well as the main treatment process of wastewater in hot climates. It has immense advantages over an aerobic process: (i) it does not require oxygen thus it does not consume energy; (ii) the gas it produces, mainly methane, can be collected and used to generate energy or be burned, reducing the emission of greenhouse gases, and carbon fund benefits can be obtained for the emission reduction, increasing financial benefits; (iii) excess sludge quantities are much smaller than those generated in aerobic process, thus expenses for sludge treatment and disposal are much smaller and so are negative environmental effects of the sludge; (iv) the occupied area is small; (v) electromechanical equipment is not required for these processes; (vi) construction is simple and uses mostly local materials; (vii) operation is quite simple; and (viii) both investment cost and operation and maintenance costs are way smaller than those of aerobic processes.

The fact that the rate of anaerobic decomposition of organic matter present in raw wastewater is similar to the decomposition rate under aerobic conditions is still not known to many professionals, who consider that because anaerobic sludge decomposition is a slow rate process, then all anaerobic processes are slow rate processes. The fact is that excess sludge, which is basically excess bacteria cells, is a very difficult matter to decompose due to the need to break the cell membranes, and even aerobic digestion of excess sludge is an equally slow process. So in anaerobic digestion of sludge the problem is the substrate (which in this case is the excess bacteria cells) and not the anaerobic process.

Considering the advantages of anaerobic processes, it is surprising that their use is not more widespread. There are several reasons for that fact. First, they are not promoted by professionals due to lack of knowledge. Second, they do not contain complicated equipment and in fact contain minimal amounts of equipment and are mainly based on local materials of construction. As such they are not attractive to equipment manufacturers, who usually discourage their use.

Anaerobic processes achieve organic matter removal in the range 40%-80%, depending on the type of process, and as such they are most valuable for developing country since they have the potential to achieve such a meaningful removal at low cost and simple to operate installation. If a higher level of organic matter removal is required, anaerobic processes can be the first stage of treatment followed by a variety of polishing processes, such as lagoons of various types, constructed wetlands, filtration, dissolved air floatation and others. It is also possible to use one anaerobic process as the first stage treatment and another as a following polishing process, for instance, a UASB followed by an anaerobic filter, or even anaerobic lagoons followed by UASB followed by an anaerobic filter.

Three anaerobic processes, which fall within the definition of appropriate technologies, are discussed below: Anaerobic Lagoons, UASB and Anaerobic Filters. Anaerobic filters achieve a higher organic matter removal (in the range 80-85% BOD5) than UASB (with removal levels in the range 60-75% BOD5) which achieves a higher removal than anaerobic lagoons (in which the removal level is in the range 40 70% BOD5). The reasons for the different removal level of organic matter in these three type reactors are different anaerobic biomass concentrations and different flow regimes in each process.

Anaerobic lagoons

Anaerobic lagoons technology is well known and widely spread over the world. It is usually the first stage in lagoon treatment plants, followed by other types of lagoons. Anaerobic lagoons are designed to receive such a high organic loading that even if algae would have developed in these lagoons they would not be able to produce sufficient oxygen to keep the lagoon aerobic, so this type of lagoons are completely devoid of oxygen and under such condition they favor the development of anaerobic bacteria, which decompose the organic matter flowing into the lagoons through the anaerobic biochemical pathway. A typical anaerobic lagoon is basically a "hole in the ground"; usually with no equipment in it, except for inlet and outlet hydraulic structures. Commonly, the depth of anaerobic lagoons is about 4 meters, but there is no specific limit to the lagoons depth. Detention times in anaerobic lagoon range from 2 to 6 days. There appears to be little treatment advantage in extending detention time to more than 2 days.

The advantages of anaerobic lagoons are low cost, simplicity of operation, effectiveness in handling high concentrated sewage, the ability to cope with high concentrations of suspended solids (TSS), the ability to handle shock loads and success in treating a variety of biodegradable industrial wastes. The main disadvantage of anaerobic lagoon is generation of odors, caused by emission of H2S when they are submitted to a too low or too high organic loading. A low loading may occur during the early years of operation and a high loading, during late years. The relationship between odor development and organic loading is now reasonably well understood so that problems can usually be overcome by proper design and also by capturing and burning of the biogas produced.

Since anaerobic lagoons technology is well known for many years, it is not further discussed here, however, capturing and burning of the biogas produced in anaerobic lagoons treating municipal wastewater is a new concept which has been used in industrial effluents treatment plants, but currently rarely used in municipal wastewater treatment plants, so it is further discussed below. Capturing of the biogas produced in anaerobic lagoons can be done by covering the lagoons with membrane sheets. The covering of anaerobic lagoons provides many benefits: (i) capturing odorous gas for removal, burning or treatment, thus eliminating odor problems; (ii) enabling to flare or reuse captured greenhouse gases thus preventing their emission to the atmosphere and contributing to the worldwide efforts of controlling greenhouse gases; (iii) enabling the mobilization of additional financial resources through the sale of "emission reductions" to industrialized countries, (iv) reducing process heat loss; (v) reducing water evaporation, and (vi) blocking sunlight, thus inhibiting algae growth.

Methane, which is an important component of the biogas produced in anaerobic lagoons (the biogas is typically a mixture of methane and other gases such as carbon dioxide ammonia, nitrogen, hydrogen and other gases, in which the methane content is about 50 to 80%), is also a powerful greenhouse gas, 22 times as potent as carbon dioxide. Covering anaerobic lagoons, capturing the biogas and selling the "emission reductions" of the greenhouse gases, can generate an additional revenue stream to a project and make it more financially viable, thus contributing to economic development while also mitigating climate change.

A recently approved World Bank project in Bolivia, the "Bolivia Urban Infrastructure Project" (The World Bank, 2006), aims to improve to improve access to infrastructure in Bolivia's major cities through targeted infrastructure investments. This project includes expansion of sewerage coverage in poor areas of the city of Santa Cruz, as well as increasing the capacity of the four city's lagoons wastewater treatment plants so as to enable them to process the increased volume of wastewater. As part of increasing the capacity, the anaerobic lagoons of the four plants are being covered and the city's utility has already signed a contract for sale of the biogas emission reduction (The World Bank, 2007). This is the first case in developing countries of an emission reduction contract based on capturing of anaerobic lagoons biogas.

Gas collection covers are floating cover systems used to collect gases from wastewater treatment lagoons (and also sludge ponds, aeration systems, flow equalization tanks and pretreatment tanks). In the case of anaerobic lagoons the cover systems are used to capture biogas, which can be disposed of in a flare, or can be burned to generate process heat or electricity, using a biogas handling system. The lagoons are covered by a floating membrane made of lined PVC or High Density Polyethylene or similar. Off-gas removal piping connects directly to the cover system. The membrane material is chosen to be chemically resistant to the biogas and the wastewater treated throughout the project life, under rigorous weather conditions. Features of the floating covers can include automatic rainwater removal, baffles and sampling ports and hatches. The floating covers are durable, UV protected, can be installed quickly without disrupting plant operation and are easy to maintain while in service. Floating covers are strong enough to support foot traffic, rainwater loads, snow loads and light vehicles. They can be designed to automatically drain rainwater or snowmelt. The membrane cover is securely anchored to the lagoon perimeter and suspended across the lagoon surface. Support columns can be added when necessary and provide easy access to internal components. The membrane cover is gas tight, but can be quickly detached and easily rolled up. This gives operators access to inspect and maintain internal components. Reattaching the membrane cover is quick and easy. Optional hatches allow accesses by plant operators without retracting the cover.

Lagoons systems are, in general, suitable for serving small and medium size cities, of up to 300,000 inhabitants. That applies also to anaerobic lagoons, which usually form part of many lagoons systems configuration.

Usually, anaerobic lagoons are not constructed as a sole unit, but rather as a part of several lagoon units. Based on lagoons plants cost it is estimated that the investment cost of only anaerobic lagoons would be about 5-10 US$/Habitant. Operation and maintenance cost is extremely low. The cost of covering lagoons in Latin America amounts to 12 US$/m2. A photo of covered anaerobic lagoon in one of the plants of the city of Santa Cruz, Bolivia, is presented in Fig. 3.

Upflow anaerobic sludge blanket (UASB) reactor

UASB technology is increasingly being considered for municipal wastewater treatment applications in warm-weather locations given its low-cost and simple operations. Although this technology can not by itself produce an effluent of the quality of a conventional secondary process like activated sludge, it can still achieve significant organic matter removal rates (e.g. 60-75 % BOD5 removals) at a fraction of the construction and O&M costs of activated sludge. In applications requiring higher treatment levels, UASB reactors are usually followed by a polishing step. Experience to date in Latin America has shown that a UASB-based plant is simpler, less reliant on mechanical components and can easily achieve double the organic matter removal rates of conventional primary treatment. In addition, the UASB process generates substantially lower quantities of sludge, therefore reducing the associated sludge disposal costs. Given the anaerobic nature of the process, a high potential for H_2S generation (thus odor and corrosion problems) exists when the sulfate concentration in the raw sewage is high. The use of UASB reactors for domestic wastewater is becoming widespread in tropical countries such as Brazil, Colombia and India (Sandino, 2004; Onofre, 1997; Chernicharo, 2000).

Figure 3: Covered Anaerobic Lagoons in the Industrial Wastewater Treatment Plant of Santa Cruz, Bolivia

A UASB reactor is a high rate anaerobic reactor for treatment of wastewater based on anaerobic granular sludge bed technology. A scheme of a UASB reactor is shown in Fig. 4. From a hardware perspective, a UASB reactor appears to be nothing more than an empty tank, thus extremely simple and inexpensive. Wastewater is fed into the tank in the bottom, through appropriately spaced inlets. The wastewater passes upwards through an anaerobic sludge bed where anaerobic bacteria in the sludge come into contact with the wastewater (the substrate). The sludge is composed of microorganisms that naturally form granules (pellets) of 0.5 to 2 mm in diameter, which have a high sedimentation velocity and thus resist washout from the system even at high hydraulic loads. The resulting anaerobic decomposition process generates biogas as in other anaerobic processes. The upward motion of released gas bubbles causes hydraulic turbulence which provides effective reactor mixing without any mechanical equipment. At the top of the reactor, the liquid phase is separated from the sludge solids and gas in a three-phase separator (also known as the gas-liquid-solids separator). This separator is usually a gas cap with a settler situated above it. Baffles are used below the opening of the gas cap to deflect gas to the gas-cap opening. The level of removal of organic matter in a UASB reactor is limited by the concentration of the sludge in the reactor. Higher sludge concentrations would have resulted in higher organic matter removal, but would have also result in higher escape of sludge in the effluent, which then controls the maximum achievable sludge concentration.

Typical Hydraulic Detention time values in a UASB reactor is in the range 5-9 hr. Maximum upflow velocity is 0.5-0.7 m/hr, volumetric hydraulic load should be less than 4 m3/day/m3, water depth in the reactor is about 4.5 meters and the recommended maximum flow per reactor is 70 l/s. UASB reactor treating municipal wastes yields an effluent that usually contains 35-100 mg/l Total BOD5, 30-40 mg/l Soluble BOD5 and 50-130 mg/l TSS (removal efficiencies are 60-75% for total BOD and 60-70% for TSS).

Based on the recent construction of several medium to large size (e.g. serving above 200.000 populations equivalents) UASB facilities in Curitíba, Brazil, and some years ago in Bucaramanga, Colombia, construction costs in the range 20-40 US$/Habitant have been documented for this technology. Even including additional treatment steps for effluent polishing, these costs compare favorably with the 80-100 US$/Habitant values considered typical for a conventional activated sludge plant. Operation and maintenance costs are in the range of 1.0-1.5 US$/Year/Habitant.

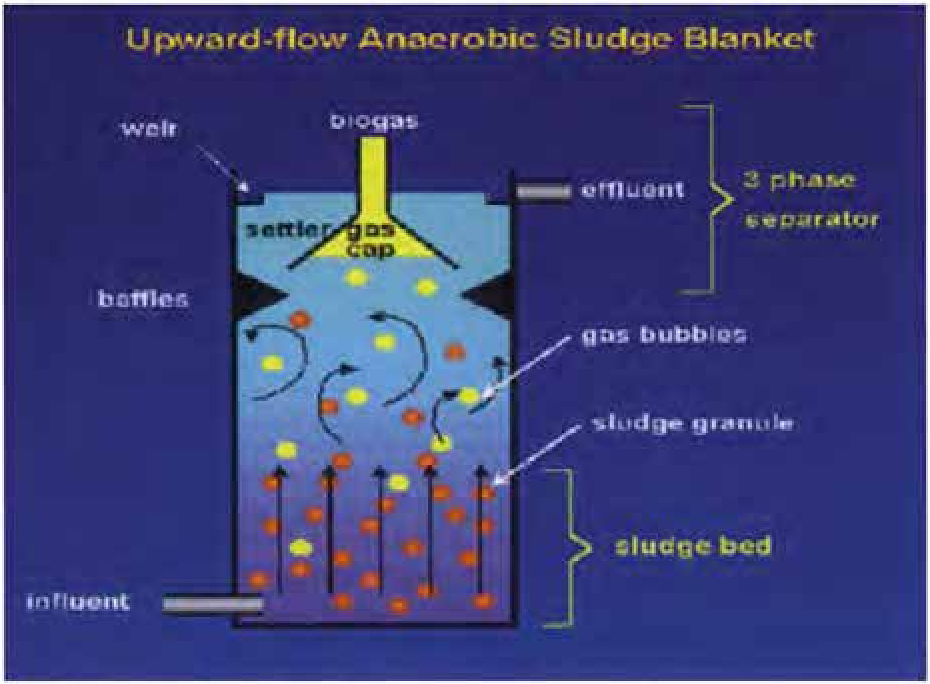

Figure 4: Scheme of the UASB Reactor

Several large plants have been constructed in Brasilia and Belo Horizonte in Brazil, each serving populations of about 1 million. The UASB technology is therefore suitable for serving all range of cities size, including large cities. Figure 5 shows a photo of the USAB plant Onca in Belo Horizonte Brazil, serving a population of about 1 million.

Anaerobic filters

Anaerobic filters perform as attached growth reactors, in which anaerobic bacteria grow on a media of rocks or plastic of large surface area and the wastewater flows through the media. The bacteria get in contact with the wastewater and consume the organic matter contained in it. An anaerobic filter can be described as the anaerobic equivalent of a trickling filter. Attached growth bacterial reactors can be divided to fixed bed, rotating bed (rotating discs) and expanding bed reactors. They also have a variety of shapes and structures. This section deals with fixed bed anaerobic reactors, also known as anaerobic filters, which are the most commonly used anaerobic reactors. Two main types of fixed bed reactors are ascending and descending flow reactors. The anaerobic fixed bed attached growth reactors consist of a tank containing the support media, rock particles or various types of plastic media. The bacteria develop in an attached form on the media and the consumption of substrate (i.e., the decomposition of the organic matter dissolved in the wastewater) as well as the growth of the anaerobic microorganism takes place on the external biofilm of each media particle. Anaerobic microorganisms can also develop in the form of flakes or granules trapped between the media particles. With increased accumulation of the biomass, parts of it detach sporadically from the media particles to which it is attached and flow out with the liquid. In spite of this process, the average residence time of biomass in the reactor is higher than 20 days. Ascending flow filters are more commonly used than descending flow filters. Descending flow filters can be operated with floated or un-floated media. In Ascending flow filters, recirculation is commonly used. The average residence time of the biomass in the anaerobic filter is very long due to its attachment to the support media, resulting in effective performance of the treatment process. The elevated residence time of the biomass in the filter which results in high microorganisms concentration, associated with short hydraulic detention time of the liquid in the filter and effective contact between liquid and sludge result in high organic matter removal and provide the anaerobic filter with great potential for its use for treatment of non-concentrated wastewater.

Figure 5: The Onca UASB Treatment Plant, Belo Horizonte, Brazil, Designed to Serve a Population of 1 million

To prevent clogging of the filter, effective removal of suspended solids from the raw sewage is required prior to its inflow to the filter. Such removal of suspended solids can be achieved by rotating fine screens. For small treatment plants, decanter-digesters (otherwise known as large septic tanks or Inhoff tanks) are used to remove suspended solids prior to an anaerobic filter. This is a common practice in Brazil. In addition to the use of anaerobic filters as the main treatment unit, they can be used as polishing unites for improvement of the quality of the effluent of a preceding unit. They are in fact more suitable to perform as polishing units since when fed with treated effluent of a preceding unit they are less bound to clog by suspended solids and have to treat a lower content dissolved organic matter. In Brazil anaerobic reactors are used as the main treatment unit mainly for small and medium size municipalities, while for polishing application anaerobic reactors are used in the entire range of cities size, including in treatment plant of large cities.

Additional information on anaerobic filters is provided by Chenicharo (2000), Onofre (1997), Onofre (2006). Cinicharo (2000) reports BOD removal efficiencies anaerobic filters of 70-80% when the filter is the main treatment unit, and 75-95% when used as polishing units. Onofre (2006) reports results of an investigation anaerobic filter which was in operation for six years. This filter, performing as the main treatment unit with 5 hours of hydraulic detention time, achieved a COD removal of more than 85%. The effluent quality was of less than 30 mg/l of BOD and less than 20 mg/l total suspended solids. Removal efficiencies are usually in the range 70-80% for both total BOD and TSS. Sludge withdrawal from the filter was undertaken once every six months. The design criteria of the descending flow anaerobic filter is provided by Onofre (1997) and is very interesting, consisting of a rectangular structure with the decanter-digester in the middle and two filter cells, on each side. Various types of filter media were used; among them one composed of portions of electrical wires plastic conduits, which was found to be the most efficient. Fig. 6 provides details of the design of the anaerobic filter, Fig. 7 is a photo taken during construction of a filter with the same design and demonstrates the simplicity of the unit and Fig. 8 shows a photo of the effluent, aside the raw wastewater, for comparison.

Detention time of the liquid in an anaerobic filter is in the range of 4-13 hours. Maximum organic load is 16 kg COD/m3.d (considering total filter volume), and usually no more than 12 kg COD/m^3.d. The effective depth of the filter media is 1.2-1.8 meters.

According to Onofre (2006), construction costs for anaerobic reactors as the main treatment unit are in the range 10-25 US$ /Habitant. Operation and maintenance costs are reported as low.

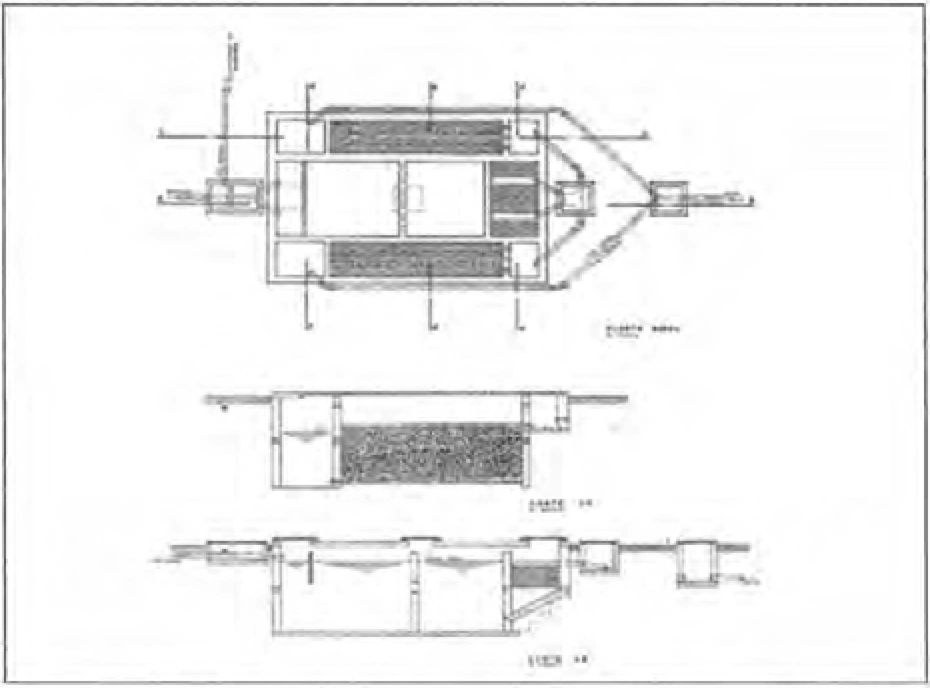

Figure 6: Anaerobic Filter Configuration, Natal Brazil, Source: Onofre (1997)

Treatment in lagoons systems

Conventional Technology

Along with the impressive advances and developments in man-made wastewater treatment processes in the past decades, some natural, old treatment systems are still being used successfully and should be considered as appropriate technology alternatives. However, most of these natural systems require large extensions of land, which may limit their applicability to small and medium-size cities, with populations of up to 300,000. Besides soil absorption, which is the natural process used in on-site disposal systems (cesspools and septic tanks); there are three major groups of natural wastewater treatment systems: stabilization lagoons (also known as oxidation pond or stabilization ponds), land treatment systems, and aquatic systems. Stabilization ponds are used extensively in developing countries and present one of the most cost-effective reliable and easily operated processes for treating domestic and industrial liquid wastes. They can produce high quality effluents, maintenance requirement are very simple and no energy is needed to make them function, other then solar energy. One of the great advantages of ponds over other treatment processes is their ability to remove pathogens without the need for chlorination, if the detention time of the effluent in the ponds is sufficient. Lagoon treatment can be classified as an excellent appropriate technology process, ideal for use in developing countries and elsewhere.

Figure 7: Photos of an Anaerobic Filter During Construction

Total BOD and TSS removal in conventional lagoons is in the range 70-90% for both, depending on the configuration and design of the lagoon system. One of The main drawbacks of lagoons is the large extension of land they require, which makes them less suitable for large cities. Another problem associated with lagoons treatment is the high algae concentration in the effluent. In many cases algae are not a desirable by-product and are themselves a source of secondary pollution, rich in carbonaceous and nitrogenous matter, which puts an environmental strain on the receiving waters. Algae removal from lagoons effluent is not an easy task. Many processes are available for this purpose, but they significantly increase the treatment cost. Recently, a new process using ultra-sound waves was developed and seems to be cost effective.

The great variety of pond combinations in use makes any systematic classification difficult. In principle, natural (non-aerated) ponds can be anaerobic, facultative or aerobic. For maximum efficiency, especially in warm climates, ponds need to be operating in series: an anaerobic pond followed by one or two facultative ponds and one or more maturation (or polishing) ponds. The inclusion of an anaerobic lagoon in a lagoons treatment plant is very important due to its high efficiency. Often, anaerobic ponds are omitted and the system includes only facultative and maturation ponds, a combination which requires a larger area. Ponds in series can produce excellent effluents with a microbial quality suitable for unrestricted irrigation. A photo of a typical lagoons system is presented in Fig. 9. It is the photo of the Eastern plant of Santa Cruz, Bolivia, consisting of three parallel trains, each including an anaerobic lagoon followed by two facultative lagoons followed by one maturation pond, all in series. Information on design and performance of lagoon systems is abundant, for instance, Mara (1976), Arthur (1983), Yanez (1993) and Rolim (2000).

Figure 8: Photo of an Anaerobic Filter Effluent aside the Raw Sewage, Natal, Brazil

It is difficult to provide information on cots of stabilization lagoon since the cost depends on the ponds configuration and cost of land, however, representative values can be mentioned. According to Rolim (2000), Arthur (1983) and Yanez (1993), construction costs of a lagoons system is in the range 20-40 US$/Habitant. Operation and maintenance costs are in the range of 0.2-0.4 US$/Year/Habitant.

Aerated lagoons, a man-made development of aerobic ponds, reduce the extension of land required by adding artificial aeration. Aerated lagoons should not be considered an appropriate technology process. Although their construction costs may be lower than those of other lagoon types, their energy consumption is high since in this process oxygen is used both for decomposition of dissolved organic matter and stabilization of the suspended organic matter present in the sewage. Usually in developing countries, and especially in small and medium size cities, there is no capacity to finance the electricity cost for operating the aeration equipment of the aerated lagoons and there is no technical capacity to keep the equipment running for extended periods of time, so frequently an aerated lagoons plant functions as a raw sewage reservoir in which nonfunctioning aerators are floating, or are deposited on the lagoons dykes.

LAS innovative technology

Innovative interesting processes have been developed during the recent years by LAS International to improve the performance of existing facultative and aerobic stabilization lagoons, and improve the design of new ones. Common problems in facultative and aerobic lagoons are: (i) short circuiting which drastically reduces the treatment efficiency; (ii) odors at night due to nonexistent of sunlight which stops the oxygen production by algae; (iii) stratification which disturbs or prevents treatment processes in lower layers; (iv) over concentration of algae in the upper layer, preventing sunlight penetration and reducing process efficiency; (v) oil film buildup in the water surface, disturbing the process; and (vi) continuous odor problems resulting from overloading of the lagoons. LAS international developed two types of solution to the facultative and aerobic lagoons problems. Both are based on the principle of installing in the lagoons equipment which does not change the nature of the process in the lagoons but rather help them.

Figure 9: Air Photo of a Conventional Anaerobic-Facultative Lagoons Wastewater Treatment Plant in the City of Santa Cruz, Bolivia

The first instrument is introducing in the lagoon gentle mixers which pump water from the depth, without breaking the facultative layer or disturbing the anaerobic layer at the bottom of the lagoon, and discharge the water near the surface. The mixers prevent short-circuits, bring to the upper layer for processing organic matter from deeper layers, prevents stratification, breaks oil films, creates uniform oxygen profiles from the top of the lagoon to the facultative layer, and actually resolves all the mentioned problems and improves the performance of the lagoon. The LAS mixer is not an aggressive aerator which consumes large amounts of energy, but rather a gentle mixer with a small motor of 0.75 HP that consumes little energy and can be operated by wind when the wind velocity in the treatment plant site is sufficiently high (over 6-8 km per hour). The mixer switches automatically to wind operation when the wind velocity passes a selected threshold. Each mixer has an influent range of 2-3 ha, and the installation of the mixers in a lagoon can significantly increase its treatment capacity.

The second instrument is injecting air into the lagoon through blowers (not compressed air) to augment the oxygen quantity produced by the algae without changing the flow regime, i.e. without transforming the lagoon to an aerated lagoon. For that purpose, a combination of blowers with air distributors and gentle mixers need to be installed in the lagoon. The addition of air to the lagoons increases its treatment capacity to a required level.

The LAS equipment principles of operation are presented in Figures 10, and 11. The mechanism by which the LAS mixers improve the performance of facultative lagoons and resolves the above mentioned lagoons problems is presented in Fig. 12.

Figure 10: LAS Mixers and Air Injectors in Facultative and Aerobic Lagoons

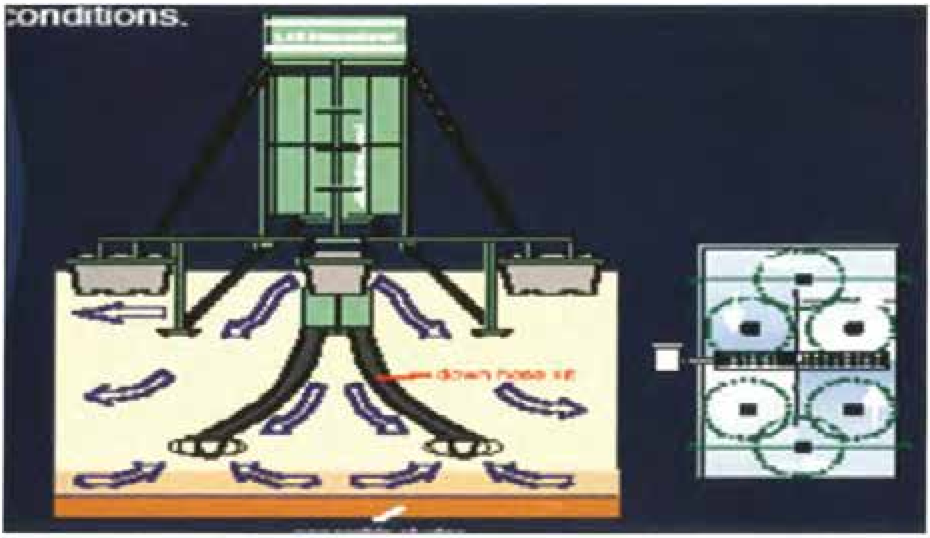

Figure 11: The Principle of the LAS Mixer Function courtesy LAS International

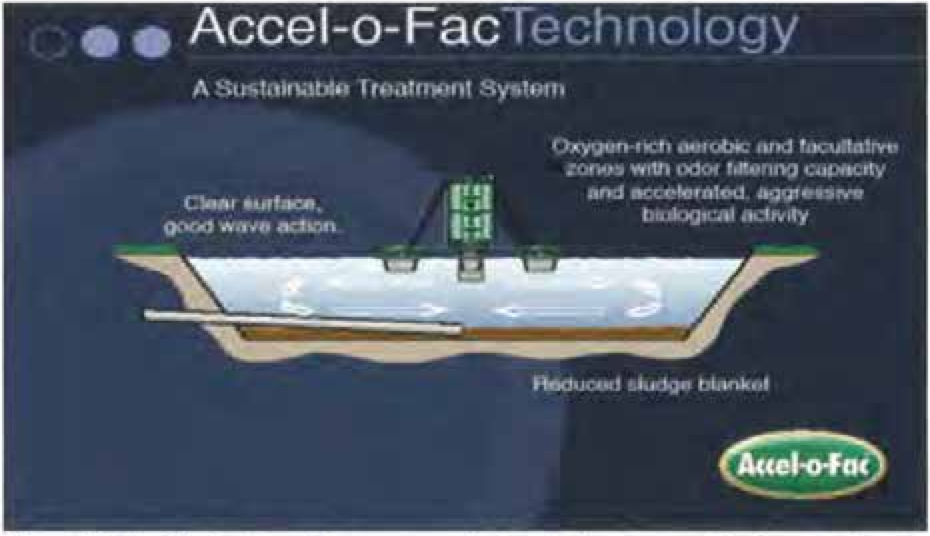

Figure 12: The Mechanism of Improvement in Facultative Lagoons Performance by the use of LAS Mixers, Courtesy LAS International

Upgrading of existing plants can be done in stages, first mixers are installed in shallow lagoons, after time, lagoon depth is increased to 3-4 meters, since the mixers are more effective at such depths, and finally, air blowers and injection equipment can be added. This is an effective method to increase lagoons plants capacity when additional area is not available. For design of new lagoons, it is proposed to provide a plant consisting of a basic unit of a covered anaerobic lagoon followed by a 4-5 meters deep facultative lagoon equipped with mixers, followed by a 4-5 meters deep polishing pond equipped with mixers followed by an ultrasonic installation for reducing algae content in the effluent. This yields effective treatment and good quality effluent using less area. With LAS equipment aided lagoons is possible to achieve effluents of higher quality than those of conventional lagoons systems and reach total BOD removals of 90-95% and TSS removals of 80-95%.

It is difficult to provide data on costs of upgrading existing plants because such costs are specific to each plant, depending on local conditions. Rough estimates would suggest an investment cost range in mixers of 5-10 US$/additional Habitant. Incremental operation and maintenance costs are very small. The investment cost of newly designed LAS mixers aided treatment plants is similar to that of conventional lagoons systems, because although an additional investment in mixers is required, the population served is larger since the plant capacity increases when using mixers, so the cost per habitant does not increase. The same applies for operation and maintenance costs.

Constructed wetlands

The use of constructed wetlands for wastewater treatment has increased dramatically in the past decade, particularly for small scale applications such as individual homes and small villages. Interest in constructed wetlands has been driven by a variety of factors including enhanced enforcement of environmental standards, limitation of regional sewerage networks to cost effectively serve remote areas in developing countries and the fact that because they use local materials and labor, constructed wetlands can readily be implemented in developing countries.

A constructed wetland bio-filter is a gravel or volcanic rock aerobic biological filter sown with marsh plants, through which preliminary treated wastewater is flow horizontally or vertically. A bacterial film of aerobic bacteria is formed on the filter bed and consumes organic matter dissolved in the wastewater. To avoid clogging of the filter bed, large suspended solids need to be removed from the inflowing wastewater. This can be achieved by preliminary treatment, preferably by rotating fine screens, or by the use of settling units such as Imhoff tanks or settling tanks. Plant roots allow airflow from the atmosphere to the subsoil thus maintaining the aerobic conditions in the filter bed. The pre-treated effluent is uniformly distributed over the whole filter bed surface and flows through the bed to the effluent outlet structure. Feeding intervals must be long enough to allow good wastewater distribution and air filling into the empty bed spaces. Once installed and properly operating, the constructed wetland plant can have a long life span due to the balance between plant growth and death cycles and biomass production. The plants to be used in the constructed wetland are selected to fit the type of contaminants that need to be removed from the wastewater. *Plantanillo, zacate taiwan, tule* and reed were found to be effective.

Advantages of constructed wetlands are: (i) operating without energy consumption; (ii) easy to operate since it does not employ equipment; (iii) integrates well in rural areas; and (iv) produces vegetal biomass (50-70 tons of dry matter/hectare/year). Disadvantage include: (i) requires large areas; and (ii) solid wastes and sludge are generated in the pre-treatment unit. Additional information and design details regarding constructed wetlands can be found in WSP (2005). A section of a horizontal flow constructed wetland is presented in Fig. 13.

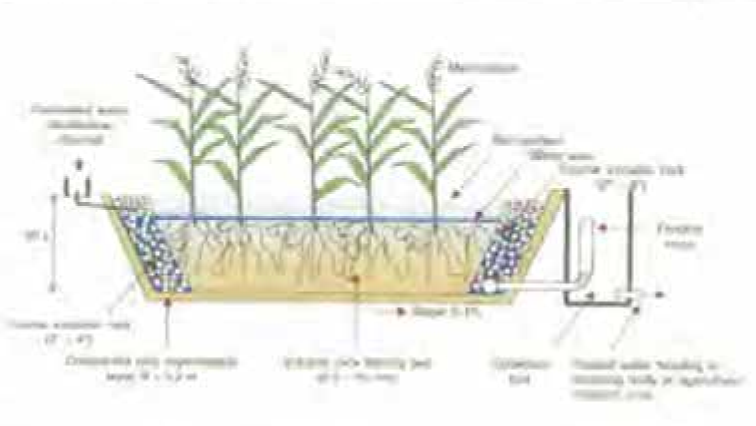

Figure 13: Section of a Horizontal Flow Constructed Wetland

Removal efficiencies of organic matter and suspended solids in constructed wetlands reach 80 to 90%. Nutrients removal efficiencies are relatively low, about 30%, and removal of pathogens is also low. When serving as the main treatment unit, constructed wetlands are used in small towns of up to 20,000 inhabitants. Constructed wetland can also serve as a polishing unit of the effluent of other treatment processes. Under this application it can be used for larger cities.

WSP (2005) reports an investment cost in constructed wetlands in the range of 30-60 US$/Habitant and operation and maintenance costs in the range of 2-4 US$/Year/Habitant. These costs seem to be high and probably refer to very small towns. For larger towns, economy of scale may reduce costs.

Chemically enhanced primary treatment (CEPT)

Chemically Enhanced Primary Treatment (CEPT), a well known physico-chemical treatment process, has been in use for over one hundred years, yet is not in widespread use as would be expected on the basis of its performance. Its main uses are: (i) treatment prior to ocean discharge; (ii) phosphorus reduction; and (iii) as a compact treatment unit. CEPT is a process by which chemicals, typically chemical salts as ferric chloride or aluminum sulfate, are added to primary settling tanks. Coagulation and flocculation cause particles to cling together and then settle faster, thereby achieving higher removal rates of TSS and BOD than those experienced in conventional primary treatment (80-85% TSS removal and 50-70% BOD removal in CEPT as compared to about 40-50% TSS and 30 35% BOD removal in conventional primary tanks) while also obtaining higher performance efficiencies measured by working at double the surface overflow rate in relation to the one used in conventional primary tanks. The increased performance efficiency of the CEPT allows for the design of smaller settling tanks in relation to those conventional primary treatment, for the same wastewater flow. CEPT is a relatively simple technology, which provides low cost, easy to implement and effective treatment.

To upgrade a conventional primary treatment facility to a CEPT facility, all that is needed is the addition of a chemical coagulant and optionally a flocculent. CEPT relies on small doses of metal salts, usually in the range of 10-50 mg/l and the chemicals themselves make only a slight contribution to the total sludge production. The greatest portion of the increased sludge production in CEPT is the result of the increased solids removal in the settling tank, which is precisely the CEPT's goal. The main options for sludge treatment, which needs to be part of the CEPT installations, are: (i) lime stabilization and use of drying beds for drying the sludge; (ii) anaerobic digestion; and (iii) composting.

The quality of a CEPT effluent approaches that of a biological secondary effluent in terms of removal efficiencies of TSS and BOD. The CEPT effluent can be effectively disinfected, and that is an important feature for developing countries, where due to the high level of morbidity originating in water borne diseases, disinfection is a priority. Removal of 70% BOD by CEPT can in many cases be sufficient prior to discharge of effluent to rivers, when the rivers' assimilation capacity is taken into account. When removal of phosphorus is required, for instance before discharge of effluents to lakes, it can be achieved through the use of CEPT. And since all that is achieved at a reduced cost, CEPT can be attractive for developing countries. CEPT treatment does not preclude subsequent additional treatment for polishing of its effluent. It makes any subsequent treatment smaller and less costly. The CEPT process can be applied to medium size and large cities. Small cities might have difficulties to operate a CEPT plant since its operation required a certain technical level.

According to Harlenam et al (2001, 1998) and Murcott(1996) the ratio of investment cost in conventional activated sludge to investment in CEPT is about 4 to 1, and the ratio of O&M costs (both including disinfection) is about 2 to 1. Construction costs of CEPT system of various sized are in the range 30-50 US$/Habitant. Operation and maintenance costs are in the range of 2-4 US$/Year/Habitant.

Fig. 14 shows a photo of a CEPT effluent sample aside a regular primary effluents sample of bench scale experiments, demonstrating the superior quality of the CEPT effluent.

Figure 14: Bench-Scale CEPT and Conventional Primary Treatment Effluents, Source: Prof. Harlemann, MIT (2004)

Wastewater reuse for irrigation, the stabilization reservoirs concept

Wastewater reuse for irrigation is not a treatment method but rather a concept of combined treatment and disposal. It can offer an additional final disposal alternative on top of conventional ones, and generate agricultural economic benefits. Reuse for irrigation is a wide topic that cannot be fully discussed in this section, however it has a close relation to appropriate treatment technologies, which needs to be clarified. Reuse of wastewater for agriculture is usually associated in peoples minds with highly sophisticated wastewater treatment technologies aimed at generation an effluent of very high quality, close to that of potable water. The fact is that effluent adequate even for unrestricted irrigation of crops eaten raw can be produced using simple treatment processes, and entire reuse systems can be constructed in such a way that they will fall within the definition of appropriate technology.

While municipal wastewater is available at a relatively constant flow, irrigation water is required mainly during the dry season. In order to compensate between the constant supply and variable demand, seasonal storage is required in every project of municipal wastewater reuse which aims to be economically feasible. A seasonal storage reservoir is the key element of any wastewater reuse system. There are two possibilities for storage: surface storage and underground storage. Surface storage can be applied in any project, while recharge into the ground depends on the hydro-geological condition of each specific site. In both cases seasonal storage installations act also as efficient treatment processes which may provide, in addition to storage, either polishing of highly treated effluents or serve as the main wastewater treatment step.

The concept of appropriate technology refers mainly to reuse projects with seasonal surface storage. The surface reservoirs are also known as Stabilization Reservoirs. This type of reservoirs was originally built in Israel by farmers in the seventies to store effluents to be reused for cotton irrigation during a three-month peak summer season. It was soon observed that the quality of the effluent after several months of storage was significantly better than the quality of the influent to the reservoir, mainly with respect to organic matter content and number of pathogens. Since then, the stabilization reservoir treatment has been developed as an innovative scheme and has been successfully applied in small, medium size and large irrigation reuse projects in Israel. The reservoir is full at the beginning of the irrigation season and empty at the end. The maximum depth of the existing reservoirs is in the range 8-12 meters. A deep reservoir is in fact a deep facultative lagoon with a water level which varies throughout the year. During the detention period of effluent in the reservoir, which varies between two to several months, the processes which take place in it include sedimentation, organic matter decomposition, biomass growth, and some nitrogen transformation through nitrification, denitrification and ammonia stripping. Biological populations which develop in the reservoir ecosystem include bacteria, algae and zooplankton. Water purification is effected by activity of aerobic bacteria and algae in the upper layer as well as by anaerobic bacteria in the bottom of the reservoir. Most of the time the reservoir is stratified, with most of its volume acting as an anaerobic reactor and only the upper layer is acting as an aerobic zone from which the final effluent is extracted. The reservoir is totally mixed only during winter or transition seasons.

The key to proper functioning of the reservoir is prevention of anaerobic incidents at the water surface. Existence of aerobic conditions, at least in the upper layer, prevents generation of odor problems and ascertains improvement of water quality. Decomposition of organic matter is an oxygen consuming oxidation process. In the event that the quantity of oxygen supplied by algal photosynthesis and re-aeration is smaller than consumption for bacterial respiration, anaerobic conditions may develop. Such conditions can be prevented by control of organic loads diverted to the reservoir. The concept of stabilization reservoirs reuse scheme is presented in Fig. 15. Oxygen balance models of reservoirs, as well as experience, established that the maximum permissible organic loads which still prevent generation of anaerobic conditions in the upper layer of stabilization reservoirs are 30-50 kg BOD/day/ha during winter and of 60-100 kg BOD/day/ha during autumn and summer. LAS mixers (see above) can be installed in odor generating reservoirs to improve their performance and increase the maximum permissible organic load on a reservoir (preliminary results indicate and increase in maximum load of up to 250 kg BOD/day/ha).

Additional information on stabilization reservoirs can be found in publications by Libhaber (1987, 1996) and Juanico (1999). A typical wastewater pre-treatment and stabilization reservoir scheme of a medium size city is shown in Fig. 16. In this case the reservoir is full.

For properly designed and operated single-cell reservoirs the expected effluent quality is: BOD 5 10 mg/l, suspended solids 5-20 mg/l, fecal coliforms 102-103 MPN/100ml and the system achieves 25 to 50% ammonia removal. Higher reduction levels may be achieved if influent flow is stopped before the irrigation period. Reduction of enteric bacteria and viruses may be explained by the influence of radiation and predation by other organisms. In terms of water quality for irrigation, the critical quality parameter is the concentration of pathogenic organisms. Reservoirs completely remove Helminth eggs and nematods with no difficulty. The level of removal of other pathogens (bacteria and viruses) depends on the mode of operation of the reservoir. To obtain a fecal coliform (indicator organism for pathogens) free effluent, a system consisting of two reservoirs is required. An additional reservoir renders the system more expensive, but also produces a higher quality effluent, which can be used for unrestricted irrigation and generate more profits by irrigating higher value crops. A photo of a reservoir effluent (Maale Hakishon reservoir) is shown in Fig. 17.)

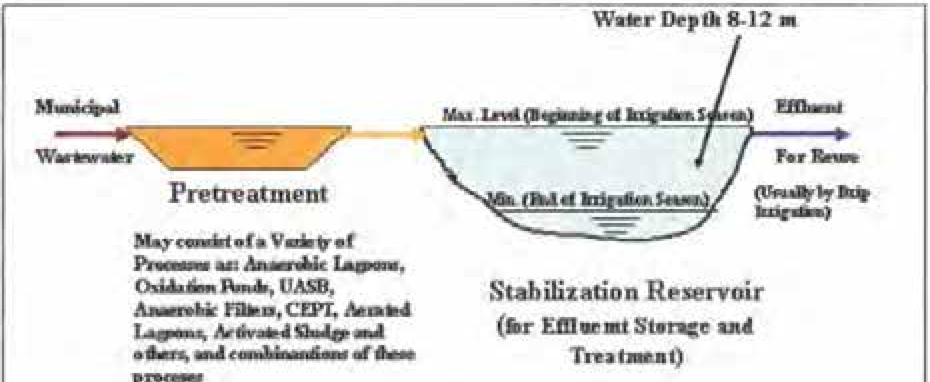

Figure 15: The Stabilization Reservoir Reuse Concept

Figure 16: The Wastewater Treatment System and Stabilization Reservoir of the City of Nazareth

The cost of a complete stabilization reservoir system, including pretreatment, depends to a large extent on the pretreatment system. The additional investment cost of the reservoir is about 20-30 US$/Habitant. When the pretreatment is based on appropriate technology, the investment cost of a complete reservoir system, including pretreatment, is about 30-50 US$/Habitant. When the reservoir is in the same site of the pretreatment installations and both are operated by the same institution, as in the case presented in Fig. 16, the additional operation and maintenance cost of the reservoir are negligible. In many cases, the pretreatment and the reservoir are not in the same site and are operated by different entities, the pretreatment by the municipality and the reservoir by a farmers association. In this case, the operation and maintenance costs of the reservoir are similar to those of operating a stabilization lagoons system, i.e., in the range of 0.2-0.4 US$/Year/Habitant.

The combined stabilization reservoir-drip irrigation reuse system is a simple, economic wastewater reuse (and disposal) method which does not require high skills for operation and maintenance. The required pretreatment of the wastewater before it is stored in the reservoir can be achieved using a variety of treatment process, among them, all the appropriate technology processes described above. If simple pretreatment processes are selected, the entire pretreatment, reservoir and irrigation system can be considered an appropriate technology system.

Figure 17: Effluent Sample of Maale Haskishon Reservoir

Submarine outfalls

About 50% of the world's population resides in or near coastal areas. The most probable receiving body of sewage and treated effluents generated by this population are the oceans and seas. Ocean disposal of sewage and its treatment prior to discharge are therefore issues of major importance. Wastewater treatment is often seen as the only way to cope with water quality problems; although effective outfalls combined with lesser treatment levels may substantially reduce costs while still reaching the same environmental objectives as higher treatment levels. For developing countries, in which resources for wastewater treatment and disposal are scarce, low cost solutions are of major importance.

The World Health Organization (WHO) has published in October 2003 guidelines for recreational water quality protection (WHO, 2003). Table 1 below presents the WHO findings on relative health risks to human health by exposure to effluent discharged from submarine outfalls, classified according to various schemes of combination of sewage pretreatment and submarine outfall length.

Table 1: Relative Risk Potential to Human Health Through Exposure to Sewage Through Outfalls (From WHO, 2003)

Treatment	Discharge type		
	Directly on beach	Short outfall	Effective outfall
None	Very high	High	NA
Preliminary	Very high	High	Low
Primary (including septic tanks)	Very high	High	Low
Secondary	High	High	Low
Secondary plus disinfection	—	—	—
Tertiary	Moderate	Moderate	Very lowm
Tertiary plus disinfection	—	—	—
Lagoons	High	High	Low

The discharge methods of sewage or effluent into oceans can be classified into three principal types: (i) discharge directly onto the beach, which also includes discharge into rivers streams or canals, a short distance from the coastline; (ii) "short" outfalls, where sewage or effluent is likely to contaminate recreational waters; and (iii) "effective" outfalls, designed so that the sewage or effluent is efficiently diluted and dispersed so as to ensure that it does not pollute recreational water areas. While the terms "short" and "long" are often used, outfall length is generally less important than proper location and effective dilution. An effective outfall is assumed to be properly designed, with sufficient length and diffuser discharge depth to ensure that the sewage does not reach the recreational area.

According to WHO, if an effective outfall is provided for discharge of effluent to the sea, the level of pretreatment of domestic sewage practically does not have a bearing on the risk to human health of the discharged effluent. The risk to human health of secondary effluent discharged through an effective outfall is classified as low. The same low risk is assigned to primary effluent discharged through an effective outfall, and even the risk of preliminary treated effluent discharged through an effective outfall is classified as low. The WHO findings lead to a conclusion that if an effective outfall is provided, preliminary treatment is sufficient prior to discharge of domestic sewage to the sea. And on the other hand, if a short (ineffective) outfall is provided, even secondary treatment is not sufficient to reduce the high risk to human health of effluent discharged trough that type of outfall. These findings of the WHO are of high importance for developing countries since they imply that only preliminary treatment is required prior to discharge of effluent to the sea through an effective outfall. Preliminary installations as pretreatment prior to discharge of effluents to the sea can save a lot of money in developing countries, in which financial resources are usually scarce. The investment costs, as well as the operation and maintenance costs of preliminary treatment are about 1/10 of the cost of conventional secondary treatment, while the use of preliminary treatment yields results comparable to those of secondary treatment. The mentioned conclusions refer to typical municipal sewage which does not contain excessive levels of toxic wastes originating from industrial wastewater.

For coastal cities in developing countries, the strategy of domestic wastewater disposal by preliminary treatment followed by an effective submarine outfall is an affordable, effective, and reliable solution. It is simple to operate and free of negative health and environmental impacts, and falls into the definition of appropriate technology. Many outfalls of this type are successfully functioning and they have a proven track record in many coastal cities all over the world.

A submarine outfall system, which includes the outfall itself and the nearfield zone, should in fact be considered a treatment plant. This treatment plant provides a high level of treatment, much superior to that which any conventional land based plant can reach. Land based plants can reach, in extreme cases, removal levels of BOD and TSS of up to 95%, and if the effluent is not disinfected, they remove 50-80% of pathogenic organisms, which is a very low removal level, leaving the effluent with practically the same level of risk to human health as that of raw sewage. On the other hand, a well designed outfall system removes over 99% of all contaminants, including pathogenic organisms. Removal of 99% of pathogenic organisms might not be sufficient; however, the mentioned value refers to physical dilution. Taking into account also the biological decay of pathogenic organisms in the marine environment, a well designed outfall can ensure their overall removal to levels lower than that of bearing risk to human health. The setup and dilution mechanism of a submarine outfall is presented in Fig. 18.

As an example, operating results of the submarine outfall of the city of Tome, in the vicinity of Concepción, Chile, consisting of preliminary treatment followed by an effective outfall, are considered, based on information provided by Leppe and Padilla (1999). The results are average results of five years of measurements near the outfall discharge point. These results show that for all quality parameters, expect fecal and total coliforms, the concentration values at a distance of 100 m from the outfalls discharge point are identical to the sea background concentrations, and that demonstrates the high treatment capacity of the outfall system. As for coliforms, their concentrations in the raw sewage and preliminary treated effluents are extremely high. Even so, their concentrations are markedly reduced at a distance of 100 m from the discharge point of the outfalls, to levels that meet the most stringent standards even though they are higher than the background level. Nonetheless, with the biological decay, the concentration of the coliforms is reduced to the background level after an additional short distance from the outfalls discharge. In the same paper, Leppe and Padilla (1999), report on another outfall, of the city of Penco, which demonstrated similar results.

The most appropriate preliminary treatment process prior to disposal of wastewater through a submarine outfall is rotating fine screens followed by a vortex grit chamber. This is the preliminary treatment selected for the city of Cartagena, Colombia (Population about 1 million) prior to discharge of the effluent to its Caribbean sea (Libhaber and Roberts, 2002).

The preliminary treatment followed by a submarine outfall is a scheme adequate for cities of all sizes: small, medium and large cities. The cost of a preliminary treatment plus outfall system depends on the length of the effective outfall, which is site specific. In Santa Marta, Colombia, the sea bed is very steep and only a 400 meter long outfall was required. The preliminary treatment consists only of bar screens. The investment cost in Santa Marta was 3 US$/Habitant. In Cartagena the preliminary treatment includes rotating fine screens followed by a vortex grit chamber, and the submarine outfall is 3 km long. The investment cost in Cartagena amounted to about 28 US$/Habitant. A range of 3 30US$/Habitant would be indicative of the investment cost of an outfall system, including preliminary treatment. Operation and maintenance costs would be similar to those of the preliminary treatment system itself.

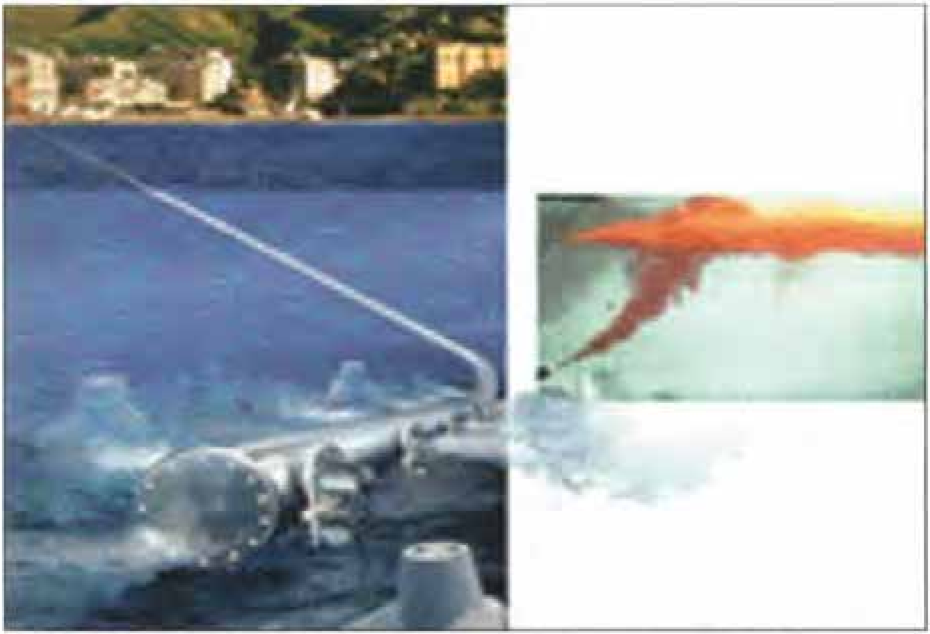

Figure 18: Setup and Dilution Mechanism of an Effective Submarine Outfall

Combinations of appropriate technology processes

Introduction

A series of appropriate technology treatment processes were presented above, each adequate for use in developing countries and each yielding a different effluent quality. In cases where higher effluent qualities are required or when regulations require higher effluent qualities, the effluents of the processes discussed above need to undergo one or more polishing steps. Combinations of the processes can be used to achieve the quality level required, i.e., certain appropriate processes can be used as the polishing steps of the effluents of other processes, and so two or more appropriate processes in series may be used to achieve the required effluent quality. However, the use of a complex process as a polishing step of an effluent of an appropriate technology process should be avoided, because it transforms the entire treatment plant to a complex plant. For example, many plants in Brazil use activated sludge or aerated filters or aerated lagoons as polishing steps of a UASB reactor effluent. Such combinations do not form an appropriate technology process. A UASB followed by activated sludge is perhaps a little less costly than activated sludge alone, but the difference is not large. In addition, running a plant composed of UASB followed by activated sludge is as complicated as running an activated sludge plant and it also generates much more excess sludge than a USAB alone.

The number of possible combined processes is very large and not all processes can be discussed here. Only some processes are presented in this section, part of them already existing and functioning as full scale plants, and part are only ideas and proposals.

RFS followed by UASB followed by facultative lagoons

Under this scheme, the effluent of a UASB plant is polished by facultative lagoons. This is a very logical scheme and an exemplary appropriate technology process. The removal of the main portion of organic matter is achieved in this scheme by the USAB process. The facultative lagoon system used for polishing the UASB effluent is a simple reliable system. Removal of pathogenic organisms can be achieved in this process naturally (without disinfection), if sufficient detention time is provided in the lagoon system. This process includes also the disposal of the screened material and the handling of the UASB excess sludge, mainly by drying beds, without mechanical equipment. The main disadvantage of this scheme is that the lagoons require large extensions of land. If area is scarce, deeper lagoons with LAS mixers can be used. An ultrasound device can be used to decrease algae content in the final effluent. Because of the use of lagoons as part of this process, it is suitable for small and medium size cities, but not for large cities. As a whole this is a very good and recommended process.

This process is being applied in several plants in Brazil and in Colombia. The largest plant of this type in Colombia is the Rio Frio plant in Bucaramanga. This plant, commissioned in 1991, is one of the oldest large scale UASB-based facilities treating municipal wastewater in the world. Removal efficiency of BOD is about 78% in the USAB plant and 33% in the facultative lagoons, achieving a total BOD removal in the range 85-90%. Construction costs for the existing facilities were approximately 33 US$/P.E. Operating costs are in the order of US$ 0.024 US$/m3 treated. The plant has been able to achieve essentially secondary treatment levels at a very low capital and O&M costs, thereby demonstrating the potential of application of this process in developing countries.

RFS followed by UASB followed by anaerobic filter followed by disinfection

A process composed of rotating fine screens as preliminary treatment, followed by UASB as the unit for removal of the main portion of organic matter, then followed by an anaerobic filter for polishing of the UASB effluent, and finally followed by a disinfection unit (chlorination or UV disinfection) for removal of pathogens is a reasonable schemes and an effective appropriate technology process. It is very similar to the process described in the previous section and is basically the replacement of the lagoons by an anaerobic filter followed by a disinfection unit. This process can be applied in cases where area is scarce and insufficient for installation of lagoons. The advantages of this process are that it is compact (does not require large extensions of area) and yields a high effluent quality. The process is adequate for application in small, medium and large cities.

This process has been applied in several pilot plants and full scale plants in Brazil, using conventional preliminary treatment or an Imhoff tank as the preliminary treatment stage of the process instead of rotating fine screens. In pilot plant experiments reported by Chernicharo (2000) a final effluent containing an average of 22 mg/l total BOD (soluble and suspended) and 15 mg/l of TSS was achieved. Such an effluent quality is similar to that of an activated sludge process effluent. Total BOD and total COD removal efficiencies achieved were 90%, soluble COD removal achieved was 81% and TSS removal achieved was 95%.

Onofre (2006) reports that many plants based on the UASB followed by an anaerobic filter process are under operation since 1996 in the state of Parana, Brazil, serving populations in the range 1,500 to 50,000 persons. Effluent quality achieved in these plants is TSS lower than 20 mg/l and total BOD lower than 60 mg/l. The same type of plants is under operation since 1997 in the state of Minas Gerais, Brazil, serving populations in the range 2,000 to 15,000 persons. One plant in Minas Gerais, at Ipatinga, serves a population of 200,000. A photo of this plant is presented in Fig. 19.

Onofre (2006) also reports that the investments costs of the UASB followed by anaerobic filter systems in Parana were in the range of 5 to 30 US$/Habitant. This process is of special importance since it is able to achieve essentially secondary treatment levels at a very low capital and O&M costs, using limited extension of area similar to that of activated sludge, thereby demonstrating the potential of application of this process in developing countries as a favorable alternative to activated sludge.

Figure 19: Photo of a UASB Reactor Followed by an Anaerobic Filter in Ipatinga, Minas Gerais, Brazil

CEPT followed by sand filtration and disinfection

If a higher effluent quality than that which can be produced by CEPT is required, a combination of CEPT followed by filtration and UV disinfection can provide good results. The filtration can be a multimedia sand filtration or membrane microfiltration. The microfiltration is a relatively new technology and its use in that combination requires investigation. The process flow diagram is presented in Fig. 43.

According to Cooper-Smith (2001) the combination of CEPT followed by sand filtration and disinfection proved capable of producing a high quality effluent (averaging 20 mg/l BOD, 15 mg/l TSS) using a Tetra Deep Bed Filter at a filtration rate of 5 m/h and a coagulant (Kemira PAX XL60, a polyaluminium silicate) dose of 40 mg/l. Further, UV disinfection of the filtered effluent complied with the required Bathing Water Directive standard and Net Present Value calculations showed this option to be considerably cheaper than a secondary biological treatment option. Sludge treatment is identical to that of CEPT sludge. CEPT followed by filtration can be used to produce an almost secondary quality effluent which would represent a good option for developing countries, as its attributes include: (i) the ability to provide a secondary effluent quality at lower cost; (ii) reduced power needs; and (iii) easy operation. This process is suitable for medium and large cities, and is not advisable for small cities.

It is estimated that the ratio of investment cost in conventional activated sludge to investment in CEPT followed by multimedia sand filtration is about 2 to 1, and the ratio of O&M costs (both including disinfection) is about 2 to 1, i.e, construction costs are approximately 50 US$/Habitant and operating costs are in the order of 2 US$/Year/Habitant.

Additional potential combined processes (only ideas and proposals)

The following combined processes are presented only as ideas of reasonable appropriate technology processes and are not known to the author to be in operation anywhere. They might however be under experimental studies or operating as full scale plants somewhere in the world. Only the name of each proposed process is provided herewith, which also describes the treatment flow scheme sequence. All these processes were considered to be of reasonable configurations and falling within the definition of appropriate technology processes.

- **RFS followed by UASB followed by Sand Filtration and Disinfection**
- **RFS followed by UASB followed by Dissolved Air Flotation (DAF) and Disinfection**
- **RFS followed by UASB followed by Constructed Wetlands**
- **RFS Followed by Anaerobic Filter followed by Facultative Lagoons**
- **RFS followed by Anaerobic Filter followed by Constructed Wetlands**
- **RFS followed by UASB followed by Anaerobic Filter followed by DAF followed by Microfiltration followed by Nanofiltration**

When an extremely high quality effluent is required, close to that of potable water, a series of units can be used including RFS followed by UASB followed by Anaerobic Filter followed by DAF followed by Microfiltration followed by Nanofiltration. The UASB followed by Anaerobic Filter process was discussed above. The effluent of this process is then subjected to Dissolved Air Flotation – DAF (which requires the use of flocculants) and then to Microfiltration, and if necessary also to Nanofiltration. Chemical oxidation of the residue of dissolved organic matter might be needed prior to the DAF. The Fenton process might be used for the chemical oxidation (oxidation of organic matter in aqueous solution by the simultaneous action of hydrogen peroxide, H_2O_2, and a soluble iron catalyst, Fe^{+2}). The effluent quality of this process would be very high, since close to 100% removal of BOD and TSS might be achieved, perhaps even only with Microfiltration, without Nanofiltration.

The process is more complex than the previously mentioned processes and small municipalities would face problems in operating it, however, medium cities and certainly large cities might be able to operate it successfully. The Microfiltration and

Nanofiltration are not that complex to operated, neither is the DAF process. In spite of the large number of unit operations in this process, it is still not too complicated, does not consume a lot of energy, does not produce large amounts of sludge and can still be considered an appropriate technology process, although at the extreme end of complexity of these processes. The process would also be more costly than the other mentioned processes, although without chemical oxidation and without Nanofiltration, the cost would be reasonable.

Summary

A series of appropriate technology processes are presented in this paper, most of them under operation in full scale plants in many parts of the world with a proved track record. In table 2, the processes are classified according to their adequacy of use in cities of various sizes, i.e., cities are classified into three categories (small, medium and large) and for each category a recommended list of appropriate technology processes adequate for this category is provided.

Table 2: Proposed Appropriate Technology Treatment Process Classified according to their Adequacy for use in Various Categories of Size of Cities

Large Cities***	Medium Size Cities**	Small Cities*
Rotating Fine Screens	Rotating Fine Screens	Rotating Fine Screens
	Lagoon Systems of various types including LAS Mixers aided systems and Covered Anaerobic Lagoons	Lagoon Systems of various types including LAS Mixers aided systems and Covered Anaerobic Lagoons
UASB Reactors	UASB Reactors	UASB Reactors
Anaerobic Filters	Anaerobic Filters	Anaerobic Filters
CEPT	CEPT	
		Constructed Wetlands
Reuse for Irrigation Systems	Reuse for Irrigation Systems	Reuse for Irrigation Systems
Submarine Outfalls	Submarine Outfalls	
UASB-Anaerobic Filter Combination	UASB-Anaerobic Filter Combination	UASB-Anaerobic Filter Combination
	UASB-Lagoons Combination	UASB-Lagoons Combination
CEPT-Sand Filtration Combination	CEPT-Sand Filtration Combination	
UASB-Sand Filtration Combination	UASB-Sand Filtration Combination	UASB-Sand Filtration Combination
UASB-Dissolved Air Flotation Combination	UASB-Dissolved Air Flotation Combination	UASB-Dissolved Air Flotation Combination
Other Combinations Need a Specific Review to determine if they are adequate for large cities	Other Combinations Need a Specific Review to determine if they are adequate for medium size cities	Other Combinations Need a Specific Review to determine if they are adequate for small cities

*Small cities: Cities with population up to 20,000
**Medium size cities: Cities with populations in the range 20,000 – 300,000
***Large cities: Cities with populations above 300,000

In Table 3, the treatment capacity of each process is presented, in terms of ranges removal rates of total BOD and total suspended solids (TSS). Also presented in this table are data on ranges of investment costs and operation and maintenance costs of each process. Investment costs as well as O&M costs are compared to those of secondary treatment in a conventional activated sludge process. Activated sludge was selected to represent processes which are not based on appropriate technology. As shown in Table 3, the investment costs of the appropriate technology processes are in the range of 4-50% of investment in activated sludge, in most cases lower than 50%. Also, in most cases, the operation and maintenance costs of the appropriate technology processes are in the range 3-30% of the operation and maintenance cost of activated sludge, and this fact is of outmost importance for developing countries.

Table 3: Treatment Capacity and Costs of the Appropriate Technology Processes Presented in this Paper

Process	Total BOD Removal Capacity, %	TSS Removal Capacity,%	Investment Cost		O&M Cost	
			US$/ Habitant	Percentage of Activated Sludge Cost	US$/Year/ Habitant	Percentage of Activated Sludge Cost
Conventional Activated Sludge (Just for reference, this is not an appropriate process)	80-90%	80-90%	80-100	100%	4-5	100%
Rotating Fine Screens	0-30%	0-30%	3-10	4-10%	0.1-0.15	2.5-3%
Conventional Lagoons Systems	70-90%	70-90%	20-40	25-40%	0.2-0.4	5-8%
LAS Mixers Aided Lagoons	90-95%	80-95%	20-40	25-40%	0.2-0.4	5-8%
Covered Lagoons Followed by LAS Mixers Aided Facultative Lagoons	90-95%	80-95%	20-50	25-50%	0.2-0.4	5-8%
UASB Reactors	60-75%	60-70%	20-40	25-40%	1-1.5	25-30%
Anaerobic Filters	70-80%	70-80%	10-25	15-25%	0.8-1	15-20%
CEPT	70-75%	80-90%	30-50	35-50%	2-4	50-80%
Constructed Wetlands	80-90%	80-90%	30-60	40-60%	2-4	50-80%
Reuse for Irrigation Systems	75-95%	75-90%	30-50	40-50%	0.2-0.4	5-8%
Submarine Ourfalls	99.9%	99.9%	3-30	4-30%	0.1-0.15	2.5-3%
UASB-Anaerobic Filter Combination	90-95%	80-95%	5-30	6-30%	1-1.5	25-30%
UASB-Lagoons Combination	85-90%	70-80%	30-50	38-50%	1-1.5	2.5-3%
CEPT-Sand Filtration Combination	80-90%	80-90%	40-50	40-50%	2-4	50-80%
UASB-Sand Filtration Combination	80-90%	80-90%	30-50	38-50%	1-1.5	25-30%
UASB-Dissolved Air Flotation Combination	80-90%	80-90%	30-50	38-50%	1-1.5	25-30%

Conclusions

In most developing countries the percentage of wastewater that undergoes any type of treatment is very low. Population growth forecasts indicate that most of the world's growth will take place in developing countries. This will further reduce the perspective of expanding the coverage of wastewater treatment in these countries. To promote wastewater treatment in developing countries authorities have to understand that the needs of these countries are different than those of industrialized countries. It is necessary to adopt in developing countries reasonable standards for effluent quality, which are flexible in terms of quality and timing, i.e., which permits development in stages and which take into account the assimilation capacity of the receiving bodies. The key to expansion of wastewater treatment coverage in developing countries is the use of appropriate technologies for wastewater treatment, based on simple processes which are less costly than conventional processes in terms of investment as well as operation and maintenance, and simple to operate. A variety of proved processes of this type are available, some presented in this paper. They are capable of yielding a wide range of effluent qualities, and it is possible to combine two or more processes into one treatment plant for achieving high effluent qualities. It is recommended to decision makers in developing countries not to fall in the trap of adopting complex, expensive treatment processes or cutting edge technologies, and to avoid as much as possible the use of artificially aerated treatment processes, since although it is possible to obtain investment financing for such processes, the inability to later finance the high operation and maintenance costs, renders such processes inoperative and of no benefits to the population.

Acknowledgement

The author wishes to express his gratitude to Huber Technology and to LAS International for the information they provided and for their authorization to include in the paper photos of the equipment they manufacture. Thanks are also due to Mr. Miguel Vargas-Ramirez of the World Bank, Prof. Cicero Onofre de Andrade Neto of the Federal University of Rio Grande do Norte, Natal, Brazil, Mr. Martin Gauss and the Water and Sanitation Program (WSP) of the World Bank, Mr. Fernando Ibanez, Mr. Fernando Yavari, Mr. Fernando Trigo and Mr. Tito Calvimontes, of SAGUAPAC, the water and sanitation utility of Sanata Cruz de la Sierra, Bolivia, Mr. Yechiel Menuchin of Environmental Protection Technologies, Israel, Dr. Marcelo Juanico, Consultant, Israel, and Mr. Klaus Neder of CAESB, the water and sanitation utility of Brasilia, Brazil, all of whom provided valuable contributions for this paper.

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[1] Prepared for the International Symposium "Water Supply and Sanitation for All", September 27-28, 2007, Berching, Germany

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An Architecture of Water Purification

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Abstract: This paper describes three architectural projects that take their inspiration from nature and propose ways of desalinating seawater, treating swimming pool water and cooling buildings in an environmentally sustainable way.

The first project that will be described is a hotel scheme in Australia in which a natural approach to treating the water in the swimming pools is proposed.

The second project is the Las Palmas Water Theatre and was the result of a collaboration between Grimshaw and Charlie Paton – the inventor of the award-winning Seawater Greenhouse. The Water Theatre is a highly productive desalination plant inspired by the Namibian fog-basking beetle that also doubles as an outdoor amphitheatre.

The final project was designed by Michael Pawlyn and Charlie Paton and was entered for a competition called 'A World Water Embassy'. The project also uses Seawater Greenhouse technology and proposes to revive the ancient Persian art of making ice using only natural processes.

These examples are representative of a body of architectural work that uses nature as a mentor.

They also demonstrate the way that buildings can cease to be static consumers and can become producers of useful resources that contribute to the restoration of the natural environment.

Keywords: Architecture, Biomimicry, Cooling, Greenhouse desalination.

Introduction

This paper describes three projects that explore ideas of water purification and celebrate this in an elegant architectural form. All three projects take their inspiration from nature and propose ways of desalinating seawater, treating swimming pool water and cooling buildings in an environmentally sustainable way.

Many current approaches to environmentally sustainable architecture are based on mitigation, which could be paraphrased as 'trying to be less bad'. The suggestion with the examples described in this talk is that it is possible for architecture to go beyond 'sustainable design' and achieve examples of 'restorative design'. Buildings can cease to be static consumers and can become producers of useful resources that contribute to the restoration of the natural environment.

Hotel project, Australia

The first project that will be described is a hotel scheme in Australia in which a natural approach to treating the water in the swimming pools is proposed. As has been widely reported, Australia is experiencing one of the worst droughts in its recorded history. There is consequently a lot of pressure to find approaches to managing water that conserve resources far more carefully.

Advocates of natural swimming pools argue that they use considerably less water because they require less emptying and refilling than conventional, chlorine treated, swimming pools. These pools use the purifying properties of plants and micro-organisms to clean the water in the same way that naturally occurring bodies of water achieve an ecological balance and a water quality that is safe. The water is circulated by a pump and drawn through a filter zone at the edges. This filter zone is filled with plants and haydite, a rock to which benign bacteria can adhere. The water is then treated in an ultraviolet filter and returned to the pool via a waterfall or other such feature that helps to oxygenate the water.

One of the design challenges of this approach is that the pools require large amounts of marginal planting in shallow water. In our proposals for the hotel project, this requirement has been turned to advantage by creating decks adjacent to the deeper parts of the pools and allowing the marginal planting to blend with the soft landscaping. These edges to the pools are able to accommodate a rich variety of biodiversity with, it is claimed, no detriment to the quality of the water for human users.

The Las Palmas water theatre

The second project is the Las Palmas Water Theatre and was the result of a collaboration between Grimshaw and Charlie Paton – the inventor of the award-winning Seawater Greenhouse. The Seawater Greenhouse won the prestigious Design Sense Award in October 1999. Before discussing the Las Palmas project it is necessary to first describe the principles on which the design of the Seawater Greenhouse is based.

The Seawater Greenhouse is a method of cultivation that provides desalination, cooling and humidification in an integrated system. Its purpose is to provide a sustainable means of agriculture in arid coastal areas where the scarcity of freshwater and expense of desalination threaten the viability of agriculture. Because the desalination process is driven mainly by solar energy, sunlight is the weather variable that most influences the performance of the Seawater Greenhouse.

Davies, Paton and Turner (2004) describe this process clearly in their document 'Potential of the Seawater Greenhouse in Middle Eastern Climates' presented to International Engineering Conference at Mutah University, Jordan.

"The Greenhouse faced into the prevailing wind that it collected through its front wall, this being a porous structure continuously wetted with seawater. The result of the air coming into contact with this large moist surface was a substantial humidifying and cooling effect.

The pressure of the wind was sufficient to drive the air through two further elements: a second wetted wall at the back of the greenhouse and finally through a tube-and-fin type condenser. This condenser was fed with cold seawater causing freshwater to condense on its surface. Water production was typically at the rate of 1.5 m^3/day. The water was of excellent quality, generally containing less than 50 ppm total dissolved solids (TDS). It was used to irrigate the plants via a drip irrigation system and water usage ranged from 0.6 to 1.2 l/m^2/day. This is several times lower than traditional outdoor cultivation which typically consumes 7 to 8 l/m^2/day."

Davies et al (2004) describe many of the advantages that this technology offers in terms of creating a more water-efficient approach to agriculture, particularly in arid regions:

"In a certain sense, agriculture is very inefficient in its use water. Of all the water used to irrigate crops, less than 1% can be expected to find its way into the final edible produce. Even in efficient irrigation systems, a very large fraction of the water is lost through transpiration.

Plant scientists have studied mechanisms of water loss in great detail. The classic model for representing water loss from crops is the Penman equation which compares the process to evaporation from an open pool of water. In simple terms the equation can be written as:

Rate of water loss = b R + c D [1]

Where *R* is the net radiation received by the crop. The term *D* is the vapour deficit, meaning the difference between the saturation vapour content of the air and its actual vapour content. The terms *b* and *c* are approximately constant for a given range of conditions.

The Penman equation suggests two strategies for reducing water requirements.

(1) Reduction of the radiation R by means of shading; or possibly selective shading to favour photosynthetically active wavelengths of light.
(2) Reduction of the vapour deficit D through humidification of the air.

Both of these strategies have been employed in the Seawater Greenhouse. In addition, the Greenhouse addresses the issue of excessive water loss from crops by incorporating them in a system that recovers some of the water transpired. The Seawater Greenhouse combines, in a single system, desalination with a water-efficient method of cultivation."

Grimshaw approached Charlie Paton when we were preparing a master plan proposal for Las Palmas in the Canary Islands. This geographical location offered many advantages to an application of similar technology to the Seawater Greenhouse. The Canary Islands have a steady wind direction throughout the year, high sunshine hours and, due to the volcanic topography and therefore steep sides to the island below sea level, relatively easy access to seawater that is at 8 degrees centigrade.

One of the main aims for the overall Las Palmas project was to propose ways in which the island could become self-sufficient in renewable energy and water. A novel form of offshore large-scale wind turbine was proposed to address the former and the Water Theatre was designed to provide large quantities of desalinated water. The approach was to use basic forms of solar thermal energy collection to heat water from the surface of the sea and to pass this through evaporator walls similar to those employed on the seaward elevation of the Seawater Greenhouse. The condenser elements would also be similar but here we had the opportunity to use water from 1000m below the surface of the sea, delivered by a pipe and pumped from sea-level to its point of use. The combination of the wind, evaporation boosted by sea water at a raised temperature and condensation enhanced by the use of cold sea water, produced an optimised system. The banks of evaporators and condensers were then arranged in a bold sculptural form as a backdrop to an outdoor amphitheatre.

The project aims to capture the public imagination by celebrating, in a beautiful architectural form, what might normally have been a mundane piece of infrastructure; the utilitarian is elevated to the level of sculpture.

With the benefit of empirical data from the three versions of the Seawater Greenhouse that have been built, the team was able to predict the performance of the Water Theatre as follows:

- Pipe length – 400m
- Pipe dia - 1m
- Delivered water temp - 9.1°C
- Roof area for solar collector - 70000m^2
- Condenser size envelope - 1000m^3
- Water production winter - 530m^3 / day
- Water production summer - 1120m^3 / day
- Area that can be irrigated - 200,000m^2 (calculated for standard grass)
- Temp of air out for A/C - 15°C
- Airflow rate - 250m^3 / sec
- Energy use - 1.6 kWh/m^3 (summer) - 2.5 kWh / m^3 (winter)

It can be seen that the energy use for desalination is 1.6 kWh per m^3 of water. This compares with between 5 and 12 kWh/m^3 for conventional desalination. The other advantage of the Seawater Greenhouse technology is that it provides valuable cooling. We proposed to use this for cooling a lot of the adjacent buildings in Las Palmas which therefore provided additional energy savings.

The world water embassy

The final project was designed by Michael Pawlyn and Charlie Paton and was entered for a competition called 'A World Water Embassy'. In this case the inspiration came from the Namibian fog-basking beetle, a creature that developed a way of creating its own fresh water in a desert environment.

Once again the principles of Seawater Greenhouse technology are employed but here, are used partly to create a cool working environment as opposed to a greenhouse. The site for the project is in the Namibian desert and while this is a very arid environment, the region has the advantage of the Benguela current which passes along the Atlantic coast and brings cold water from the Antarctic. By once again installing a sea pipe (but this time using sea water from close to the surface) the project proposes to create a building that is self-cooling and a net producer of distilled water using entirely solar energy.

On the seaward side of the building a solar thermal collector is used to raise the temperature of the seawater that will be passed through the evaporator wall to increase the volume of water that is evaporated. The outer roof of the building uses a highly reflective membrane to exclude as much heat as possible. The air that has been cooled and humidified by passing through the evaporator then flows over the lower roof which is a metal surface cooled by low temperature water from the Benguela current, delivered by means of an insulated pipe from the sea. Condensation will form on these surfaces and be collected in channels on the edges of the roof. On the underside of the metal roof a cool radiant effect will create habitable conditions for those that work in the building.

The project also proposes to revive the ancient Persian art of making ice. At this stage we have been unable to find reliable technical information about this process. Historical accounts describe a technique that employed ceramic trays with a matt black surface. These trays were filled with a shallow quantity of water and put out at night resting on straw to minimise thermal contact with the ground. In clear conditions in a desert environment a matt black surface will radiate to the night sky and effectively to outer space. The historical accounts confirm that this was sufficient to achieve frozen water. We propose to explore this further with empirical testing in order to develop a system of cooling for use in arid environments.

Our proposal for the Water Embassy would be the first contemporary building in a desert environment to combine the technologies of the Seawater Greenhouse and cooling based on ancient Persian ice-making.

Conclusion

These examples are representative of a body of architectural work that uses nature as a mentor.

The projects described show that it is possible to create inspiring works of architecture and achieve radical increases in resource efficiency – producing fresh water with a fraction of the energy required by conventional approaches.

We are currently in the early stages of the sustainability revolution and it is the contention of the author that many of the lessons that we will need for this new age are to be found in nature.

What is commonly called the industrial revolution (but could also be referred to as the carbon age) has in many ways been a huge diversion from ingenuity. The ubiquity and convenience of fossil fuels has allowed extreme inefficiency to develop and has effectively undermined resourcefulness. The lessons from nature which informed many vernacular approaches were therefore abandoned and largely lost from our collective memory. Now that the folly of releasing many millennia of stored carbon is becoming increasingly apparent, there is an opportunity to explore the incredible effectiveness of the responses that natural organisms have evolved. For every problem that we currently face, whether it is producing energy, or finding water, or manufacturing benign materials, there will be numerous examples in nature that we could benefit from studying.

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Session III – Purification to Recovery
Introduction

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From Waste to Resource – Singapore's Experience in NEWater

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Abstract: Singapore, being a small island city-state faces high competing demands on its limited land area. Even with half its total land area as catchment, Singapore was unable to secure a sustainable water supply for its population. Traditionally, Singapore has thus depended on imported water from Malaysia to supplement the water supply from its local catchment. In order to achieve sustainability in its water supply, Singapore adopted the addition and multiplication approach. Augmentation of water supply is achieved through the Marina Barrage and Punggol/Serangoon Reservoirs projects which will increase the water catchment from the current 50% to 67% of its land area. It is also achieved through the adoption of seawater desalination. Multiplication of water supply is achieved by using water more than once through water reuse. Since 2003, water reuse has been successfully implemented in Singapore. The high-grade reclaimed water, termed NEWater, is produced by passing secondary treated effluent through dual membrane process. An ongoing comprehensive Sampling and Monitoring Programme (SAMP) in which NEWater is tested for about 295 parameters showed that NEWater is consistently well-within international drinking water standards/ guidelines. A 2-year NEWater study which included a 10,000 cu m per day demonstration plant that commenced operations in 1999 has concluded that NEWater is safe for indirect potable use (IPU) through SAMP and a Health Effect Testing Programme. This NEWater study also yielded valuable operational data and experience that were incorporated into the engineering and design of the full-scale NEWater Factories. The multi-barrier approach that includes a high percentage of domestic waste (> 85%), stringent source control and treatment of reclaimed water to drinking water standards is instrumental in ensuring the consistent and high quality of the reclaimed water for IPU. NEWater's primary application still lies in direct non-potable use (DNU) in wafer fabrication and cooling towers. Complementary to the science and engineering involved in the development of NEWater programme, public education is paramount in instilling public confidence in the water reuse scheme. This includes independent expert evaluation from the International Expert Panel, as well as educational programme like roadshows and

dialogues with stakeholders, bottling of NEWater and constructing educational facilities like the NEWater Visitor Centre. Since the implementation of the NEWater scheme, NEWater demand has increased by about 2.5 times from 72,000 cu m per day in 2003 to the current 180,000 cu m per day, and is expected to increase to 460,000 cu m per day by 2011.

Introduction

Singapore is a small island city-state with only 704 square km in land area and a population of 4.5 million. Modernisation and population growth have placed high demand on its available land and makes it challenging for Singapore to balance the land uses for both socio-economic growth and rainwater collection. Currently, although half of Singapore's land area is already water catchment, water is still a scarce commodity on the island. The population in Singapore was about a million in 1950, and its water demand about 142,000 cu m a day. Today, its water demand has increased 10 fold to 1.36 million cu m a day, a rate that is 2.5 times that of population growth. With active water conservation efforts, water demand has been kept consistent over the recent years. In spite of demand control, it is still not possible for Singapore to depend solely on rainwater collection in its surface reservoirs as its only drinking water source. Hence Singapore imports water from Malaysia to supplement its drinking water.

The scarcity of clean and safe drinking water is not unique to Singapore. With climate change, population growth, industralisation and modernisation, many parts of the world are thrown into a water demand and supply disequilibrium and/or plagued with polluted source water. In response, more and more are turning to innovative ways and technologies as plausible solutions to help augment their drinking water supplies.

In the case of Singapore, it has adopted the approach of both addition and multiplication to ensure the sustainability of its water resources. One of the ways to add to our water resources is to increase the water catchment areas and building of more reservoirs. Indeed projects such as the Marina Barrage and Punggol/Serangoon Reservoirs are being implemented to enable Singapore to use 2/3 of its area as water catchment by 2010. Another way to add to the water resources is by desalinating seawater to produce potable water. A 136,000 cu m per day capacity desalination plant was built and has commenced operation since 2005. Multiplication of water resources is achieved by using water more than once through water reuse and closing the water loop. Please refer to Annex A on the illustration of the multiplication effect brought about by water reuse. Since 2003 the high grade reclaimed water, termed NEWater, obtained by further treating secondary effluent using dual membrane process forms another source of water for Singapore.

Water reclamation studies

Effort over the past three decades to put in place a world-class sewerage infrastructure in Singapore has enabled 100% of the island to be provided with modern sanitation. All wastewater is collected and treated at centralised sewerage treatment works, named as Water Reclamation Plants (WRPs) in Singapore. The wastewater receives secondary treatment based on activated sludge process, to international standards before being discharged into the sea.

The exploration of the feasibility of reclaiming this secondary treated effluent to drinking water dated back as far as the 1970s. Then, the study concluded that producing drinking water was technically achievable. However, it was not implemented due to the high cost of chemical treatment and unreliability of membrane technology.

The 1990s saw a tremendous improvement in membrane technology in terms of performance and reliability. More importantly, the cost of membrane has come down substantially. There is also a growing trend on the use of membrane technology in water treatment and water reclamation, especially in the United States.

In 1998, a water reclamation study team was set up in PUB to test the latest proven membrane technology to produce drinking water from secondary treated wastewater effluent. The water reclamation study includes:

- The commissioning and operation of a 10,000 cu m per day full-scale demonstration plant called the NEWater Demonstration Plant;
- A comprehensive Sampling and Monitoring Programme (SAMP); and
- A Health Effects Testing Programme (HETP).

NEWater demonstration plant

The NEWater Demonstration Plant was used to undertake extensive full-scale plant studies to test the quality of reclaimed water and the technical capability and operational reliability of the membrane technology to recover good quality water from treated effluent of a municipal activated sludge wastewater treatment plant. The treatment processes used in the NEWater Factory are dual membrane processes, comprising microfiltration (MF) and reverse osmosis (RO). Ultraviolet (UV) disinfection is included after RO as an additional barrier. Together, they formed the three-stage process that treats treated secondary effluent to high-grade reclaimed water, which came to be named "NEWater" subsequently. The MF/RO treatment scheme was selected based on the stringent product water quality goals and the successful application of this treatment combination at various water reclamation facilities in the U.S. The process schematic for the NEWater Factory is shown in Figure 1.

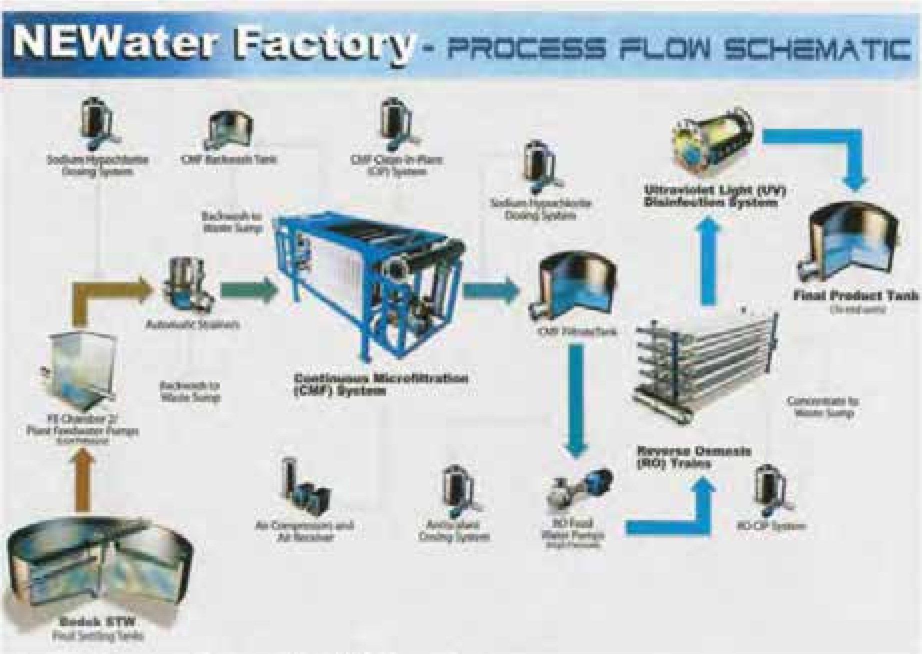

Figure 1: Process Schematic of NEWater Factory

Some of the technical details of the membrane processes are given in Table 1.

Table 1: Details of Treatment Processes at NEWater Factory

Treatment Processes		
Microfiltration	Supplier	Memcor, Australia
	Type	CMF – P
	Pore Size	0.2 µm
	Water Recovery	> 90 %
	No of Trains	5
	Capacity of each train	115 m3/h
	Backwash interval	30 minutes
	Cleaning Frequency	21 days, minimum
Reverse Osmosis	Supplier	Hydranautics, US
	Type	LFC 1
	Water Recovery	85 %
	No. of Trains	2
	Capacity of each train	5,000 m3/d
	Cleaning Frequency	1 month, minimum
Ultra-violet Disinfection	Supplier	Hanovia
	Type	Medium Pressure
	No of units	2 duty, 1 standby
	Dosage (minimum)	80 mJ/cm2

In order to have continuous monitoring capability of the plant's operations, process parameters and operation are monitored continuously using a SCADA system. The operation of the plant is also fully automated and manned by one operator.

Sampling and monitoring programme (SAMP)

A comprehensive water sampling and analysis programme was implemented and the quality of the NEWater benchmarked against World Health Organisation (WHO) Drinking Water Guidelines and the United States Environmental Protection Agency (USEPA) Drinking Water Standards. Leading advanced water testing laboratories of local and foreign institutions were engaged to carry out extensive and comprehensive physical, chemical and microbiological tests for the water at various stages of the production process over a 2 year period. Chemical parameters of emerging concerns were also included. In all, some 190 parameters and over 25,000 analysis were carried out.

Since then, PUB has continuously monitored the quality of NEWater. Currently, NEWater is being tested for 295 parameters, more than the 113 parameters outlined in the WHO Drinking Water Guidelines and 96 stipulated in USEPA Drinking Water Standards. The water quality of NEWater has consistently surpassed these international guidelines/standards. The typical qualities are listed in Table 2.

Table 2: Typical NEWater Quality

Water Quality Parameters	NEWater	USEPA Stds / WHO Guidelines
Physical		
Turbidity (NTU)	< 5	5 / 5
Colour (Hazen units)	< 5	15 / 15
Conductivity (µS/cm)	< 200	Not specified (- / -)
pH Value	7.0 – 8.5	6.5 – 8.5 / -
Total Dissolved Solids (mg/L)	< 100	500 / 1000
Total Organic Carbon (mg/L)	< 0.5	- / -
Total Alkalinity (CaCO3) (mg/L)	< 20	- / -
Total Hardness (CaCO3) (mg/L)	< 20	Not available
Chemical (mg/L)		
Ammonia nitrogen (as N)	< 0.5	- / 1.5
Chloride (Cl)	< 20	250 / 250
Fluoride (F)	< 0.5	4 / 1.5
Nitrate (NO3)	< 15	- / -
Silica (SiO2)	< 3	- / -
Sulphate (SO4)	< 5	250 / 250
Residual Chlorine (Cl, Total)	< 2	- / 5
Total Trihalomethanes (as mg/L)	< 0.08	0.08 / -
Metal (mg/L)		
Aluminium	< 0.1	0.05 – 0.2 / 0.2
Barium (Ba)	< 0.1	2 / 0.7
Boron (B)	< 0.5	- / 0.9
Calcium (Ca)	< 20	- / -
Copper (Cu)	< 0.05	1.3 / 2
Iron (Fe)	< 0.04	0.3 / 0.3
Manganese (Mn)	< 0.05	0.05 / 0.5
Sodium (Na)	< 20	- / 200
Strontium (Sr)	< 0.1	- / -
Zinc (Zn)	< 0.1	5 / 3
Bacteriological		
Total Coliform Bacteria (Counts/100ml)	Not detectable	Not detectable
Enterovirus	Not detectable	Not detectable

Health effect testing programme (HETP)

The Health Effects Testing Programme (HETP) was included in the NEWater study to complement the comprehensive SAMP in the determination of the safety of NEWater. The HETP involves the toxicological assessment of NEWater against raw surface reservoir water from Bedok Reservoir. The HETP covering both short and long term health effects is carried out using two animal species, which are mice and fish.

The long-term chronic toxicity and carcinogenicity potential of NEWater compared to raw surface reservoir water is being tested by the mice study. The test mouse is the B6C3F1 strain, one of the most sensitive mouse strains used for toxicological and carcinogenicity assessment. It is widely used for conducting long-term health effects studies of new pharmaceuticals. Pathology reports received for the short- and long-term mice study at 3-month, 12-month and 24-month exposure times showed that the exposure to concentrated NEWater at 500 and 150 times does not cause any tissue abnormalities or health effects attributable to its consumption.

The orange-red strain of the Japanese medaka fish (Oryzias latipes) is the test animal selected for the study because of its extensive biological database. The long-term chronic toxicity, as well as the estrogenic potential (reproductive and developmental) were being assessed. From the study, the first and second fish generations showed no evidence of carcinogenic or estrogenic effects from exposure to NEWater.

International expert panel

An international panel of experts comprising renowned local and foreign experts in engineering, biomedical science, chemistry and water technology was formed to provide independent advice on the water reclamation study and to evaluate the suitability of NEWater as a source of water for potable use. The test results and the plant operation were regularly audited and reviewed by the Panel. The Expert Panel concluded that NEWater is consistently of high quality, well within the requirements of the USEPA and WHO standards for drinking water. It is safe as a source of water. The Panel also recommended indirect potable use (IPU) by introducing NEWater into raw water reservoirs to supplement Singapore's water supply. This practice of planned indirect potable use is not new and has been done in parts of the United States for more than two decades – Orange County Water District in Southern California and Upper Occoquan Sewage Authority in North Virginia.

Full scale implementation of water reuse

Following the success of the NEWater study, NEWater became the fourth source of drinking water through water reuse and it has been successfully implemented in Singapore nation-wide since February 2003. Four full-scale NEWater Factories have since come into operation, with the latest being officially opened in March 2007. The four NEWater Factories have a total design capacity of 240,000 cu m per day. Plan is currently underway to expand two of the existing NEWater Factories at Bedok and Kranji by 77,000 cu m per day. There is also plan to build a fifth NEWater Factory at Changi with a capacity of about 227,000 cu m per day by 2010, bringing the total NEWater capacity to 544,000 cu m per day.

Operations

The operation of the NEWater Demonstration Plant has provided valuable operation data and experience which are incorporated into the improved design and reliability of the new NEWater Factories. They are:

i) **Ability to do 2nd stage RO water recycling**
This refers to the provision for the 2nd stage permeate to be recycled back into the MF/UF filtrate tank. Provision of 2nd stage RO water recycling provides flexibility to the plant to ensure consistent NEWater quality for all operating conditions. For example, the conductivity of the effluent feed water could vary from 800 μS/cm to 2500 μS/cm, caused by sea water intrusion. This recycling provision enables the plant to produce NEWater with only small variation in conductivity. It also enables the plant to produce consistently low TOC levels in the NEWater in the event of upstream wastewater treatment process upset.

ii) **20% more membrane in the pre-treatment unit**
Allowance of 20% more membrane area in the pre-treatment stage to ensure stable operating condition. Higher filtration rate in the microfiltration process during chemical cleaning of individual units would have a long term adverse impact on the chemical cleaning intervals. For the first 3 months, chemical cleaning intervals of 21 days were achieved. But the interval started to reduce to 14 days after 6 months and then to 7 days after 8 to 9 months, affecting NEWater production. By allowing 20% more membrane area, normal filtration rate and 21-day cleaning intervals are maintained at all times.

iii) **Chloramination to prevent membrane bio-fouling**
Ammonia is naturally present in the effluent which can combine with the hypochlorite added to form chloramines. By maintaining 1 to 2 ppm of chloramine concentration in the feed effluent, cleaning at more than 6 months interval for the 1st (50% recovery) and 2nd (50% recovery) stages of the RO trains is achieved. The 3rd stage RO trains require cleaning every 3 months due to organic fouling. No deterioration in the performance of the RO membranes was observed after more than 3-year exposure to chloramines.

iv) **RO trains on elevated platform to prevent net positive pressure from the permeate side**
Net positive pressure from the permeate side could damage the RO membranes due to failure of the glued line. On elevated platform, all inlets and outlets of the RO trains during cleaning will be at atmospheric pressure and the possibility of net positive pressure from the permeate side is negated.

v) **Accuracy of on-line readings**
Regular checks on the accuracy of the on-line readings by comparing with laboratory test results are instituted. Water samples are collected and tested for each 8-hour shift (or 3 times a day) to ensure the accuracy of the on-line readings. The on-line readings are also regularly calibrated for accuracy.

vi) **On-line TOC analyser for on-line RO integrity monitoring and Pressure Decay Test for on-line Microfiltration / Ultrafiltration integrity**
The TOC analyzer is found to be more sensitive than on-line conductivity meter for monitoring RO integrity as it can measure very low TOC concentrations in parts per billion. For microfiltration / ultrafiltration membrane, pressure decay test is the preferred method, complemented by on-line turbidity and particle counter. The pressure decay test is the most sensitive method to detect broken fibres in the microfiltration / ultrafiltration process units.

vii) **No enhanced performance polymer or dispersant in anti-scalant**
Anti-scalant reagent without any added enhanced performance polymer or dispersant is found to be most suitable for the RO treatment units. It was observed that the polymers or dispersants present in anti-scalant reagent tend to "react" with the organics present in the feed water, accelerating the rate of organic fouling.

Applications of NEWater

NEWater is primarily used for direct non-potable use (DNU) in industrial applications like wafer fabrication production and in cooling towers of commercial buildings. A small percentage of NEWater produced is injected into reservoirs for indirect potable use (IPU). The blend of surface water and NEWater is subsequently fed into Water Works and further treated before being piped to homes and industries as the Singapore's potable water supply.

Wafer fabrication plants using NEWater have reported savings in the production of ultra pure water by up to 20%. Similarly, commercial complexes using NEWater for their cooling towers have reported using less volume of NEWater by up to 10%, compared to using drinking water and also less chemicals for fouling control. This is because the higher quality NEWater allows it to be used for more cooling cycles before blow-down. The companies are hence able to enjoy savings from lower water demand as well as the lower cost of NEWater and chemicals. Since the implementation of the NEWater scheme, NEWater demand has increased by about 2.5 times from 72,000 cu m per day in 2003 to the current 180,000 cu m per day, and is expected to increase to 460,000 cu m per day by 2011.

Multi-barrier approach

The consistent high quality of NEWater has a vital role to play in its successful implementation. Other than a robust dual membrane process using micro/ultrafiltration (MF/UF) and reverse osmosis (RO), coupled with Ultraviolet (UV) disinfection, that treats secondary effluent to drinking water standards, strict source control, high percentage of domestic wastewater (> 85%) and a comprehensive secondary treatment of wastewater are instrumental in ensuring the consistent and high water quality of NEWater. Together with the dilution and natural degradation in reservoirs and the treatment in water works for surface water, a multi-barrier approach is put in place to ensure the safety of NEWater for IPU. Dissolved solids are also not retained in the system as the brine from the NEWater Factories is largely diluted with secondary effluent from the WRPs before being discharged into the sea.

Public education

Without the buy-in from the stakeholders, including the industries and the general public, it will be extremely difficult to develop NEWater into another source of water. Public education has hence played a significant role in the successful full-scale implementation of water reuse in Singapore. Since the successful 2-year NEWater study, the public has been actively engaged and informed about the intention to implement water reuse in Singapore. The key messages were:

- Water reclamation for indirect potable use is not new - It has been practised in the US for more than two decades without any long-term health concern. It is a growing trend as more countries face problem of water shortage.
- NEWater is "WHO+" and "PUB+" - The quality of NEWater is comparable to or even exceeds that of drinking water anywhere in the world. It is even cleaner than PUB tap water. NEWater is not used directly as potable water because mixing it with raw water in the reservoir is the easiest way to put back the minerals.
- NEWater is a cost competitive source of water supply compared to desalinated water and even other unconventional sources of water supply in future. The cost of producing NEWater is also expected to come down with advances in membrane technology.
- On the whole, NEWater is a safe and valuable source to supplement our potable water supply over the long term.

The avenues and approach with which the PUB brought the key messages to the public were also multi-pronged, including:

- Through media and roadshows at communities hub;

- Illustrating the high quality of NEWater through the NEWater bottling programme; and
- Through interactive and educational channels to understand the processes of NEWater production at the NEWater Visitor Centre.

The NEWater Demonstration Plant was opened for site visits by various key stakeholders, including the grassroots leaders, Singapore Business Federation, fellow governmental agencies, and the media too. Here, they were brought through the NEWater production processes and dialogues held to convince them that the NEWater study was comprehensive and conclusive that NEWater is safe and suitable for IPU. In addition, through interesting and colourful illustrations, panels containing the key messages were brought around various communities as roadshows to educate the public.

NEWater was also bottled and distributed to the public with the objective to educate the public that NEWater is safe to drink and help them overcome the psychological barrier associated with the use of reclaimed water. Since Aug 2002, about 10 million bottles of NEWater have been distributed to both the local communities and even to some of PUB's overseas counterparts.

To have a sustainable education programme, PUB believed that an educational facility would be necessary. The NEWater Visitor Centre was hence constructed and officially opened in Feb 2003, becoming the key focus of PUB's public education programme on NEWater. Incorporating an operational NEWater Factory, as well as multi-media presentations and computer interactives, visitors get a first-hand experience with the production of NEWater and learn about issues that include water conservation, wastewater treatment and the uses of NEWater. To date, the NEWater Visitor Centre has seen more than 500,000 visitors and was awarded the Singapore Tourism Awards (Best Sightseeing/Leisure/Educational Programme) in 2006.

To study the effectiveness of the NEWater education programme, PUB commissioned Forbes Research Pte Ltd to carry out research study, with the intention of assessing the public's awareness and response towards NEWater. Completed in Oct 2002, the results pointed towards an overwhelming public acceptance of NEWater, with 82% of the respondents indicating that they were prepared to drink it directly, with an additional 16% prepared to drink it indirectly, through mixing it with reservoir water.

Conclusion

Water scarcity is an issue that sees no national boundaries. Among the options available to achieve a sustainable drinking water supply, water reuse can be considered one that is viable and reliable. Singapore has leveraged on advanced technology and innovative solutions to increase its limited water resources. Since 2003, NEWater has been successfully introduced as another source of water for Singapore. The key factors identified to be vital for the successful implementation and management of a water reuse scheme are namely comprehensive scientific and technological studies, best practices in engineering and design of the treatment processes, operational experience as well as a proactive public education programme. By closing the water loop, NEWater has provided Singapore a safe and sustainable alternative source of water supply, complementing rainwater collected in local catchment, imported water and desalinated seawater to form an overall sustainable water resource for Singapore.

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Annex A

The adding of fresh water supply and the reuse/reclaim yield of used water is essentially a geometric progression. If a is the fresh water source and r the reclaimed yield and n the number of reclamation, the total water supply can be calculated as follows:

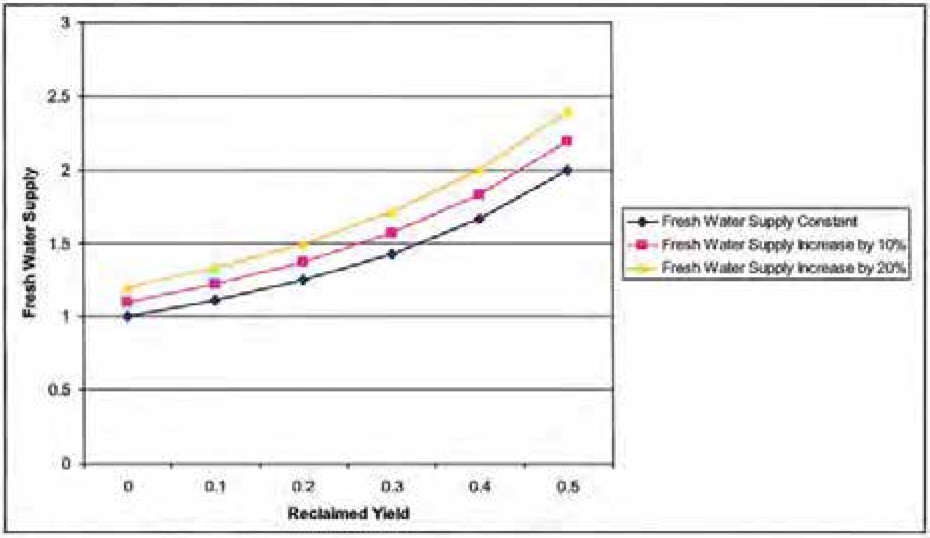
$$\text{Total water supply} = \Sigma\, a + ar + ar^2 \ldots + ar^{n+1}$$

$$= \frac{a\,(1 - r^{n+1})}{1 - r} \quad \text{for } r < 1$$

For infinite reclamation, i.e $n \longrightarrow \infty$
Total water supply = $a/(1-r)$
Hence if fresh water supply is increased by 20%, $a = 1.2$ and reclamation yield is 30%; $r = 0.3$
Thus total water supply = $1.2/\,(1-0.3) \approx 1.7$
$\longrightarrow$ 70% increase in total water supply.

Graphs for total water supply versus reclaimed yield can be plotted for different scenarios.

r	0	0.1	0.2	0.3	0.4	0.5
Total Water Supply (= a/(1-r))	1	1.1	1.3	1.4	1.7	2.0
	1.1	1.2	1.4	1.6	1.8	2.2
	1.2	1.3	1.5	1.7	2.0	2.4



Mr. Yuen Long Wah

Water Supply and Sanitation Developments for Future Space Missions

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Abstract: Up to now, Europe's efforts in the area of life support technology have been largely directed at ensuring Europe's capability to support manned operations in low Earth Orbit. However, long term-manned exploration beyond LEO implies a high mass of metabolic consumables. Taking into account the current capabilities of the launchers, regenerative technologies for water, air, and food shall be developed. It is no secret to say that life support technologies necessary to support extended missions to the Moon or Mars (i.e. Advanced Life Support) are long lead technologies.

Today ESA is investigating almost all issues of Life support system, from: - independent recycling unit (i.e. grey water, urine, black water, ..), - quality control (i.e. microbial and chemical), up to - the ultimate concept of closed ecological life support systems (i.e. MELiSSA). Within this last one, investigations are being performed on food production issues to be able to cover as well human nutritional requirements.

To validate their efficiency, as well as their reliability, ESA's technologies need to be tested in the most analog conditions (i.e. isolation, limited spare part, ...). Today ESA is considering three location: - the MELISSA pilot Plant, - the permanent French-Italian settlement called Concordia, in the Antarctic continent, and - collaboration with our Russian colleagues in BIOS facility in Krasnoyarsk Siberia. Within the MEliSSA pilot plant, all developed MELiSSA technologies are progressively assembled to cover all metabolic needs of an animal compartments, excepted food. Within Concordia station: a Grey Water Treatment Unit and a Black Water Treatment Unit will be assembled at the size of 15 to 70 persons to fulfill the Concordia needs in waste and water recycling. The first technology is a multi step filtration system and will recycle the shower, washing machine, dish washer and cleaning water. The second technology, issued of MELiSSA project development, is composed of three bioreactors and will be used to process the fecal material, the urine and the kitchen wastes generated by the crew. Within BIOS, our collaboration is so far devoted to the preparation of isolation campaign with man in a completely closed system. The long-term life tests of these technologies will allow ESA to test regenerative life support technologies in the most realistic conditions. Technical parameters (i.e. efficiency, reliability,..) as well as human factors issues (i.e. psychology) will be continuously studied. Within this paper we will review of ESA developments, presents the main results including plans for future developments.

Keywords: closed recycling system, space missions, water recycling.

Introduction

For a space mission, the mandatory metabolic consumables (i.e. oxygen, water and food) represent a mass of around 5kg per person and per day. The produced wastes (i.e.CO2, perspiration, urine, faecal material) represent roughly the same mass. It is interesting to note that these values are of course more or less the same on Earth. To these amounts, a minimum of hygiene waste (e.g. wet towels, shower water,..) and packaging amount shall be added. This amount varies from 5 kg to 25 kg per day and per person. These second range of values is from far different of have of the terrestrial values. So far, and mainly due to the extreme proximity of our space stations, today, and all over the history of manned space missions these consumables are brought by space vehicles (e.g. US Shuttle, ATV, ..) and the amount of recycling products has always been very limited (e.g. condensate, urine,..).

For long term-manned exploration beyond Low Earth Orbit (i.e. LEO) and due to the almost impossibility to re-supply the missions, the overall mass of metabolic consumables represent mass which are not compatible with the performances of our current launchers. For this very basic reason, manned exploration of the universe cannot be foreseen without regenerative technologies for air, water and food (ESA 1999, Lasseur 2003).

For the last 20 years, ESA developed life support system for almost all existing and future missions (e.g. ISS, ATV, Moon and Mars base,..). These developments include air revitalization, grey (i.e. hygiene water) yellow (i.e. urine) and black (i.e. organic and faecal material) water recycling, food production. In parallel of these recycling technologies development all associated quality control either for chemical or microbiological issues or simulation system (e.g. ALISSE) are as well developed. These developments are generally independent units, aiming at the end to be part of a very complex and closed system: the MELISSA project. MELiSSA (Micro-Ecological Life Support System Alternative) is a multidisciplinary project which has been conceived as closed life support system. The driving element of MELiSSA is the recovery of oxygen, water and edible biomass from organic waste, waste water and carbon dioxide.

ESA Life support system developments are organized in 5 phases:- Phase 1 : Basic R&D ; - Phase 2 Preliminary flights experiments ; - Phase 3: ground and Space demonstration with a consumer ; - Phase 4: Technology transfer ; - Phase 5 Education and communication. Due to the high specificities and objectives of the conference, only key elements of phase 1 and 3 will be presented in this paper.

Phase 1: basic R&D technologies

Phase 1 gather all ESA activities in terms of basic R&D, from early technologies survey up to pre-pilot developments. This phase includes as well the developments of associated tools (e.g. mathematical simulator)

Grey water recycling system

When we consider the three vital loops of a life support system air, water and food, the most demanding in terms of mass constraints is the water loop. Therefore closing the water loop will provide already a reasonable autonomy of man in space. Conclusions from successive studies dealing with water recovery and undertaken by ESA (Amblard et al., 2000) have demonstrated the excellent potential of membrane based technology. Therefore to validate such technology a development model test-bed was designed and built. This water recovery unit consists in one ultra-filtration step and 3 reverse osmosis steps:, see figure 1. This demonstration hardware was sized to produce approximately 2 liters of drinking water per hour. The developed hardware has been tested with shower water in a life test configuration for 6 months. During this test campaign, two main results were demonstrated: - the recovered water complied with ESA standards for drinking water, - in all tests neither bacteria nor viruses were detected after the UF unit.

Figure 1: The Grey Water Treatment Unit

Microbial identification system

Micro-organisms are natural members of any human inhabited system. However pathogens can affect crew members and lead to illness and allergies, damage the payloads, equipment, subsystems and in fact even the structure of the spacecraft itself.

Therefore the presence on-board of harmful micro-organisms must be rapidly identified and controlled. Traditional microbial cultures methods (e,g based on agar) are unsafe (i.e. formation of larger colonies), slow (several days) and time consuming. In addition many organisms are not cultivable on the proposed culture medium and pathogens active in the sample are not obviously detected by this method. Over the last 10 years, based on the genetic information, molecular biology have opened a large field of perspective. The possibility to perform microbial identification can now be considered. Recently ESA has initiated a review of requirements for an automated instrument. A development plan has been as well established.

Architecture evaluator

So far, besides the journeys to the Moon manned space flights have been limited to LEO and the main part of the crew metabolic consumables has been brought from Earth. Consequently the development of life support hardware has been limited to independent units (i.e. water electrolyser, catalysers, etc). Today, it is well accepted that missions beyond LEO will need a high level of regenerative life support, from waste management up to food production. These closed life support systems, target a very high level of closure leading to a high level of interfaces between independent units.

In addition, it is anticipated that the life support system will be a hybrid of physico-chemical and biological regenerative subsystems including associated technologies to ensure optimal functionality of the system. Therefore, the overall life support system performance, including all sub-systems, must be evaluated at system level. These new life support architectures are becoming rather complex and a systematic evaluation of these architectures must be done with the help of appropriate tools (Adersa 2003).

ESA initiated a study with the goal of the initial development of an evaluation methodology in terms of method, criteria and of an associated simulation environment using EcosimPro, an ESA standard analysis tool, for advanced life support systems. This methodology shall allow the comparison of several life support architectures, and shall support the evaluation of effectiveness at loop level, the identification of critical units, the rapid adaptation to different mission scenarios, and shall be suitable for implementation with concurrent design methodologies.

A closed recycling system: the MEliSSA project

MELISSA has been conceived as a terrestrial closed life support system intended as a tool to gain understanding for building future space closed life support system (i.e. from waste to food) (*Mergeay et al., 1988*). The research activity is established through a Memorandum of Understanding and is directly managed by ESA. It involves several independent organisations IBP, SHERPA, university of Clermont Ferrand (F), EPAS, VITO and University of Ghent (B), Autonome University of Barcelona (E) and University of Guelph (CND). It is co-funded by ESA, the MELISSA partners and national authorities. Based on the principle of an aquatic ecosystem MELISSA comprises today 5 compartments from the anoxygenic fermenter up to the photosynthetic one (algae and higher plant). The Melissa system is schematically depicted in figure 2. Over the last 18 years of MELISSA research, a very progressive engineering approach has been followed, from the selection of the microbial strains up to their characterisation and study of the loop mass balance (Poughon *et al.*, 1997, 2000). Nowadays, the main objective of the project is a ground demonstration (Godia *et al.*, 2000).

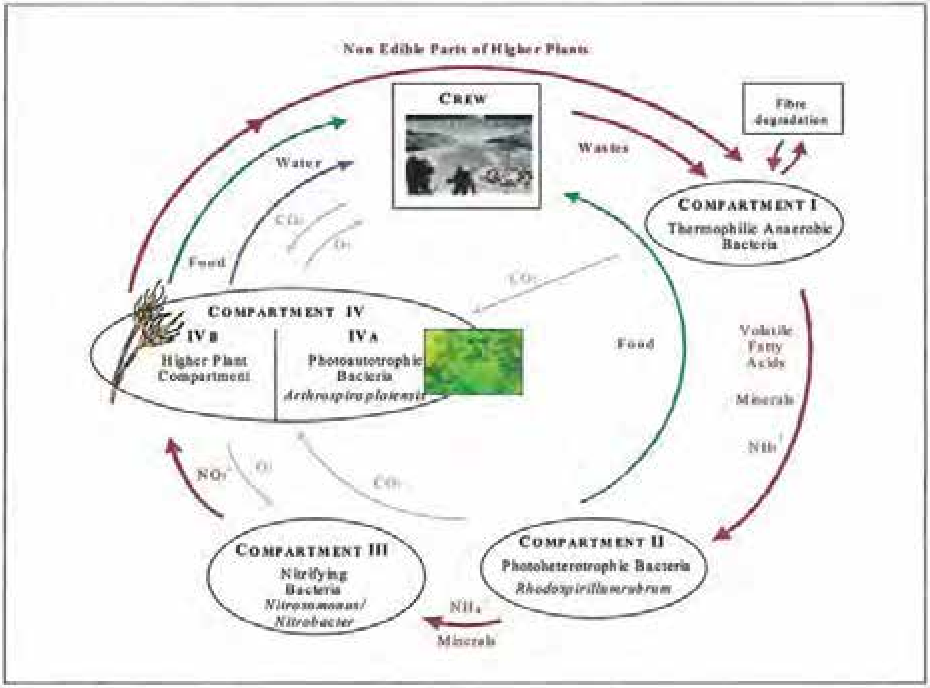

Figure 2: MELISSA concept

Phase 3: ground and space demonstration

Regarding the ground demonstration of life support system, ESA approach is currently organized with three locations: MELiSSA pilot plant, South pole base – Concordia, BIOS facility in Krasnoyarsk (Russia).

MELiSSA pilot plant

In 1995, the existing ESA laboratory has been transferred and extended in the campus of the Autonome university of Barcelona (i.e. UAB) Spain. This facility is dedicated to the physical integration and demonstration with a animal consumer of all selected processes. Due to the non-relevance to work with animal waste, the objectives of the current demonstration are limited to: 20% of food production, 100% of water and air recycling.

After preliminary testing during 600 hours in 1998, bench scale reactors representing compartments II, III and IVa have been recently connected and operated on their liquid phases during more than 1000 hours. Artificial perturbations via the light level have been created on compartment II to study extreme behaviour of the successive compartments (III and IVa). Despite rather high level of volatile fatty acids, no obvious toxic effects have been observed. With exactly the same approach but on a pilot plant scale, including all the control hardware and control procedure in place, compartment III and IVa have been connected and operated during 2000 hours. Figure 3 shows the good stability of the biomass production (OD) despite the very high level of variation of nitrogen sources.

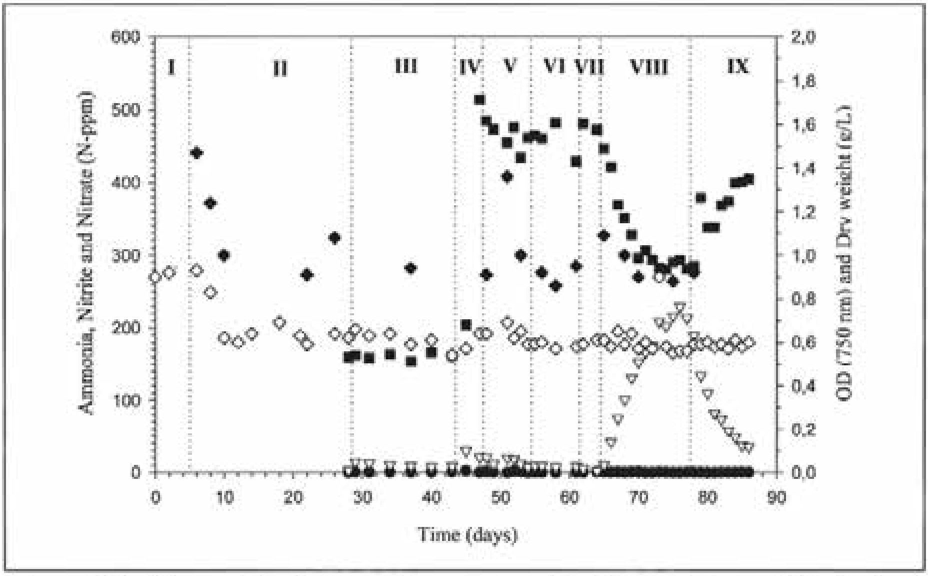

Figure 3: Liquid connection between Compartment III and Compartment IV: Evolution of compartment IV after step change in compartment III efficicency I, II, III IV, V, VI, VII, VIII and IX are the different operational conditions used in compartment III (Creus et al., 2001). • Dry weight (g/L); ▪ Nitrate (N-ppm); ◊ OD (750 nm); ∇ Nitrite (N-ppm); ● Ammonia (N-ppm)

Although it is well accepted by all MELISSA partners that a lot of work remains to be performed to demonstrate the complete loop, the results achieved so far are very promising and the MELISSA project is considered, as the European project for closed life support system. In 2005, a new facility has been created allowing to work in conditions closer to industrial standards and to welcome external scientist as well as the European industry involved in life support developments. The current planning foresees a loop connection then optimisation up to 2015.

The concordia base

Concordia is a French-Italian permanent settlement currently being built in Antarctica operated by IPEV and PNRA. The station is located at Dome C at 3233 m altitude and 1200 km away from the Dumont D'Urville station that is situated at the coast. It is accessible, during summer, after a ten-day trip on the ice from Dumont D'Urville or by plane from the Italian Terra Nova Bay station in 4 hours. The base is not accessible during eight months per year. The environmental conditions are harsh: the average air temperature in summer is -30°C and in winter, -60°C with minimum registered temperatures of -84°C. The atmospheric pressure is 645 hPa. It is designed to accommodate 15 persons in winter and up to 70 persons during summer (figure 4). Due to extreme environmental conditions, the crew re-supply with consumables is virtually impossible therefore the base is a good analog of long term manned space base. However, due to its operational constraints, the Concordia facility is not air-tight, and partially exposed to Sunlight, consequently the life support demonstration cannot be extended to atmosphere and food recycling.

Although the ESA/IPEV-PNRA collaboration is far to be limited to life support issues, the need to minimize crew re-supply, as well as to cope with international treaties regarding Antarctica preservation of virgin environment, a grey water treatment unit base on ESA technologies has been developed.

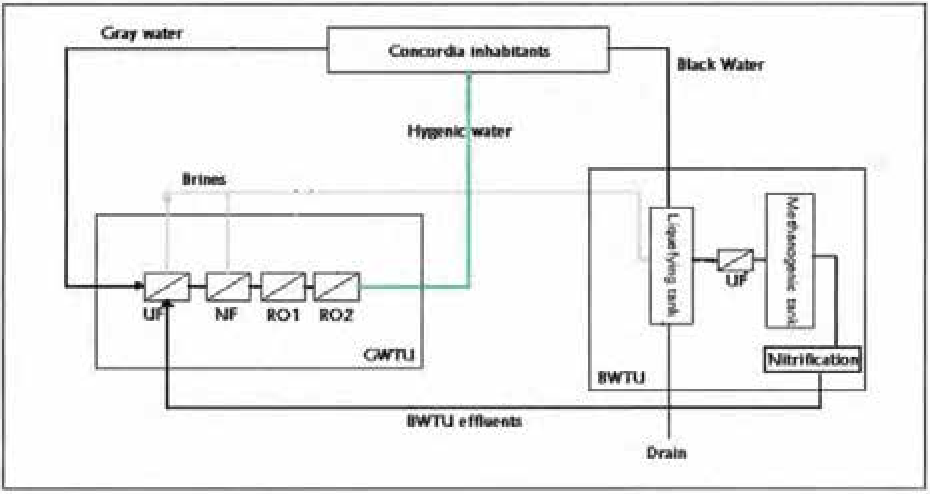

Figure 4: The Concordia station (S. Drapeau, IPEV)

Figure 5: The recycling system – Schematics

The water and waste management plant is composed of two different units (figure 5), sequentially developed.

The overall system is designed to recover hygiene quality water from the gray water produced through the multi-step filtration unit, Grey Water Treatment Unit (GWTU) and to recover part of the wastes via the Black Water Treatment Unit (BWTU). Even if original streams of waste can be treated separately, ideally the two units should be interconnected to reach the highest percentage of recycling.

The GWTU is a multi-step filtration process that uses a combination of ultrafiltration (UF), nanofiltration (NF) and two reverse osmosis (RO) steps. It produces water that matches with ESA hygiene quality standards. Water streams are collected at their respective production site and mixed together before being treated. As gray water is being processed, chemical and bacterial contaminants are retained by membranes as well as dissolved salts originally contained in the water. The residues of the filtration steps are retentates that are more and more saline. In order to keep the system operating at its best performance, these retentates have to be regularly purged. Purge frequency mainly depends on the quantity of water processed, and so, on the occupation level of the station. Regular rinsing of the membranes are performed with a sodium hydroxide solution, which keeps the unit running efficiently and increases membranes lifetime. Based on the breadboard developed within phase 1, the Concordia unit has been scaled up and has the capabilities of recycling gray water produced by 30 persons at nominal load, i.e. 3 m3/d. Figure 6 presents the obtained recovery rate from January 2006 up to March 2007.

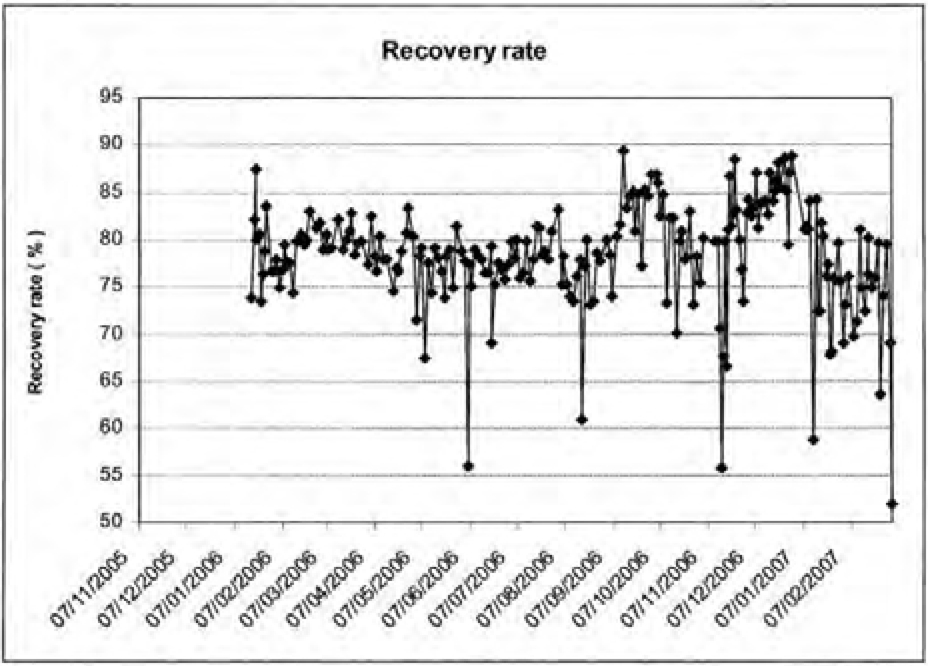

Figure 6: Evolution of the water recovery rate through the grey water treatment unit from January 2006 to March 2007 (Doulami and Lasserre 2007)

The recovery rate is close to 80% along the whole production period except from January 2007 when it ranges between 68 and 80%.

The BWTU is directly derived from the MELiSSA loop planned to complement the GWTU and to recycle the organic wastes produced, i.e. fecal material, toilet paper, kitchen wastes, and urine. It is composed of two anaerobic thermophilic bioreactors and of an aerobic nitrifying bioreactor (Fig 7).

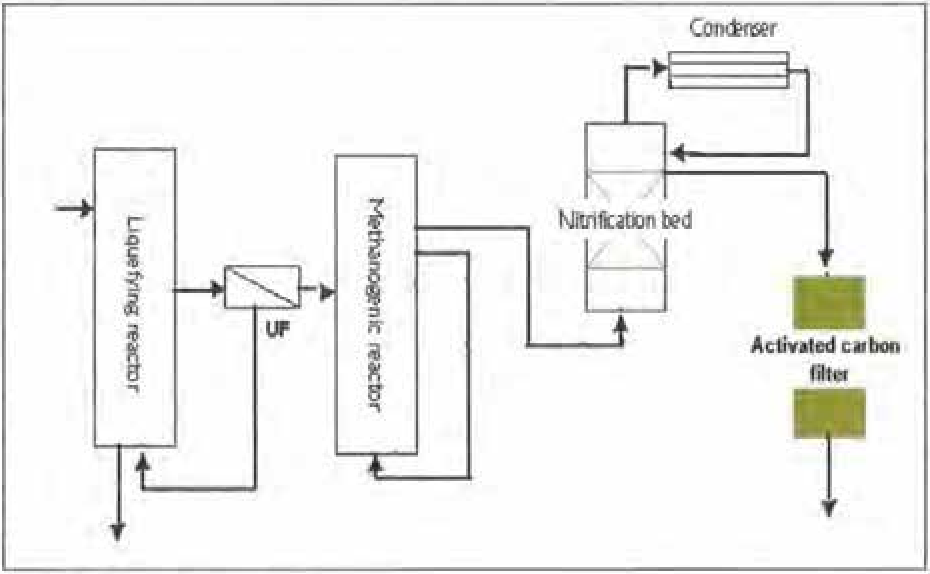

Figure 7: BWTU Schematics

The three bioreactors are working together and are connected via ultrafiltration units to avoid bacterial cross contamination. Waste material is collected at its production site, and the different streams are joined together in a buffer tank. Waste material is then prepared for further processing. In the first stirred reactor of BWTU, liquefaction of waste material occurs at 55°C. In the second anaerobic reactor, VFAs are consumed by the bacterial methanogenic community and are transformed into biogas (i.e. methane and carbon dioxide). The effluent of the methanogenic reactor is then directed to the nitrifying reactor that is derived from the one developed within the frame of the MELiSSA loop.

Today the detailed design of the BWTU has been finalized, discussion are in progress to decide the manufacturing of the unit.

The BIOS facility

Established in Krasnoyarsk Siberia, the BIOS facility remains the location where the most advanced and successful research have been performed (Gitelson and Mac Elroy 2003). The research has lead to several manned isolation campaigns. ESA is currently collaborating to establish join life support system demonstration.

Conclusion

Over the last 20 years ESA has constantly increased its activity in Life Support System. This activity is organized in three phases:

Within phase 1, all recycling technologies and contaminants are not studied, a few innovative concepts have been demonstrated at breadboard level.

For phase 2, the current access to space is extremely limited. However a few experiments of fundamental research on microbiological processes has been successfully been performed.

Phase 3, using consumer has been very seriously extended over the last 3 years. Preliminary closure test in MELiSSA pilot plant and in South Pole Concordia base are promising and allows to progressively validate our core technology in real operational conditions.

Acknowledgements

ESA would like to take the opportunity to thank all its contractors, MELiSSA partners as well as IPEV-PNRA , without them all the presented work would be achievable.

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Pilot Study on the Treatment of Domestic Wastewater by SMBR System at Low Organic Lording

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Abstract: A pilot study was conducted in a residential area to test the SMBR system performance. For the climate, wastewater collection system and habit of life, the raw wastewater concentration is very low with the average of around 0.1kgCOD/kgMLSS.d, which resulted in the suspended sludge in the reactor processed in the endogenesis respiration, negative growth and low activity. The concentration of COD and polysaccharide in supernatant are higher than that in the influent and effluent; The gelatin layer formed by the accumulation and adsorption of the metabolizable matter on the surface of the membrane, transfer resistance force of the membrane filtration increased, the activity of bacteria decreased, the un-active bacteria has lower adsorption and weaker degradation for the SMP.

Keywords: Extracellullar polymeric substances (EPS), Low organic loading, Membrane Reactor, Plate ultra-filtration membrane, SMP (soluble microbial product).

Introduction

It is well know that the MBR system has some distinctive advantages compared with conventional treatment systems: the membrane withholds all biomass and other suspended solids and ensures a high effluent quality(Ruofei Jin, eta, 2004; Yuanhong, Ding, eta., 2005); However, the high concentrated sludge make the MBR operate at a low F/M ratio, when the influent organic loading is too low to maintain the system work at normal level, the soluble microbial products and extracellullar polymeric substances will exhibit strong effect on the performance of MBR system (Yuanhong, Ding , etc. 2005; Folasade Fawehinmi, etc. 2004).

A pilot MBR system was used to treat the residential domestic wastewater, the residential area was located in remote small village with 20 buildings, and about 2500 populations. Three chambers septic was built in front of the each building, extended retention time made the organic loading is lower, MBR system processed the endogenesis respiration. The varation of EPS and SMP were observed to identify the effect of low organic loading on the membrane pollution, gelatin layer formation and chemical cleaning period.The membrane polllution was discussed, the EPS and SMP were emphasised as the main reason to induce the membrane pollution, this is the first time, the EPS and SMP were related to the membrane pollution, which will give us a comprehensive thinkings of membrane materials, organic loading, EPS and SMP.

Material and methods

Raw wastewater

The residential area is located at the Laoshan district, Qingdao, the community wastewater was treated by a MBR system, wastewater quality is shown in Table 1

Table 1: Raw wastewater quality for MBR system

Parameters	COD mg/L	TN mg/L	$NH4^{+}N$ mg/L	TP mg/L	SS mg/L	pH
Range	160~535	41.7-80.5	37.1-72.8	4.0-6.9	90-150	7-8
Mean	228	57.7	53.5	5.1	110	

Test facility

The treatment facility is shown in Figure 1.

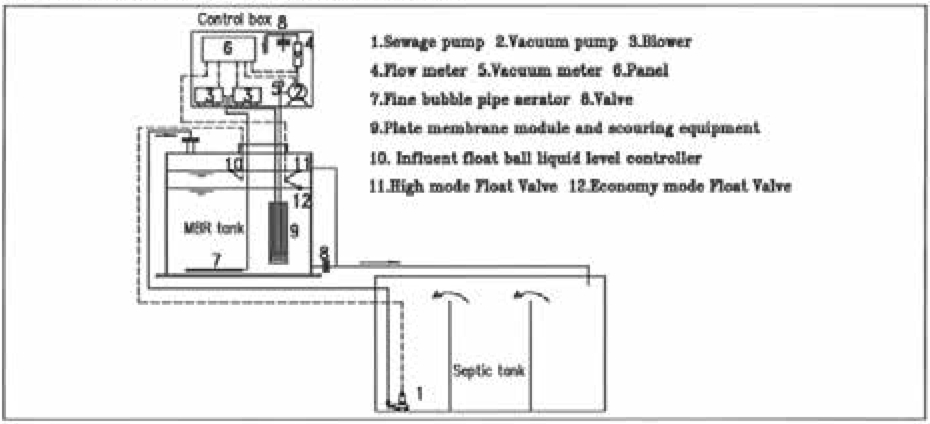

Figure 1: Test facility

As shown in Figure 1, a submerge pump was put into one chamber of three chambers septic tank, the pump was controlled by a liquid level gauge in MBR reactor. A perforation pipeline flusher was installed at the under of membrane model to flushing the membrane by air blowing, micro-pore pipeline performs two functions: provide oxygen to the bacteria, and mix the liquid in the tank. There are two floating ball valves controlling the highest water level and the lowest water level. Three work mode were given by high mode, normal mode and economic mode, the operation parameters for each three modes are shown in Table 2.

Table 2: Operation parameters for the different modes

Equipments	High mode	Normal mode	Economy mode
Vacuum pump	On:Off=270s:30s Q=100L/h	On:Off=270s:30s Q=60 L/h	Off
Blower (Cleaning)	On	On	On:Off=60s : 3600s
Blower (Aeration)	On:Off=60s:60s	On:Off=60s:60s	On:Off=20s:300s

Effective capacity of MBR tank is 1.0m³, with the water depth of 1.2-1.0m. One unit model with 56 plates PES ultrafiltration membrane was used. The characteristic of the membrane is as follows: membrane pore 0.038μm, effective area: $4m^2$, critical flux 30 $L/m^2.h$, flushing flow of air: 4 m^3/h.

The active sludge was taken from Tuandao wastewater treatment plant, suspended sludge concentration in the MBR tank is about 4g/L at start-up, the system was switched between high mode and normal mode automatically, no sludge was discharged during the test.

Analysis

COD, NH3-N、TN、TP、MLSS、MLVSS、were analyzed by standard method (National standard, 1989), EPS was abstracted by formaldehyd, Polylose, phenol-vitriol method, protein, Bradford method and so on (Zhang X, etc. 1999).

Results and discussion

Performance of the system

The test results was drew in Figure 2, Influent COD varied in big range, from 160mg/L to 535mg/L, the effluent COD maintained in stable level, 50mg/L, with average removal of 83.4%, the strong capability to overcome the loading impact was obviously observed. On 11th, the COD in supernatant was higher than that in influent, and continuously increased to the highest point of 850mg/L. The phenomena was analysis as the lower organic loading at start-up, the disaggregation of the sludge released the big molecule organic matter, which was hold up and accumulated in the supernatant, this phenomena was alleviated by addition of carbon resource to increase of the sludge activity. On 64th, the water temperature dropped to 6°C, the active sludge processed dormancy, the COD in supernatant increased again, heating the wastewater to over 13°C, the figure dropped again.

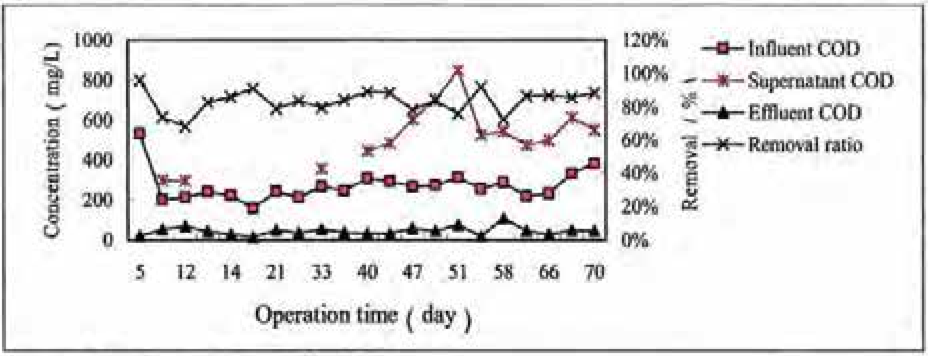

Figure 2: Test results of the MBR system

The influent NH3-N varied at 7.12~72.84 mg/L, with the removal of 7%-79%, as shown in Figure 3. At first few days of start-up, the effluent NH3-N kept in high level for the limited amount of nitrification bacteria, and gradually decreased with sludge age prolonged. On 40[th], the effluent NH_3-N suddenly reached the highest point for the impact loading occurred accidentally, the system could not bear the big change of the NH_3-N loading, for the bacteria could not remove the NH_3-N on time, the membrane could not withhold the small molecule matters and inorganic matter, the NH_3-N, the NH_3-N in the supernatant and in the effluent obeyed the same variation curve, which also illustrates that the membrane has no removal for the NH_3-N. the removal of the NH_3-N depends on the nitrification bacteria in the reactor system, the amount and activity of the nitrification bacteria will have significant effect on the removal. The activity affect also exhibits in the figure 2, on 64[th], when the water temperature dropped to 6°C, the activity of the sludge dropped also, the removal of NH_3-N was lower than 48%, even through 3 days later, the water temperature was heated to 13°C, however the removal was only 7%, the recovery of the activity of the nitrification bacteria is quite slower than that of the organic matter removal bacteria. Therefore the removal of NH_3-N has different principle from the COD in the MBR system.

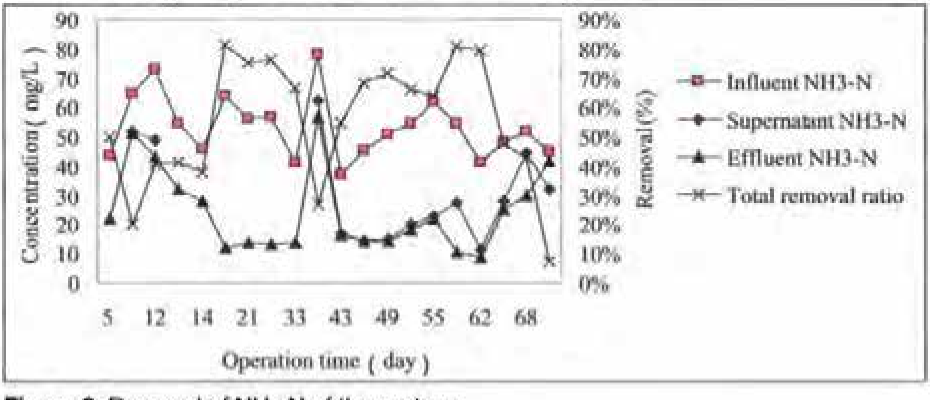

Figure 3: Removal of NH_3-N of the system

Variation of the liquid characteristic in the reactor

At the start-up, the sludge concentration in the reactor is about 4g/L, the sludge loading is only 0.03kgCOD/kgMLSS.d, the bacteria was in the state of poor nutrition, and processed disaggregation, lots of foaming occurred. After 14 days operation, the sludge concentration dropped to 2.6g/L, the OUR of sludge was 15.84 mgO_2/gMLSS.h. Glucose was added as additional carbon on 58[th], the sludge loading was increased to 0.2kgCOD/kgMLSS.d, the balance was formed between proliferation and death, after 4days operation, the sludge concentration was about 2.7g/L, the sludge concentration kept in stable. When wastewater temperature dropped to lower than 6°C on 4[th], the bacteria in reactor was in the state of dormancy. Heating the wastewater to over 13°C, the sludge activity was recovered, the variation of sludge concentration is shown in Figure 4 and 5.

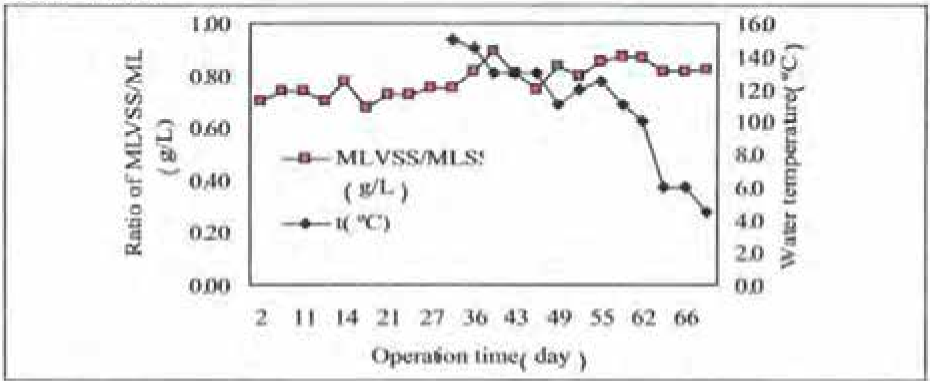

Figure 4: Variation of temperature and ratio of MLVSS and MLSS

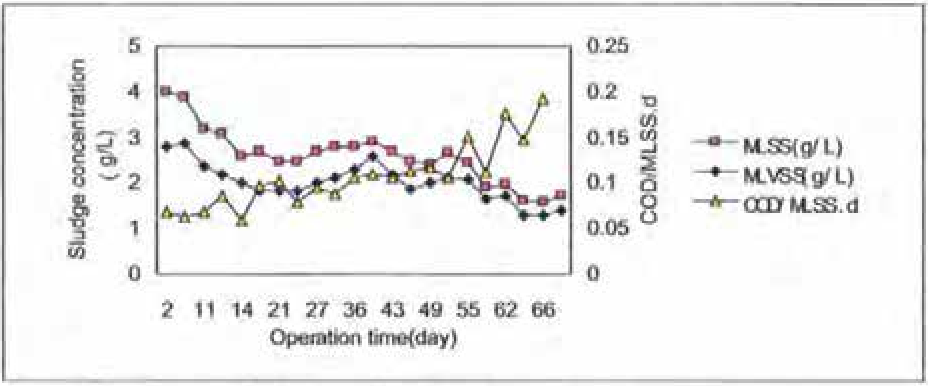

Figure 5: Variation of Sludge concentration in the reactor

The activity of sludge varied with operation time, as shown in Figure 6, the OUR of the sludge is about 47 $mgO_2/gMLSS.h$ at start-up, After 14days operation, the sludge concentration dropped to 2.6g/L, the OUR of sludge was 15.84 $mgO_2/gMLSS.h$. By addition of glucose, the OUR of sludge gradually increased to 47.5$mgO_2/gMLSS.d$. When the water temperature dropped to lower than 6°C, the OUR was not analyzed; when heated the water to 13°C, the OUR increased to 55 $mgO_2/gMLSS.h$, which means the temperature and organic loading effect on OUR of sludge.

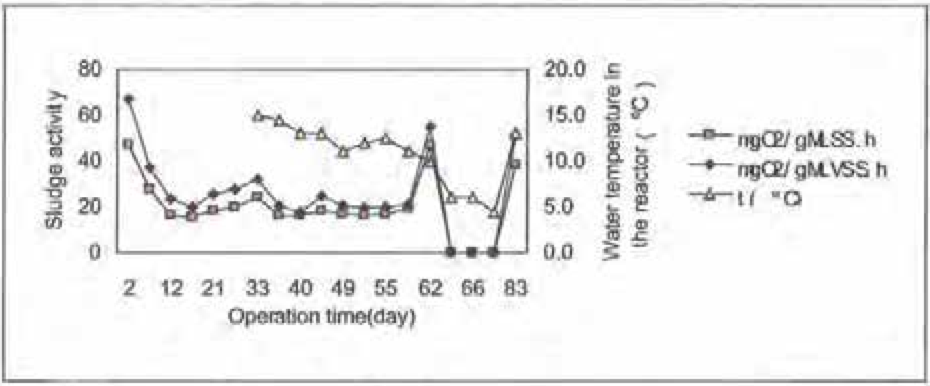

Figure 6: Variation of Sludge activity in the reactor

Variation of the byproduct of microorganism

The byproducts in here indicate the extracelluar polymeric substances (EPS) and Soluble microbial production (SMP). SMP indicates the excretive materials, including energy produced by microorganism decomposing substrate, and UAP(substrate utilization associated production) produced by microbial proliferation; BAP(biomass associated production) released during the cell disaggregation for the microbial endogenesis respiration; EPS comprises of extractable EPS and suspended EPS, which are produced in metabolizability of microbial, including the excretive materials, the matters of cytolysis or hydrolysate. SMP and EPS are cumulated in the reactor for the membrane holdback, and they are degradable, however need a long time. The accumulation of the metabolizing byproducts restrains the sludge activity, including the activity of nitrification bacteria, this affection will be enhanced by the concentration increase. Accumulation of EPS increased the viscidity of liquid and the transfer resistance. Gelatin layer prior to the membrane is mainly formed by the reaction of SMP. The membrane pollution is separated into quick pollution and slow pollution, the quick one is due to the EPS, the slow one is from SMP.

As shown in Fig. 7, the extracelluar polysaccharide and extracelluar protein of outside of the sludge cell kept in stable level during the operation period, the extracelluar polysaccharide varied from 26.2mgEPS/g.MLSS to 33.8 mgEPS/g.MLSS with average of 29.4 mgEPS/g.MLSS. The extracelluar protein varied from 1mgPP/gMLSS to 1.71mgPP/gMLSS with average of 1.29 mgPP/gMLSS. The extracelluar polysaccharide of outside of the sludge cell diffused into the water, and kept in stable level, the diffusion of the extracelluar polysaccharide is also illustrated by Fig. 8, the variation of the extracelluar polysaccharide in the supernatant.

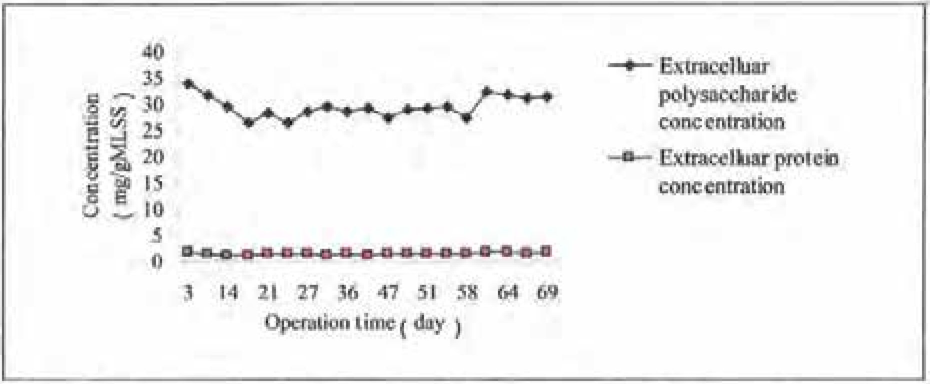

Figure 7: The variation of EPS and extracelluar protein of outside of the sludge cell

As shown in Figure 8, the extracelluar polysaccharide concentration in supernatant gradually increased and reached 490mg/L on 49th, and continuously increased to 604mg/L, after addition of glucose on 58th, and then decreased to around 311mg/L with the increase of the sludge activity. Which is because the concentration of the sludge in the reactor is too low to adsorb and degrade EPS, the increase of viscidity of the liquid resulted the foaming of the reactor. After decreasing aeration strength. the sludge activity was increased, extracelluare polysaccharide concentration decreased to low level for the degradation of the extracelluare polysaccharide concentration by sludge.

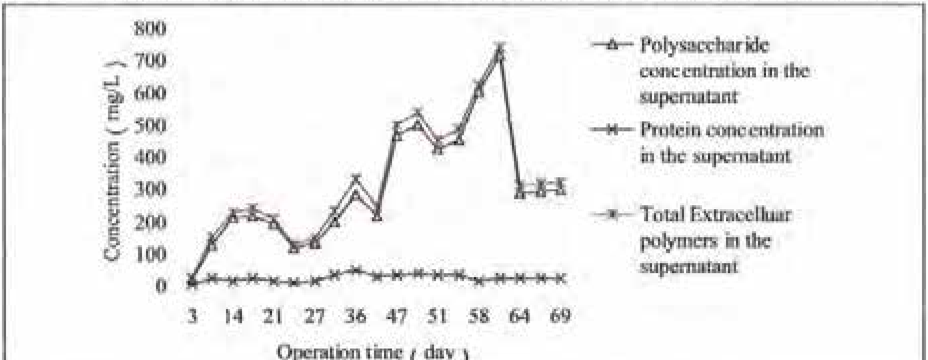

Figure 8: Variation of microorganism products in the reactor

The comparision of the extracelluare polysaccharide concentration in supernatant, in the influent of the reactor and in the effluent of the membrane was conducted, the results was shown in Figure 9, the concentration of the extracelluare polysaccharide in the supernatant is higher than that in the effluent of the membrane, and in the influent of the reactor. The curve of the Fig.9 illustrated that the extracelluare polysaccharide was produced by the sludge and released into the supernatant, and the content in the supernatant and in the effluent is higher than that in the influent. The large amount of extracelluare polysaccharide in the supernatant is resource of the membrane pollution.

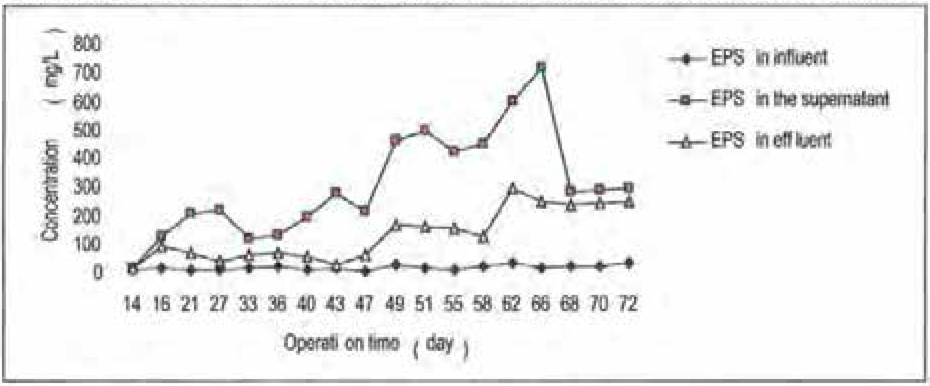

Figure 9: Variation of polysaccharide concentration in the reactor

Specific flux variation and membrane clean

At the normal mode of 62L/h, and high mode of 118L/h, specific flux of the membrane was 620L/h, and 983L/h, separately, at the beginning of the start-up, the specific flux of the membrane decreased quickly, after stop feeding the raw wastewater on 13th, aeration whole day, it increased, and then decreased slowly again until reached 143L/h on 66th. The feeding was stopped again on 77th, 2h aeration, the polluted membrane was cleaned by hypochlorous of 400mg/L for 2h, the flux of the membrane was recovered to 458L/h at the normal mode with recovery rate of 74%. As shown in Fig. 10 the flux variation with the operation time. Comparing the Figure 10 with the Figure, with the increase of the EPS concentration in the system, the flux decreased correspondlly, when the concentration of EPS in the supernatant reached highest Point of 716.6mg/L, the pecific flux in the normal mode and in the high mode reached lowest point of 143L/h on 66th, which also illustrated that the EPS is the main resouce of the membrane pollution.

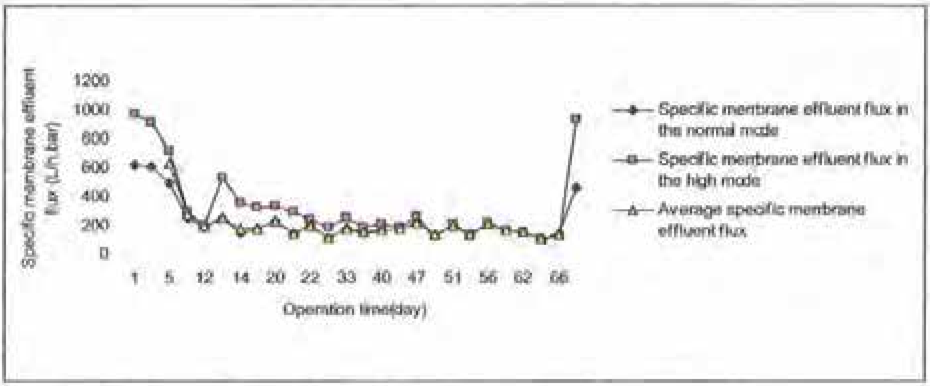

Figure 10: Variation of specific membrane effluent flux

Conclusion

The organic loading of the reactor was too low to make the activity sludge was in the state of low nutrient, endo-respiration, the rate of the sludge proliferate was so low that sludge was in the negative growth, the concentration of the sludge decreased, and the activity became bad. The OUR of the sludge was only15.84 mgO_2/gMLSS.h at lowest point. By addition of carbon, the organic loading was increased to higher than 0.3kgCOD/kgMLSS.d, the activity of the sludge was recovered to 47.5 mgO_2/gMLSS.h.

When the influent COD varied in the range of 160~535mg/L, the effluent COD was lower than 50mg/L, even at condition of the sludge activity of 15.84 mgO_2/gMLSS.h, the effluent COD was still lower than 50mg/L, the organic molecule is effectively retained in the reactor for the membrane's effective holding up.

The denitrafication bacteria is very sensitive to the outer condition, it could not overcome the big variation of the NH_3-N, and the membrane nearly had no hold up to the NH_3-N, the concentration of NH_3-N in the supernatant is the same as that in the effluent of the membrane, denitrafication bacteria was afford ability to remove the NH_3-N.

For the accumulation of the EPS and SMP, the EPS and SMP in the supernatant is much higher than that in the effluent of the membrane, the accumulation of EPS and SMP repressed the activity of the sludge.

For the accumulation of the SMP, the gelatin layer formed prior to the membrane, the transfer resistance increased quickly, and the specific flux decreased to 23% of the initial figure of the membrane. The main part of the SMP is extracelluare polysaccharide, and easily to be degraded by the bacteria, after 2h of aeration without feeding the raw water, and cleaned the membrane with hypochlorous acid of 400mg/L, the specific flux of the membrane was recovered to 74%.

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Franchising – A new Approach for Financing and Realisation of Sustainable Solutions for Water and Sanitation

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Abstract: Especially in developing and transition countries, public utilities (working under political priorities) often seem unable to deliver the necessary water and sanitation services.
Twinning and homostructural PPP may help for a certain time with limited effects, but will not be able to heal the situation in most cases. The same applies to Benchmarking.
PSP approaches, like BOX, PPP, management contracts, concessions etc., have been successful in many cases, but are facing growing resistance.
Franchise might become a feasible solution, acceptable to municipalities and the local communities, because it does not delegate tasks and values added to global players from outside.
There is not yet much experience existing with Franchise models, although the basic components are well established (e.g. with contracting models), as is the overall scheme (Mr Minit, McDonalds ...). The Author hopes to conclude the first "Water-Franchise-Pilot-Project" in South Africa until next year, and to commence more projects in other regions. Then, it will be possible to evaluate, whether and under which conditions Franchise can be a favourable option.

Keywords: Development Co-operation, Financing, Franchise, Operations and Maintenance, Sanitation, Water.

Sustainable O & M is the bottleneck factor of success in water and sanitation

In developing water and sanitation facilities, including many developing and transition countries, the status of NEW PROJECT development has passed. In most cases, we need rehabilitation of the first, second or even third generation of networks and plants, plus modernisation, extension etc. More than financing capacities, poor operations and maintenance (O & M) are the dominating problem and the bottleneck factor of success.

Even comparably expensive systems for water and sanitation (like existing in Germany) are much cheaper (in specific costs, €/m³-served at appropriate quality and reliability standards) than systems with poor performance (see **Figures 1 + 2**).

Figure 1

Figure 2

Poor quality in equipment and technology causes high costs

Quite often, fake equipment, e.g. from certain Asian countries, poor quality in materials and technology may look cheaper in budgeted expenses than products from competitors like (often) from Germany. **Figure 3** shows a wastewater pond in Peru, which caused odour problems and finally failed in operations, for the main reason that the input screen was too cheap - it did not work, was by-passed in day-to-day operations etc. Instead of replacing it with a high-quality fine screen, the donors' engineering consultants (suffering the incentive that their fee is higher, if investment costs are high) have recommended to cut down the wastewater pond system and build a conventional activated sludge plant instead.

From **Figure 4** you can see that it does not pay out to buy a chemical dosing unit at low quality level. In the end, the operators will have to distribute by hand and will utilise a lot of chemicals, compared to the high-tech high-quality solution.

Figure 3

Figure 4

The following calculation **(Figure 5)** indicates the results of poor investments and management from a case study in Asia.

a)	Theoretical CAPEX	=	1 €/m³ = 1 €/1 000 l
	Leakage rate 45 %	≙	450 l lost
	Technical failure 30 %	≙	300 l lost
			750 l lost
	Real CAPEX	=	1 € per 250 l
		≙	**4 €/m³**
b)	Theoretical CAPEX	=	1.15 €/m³ = 1.15 €/1 000 l
	Leakage rate 8 %	≙	80 l lost
	Technical failure 6 %	≙	60 l lost
			140 l lost
	Real CAPEX	=	1 € per 860 l
		≙	**1.33 €/m³**

Figure 5

The reasons of failure are rather the priority of political motivations in public utilities, not technological or financial reasons

In the water sectors, some colleagues spell the word democracy like *demo-crazy.* This, because certain politicians (hunting for votes from people with sometimes poor education and little understanding), tend to promise high investments and low water tariffs or even water and sanitation for free. The result is a vicious circle, as shown in **Figure 6.** It is necessary to break that vicious circle, as indicated in **Figure 7.**

But how can we do this, what is the appropriate strategy, approach, method???

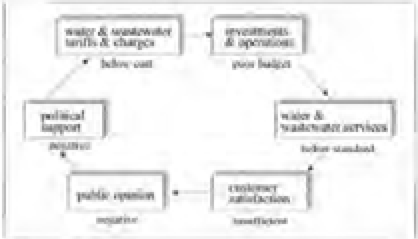

Figure 6

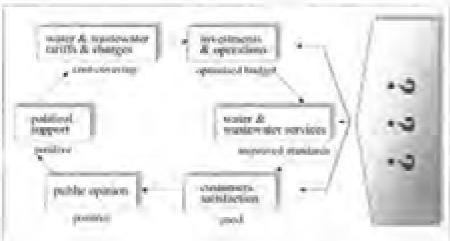

Figure 7

To break this *vicious circle*, banks and donors have pushed PSP schemes into the public water sector

If you want to improve your future, it is always good to understand the past. A short review of PSP development can be outlined as follows:

The first driver was the understanding that integrated, competitive optimisation of CAPEX + OPEX is needed. BOOT models provided better service results than the conventional approach with split responsibilities and contra-productive incentives for design, construction, operations and financing. The first BOX models under this motivation, mainly BOOT, were developed in Lower Saxony, since the 1980s **(Figure 8)**.

More sophisticated models with joint venture companies (co-operation models or "PPP" in the exact meaning) were also developed and executed successfully, especially after the reunification of Germany West and Germany East, to meet the huge demand under enormous time pressure. **Figure 9** shows the industrial plant at Bitterfeld, which will be extended after 14 years of successful and financial sustainable operations (and the Author is proud to be involved in this large project since its first stages of development).

Figure 8

Figure 9

Such positive examples from old European countries like (in alphabetical order!) England, France, Germany, Spain have convinced international donors and financing institutions to introduce PSP as a solution of the capacity deficits in developing and transition countries. Very large projects were developed and implemented, many successful, but quite a number received growing political resistance. Since its peak year 1999, the classical PSP project development went down. **Figure 10** shows the number of PSP projects implemented in the water sector (including sanitation) under regime of the World Bank.

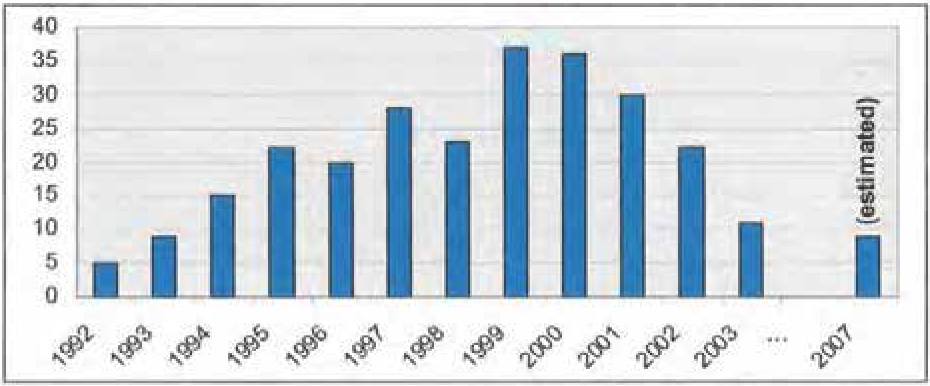

Figure 10: [Source: Prasad (2006); own calculations; see CESifo DICE Report 2/2007]

One might outline the reasons for failure and public/political resistance against the so-called "privatisation" (which, in very few countries only, includes the privatisation of property rights for water resources. In most cases, PSP is limited by law to the delegation of water services). One might also discuss a lot about the donors' PSP record, sometimes paying more for lawyers and financing specialists than for engineers and operational management expertise. One might also complain about the pressure, which donors imposed on municipalities, and the counteraction emerging from that.

But we should not forget that the number of failures with Non-PSPs is much higher world-wide. Many times failures are resulting from reasons beyond the question, "to PSP or not to PSP" - like inappropriate investment, lack of willingness to charge, low or no-budgets for M & O, poor enforcement of law, unstable behaviour of sponsors etc.

Maybe it would not help much to discuss this in the public among water experts, because the official arguments are quite different from real motivations and dominating drivers of the individuals, the NGO networks, of public administration/utility lobby groups etc. One outcome from the PSP history so far is that the market is strongly dominated by very few global players, usually winning large tenders with the bureaucracy and complexity (and, what the Author regrets, intransparency) of most of the big "transactions" driven by investment banks, law firms and global accountants.

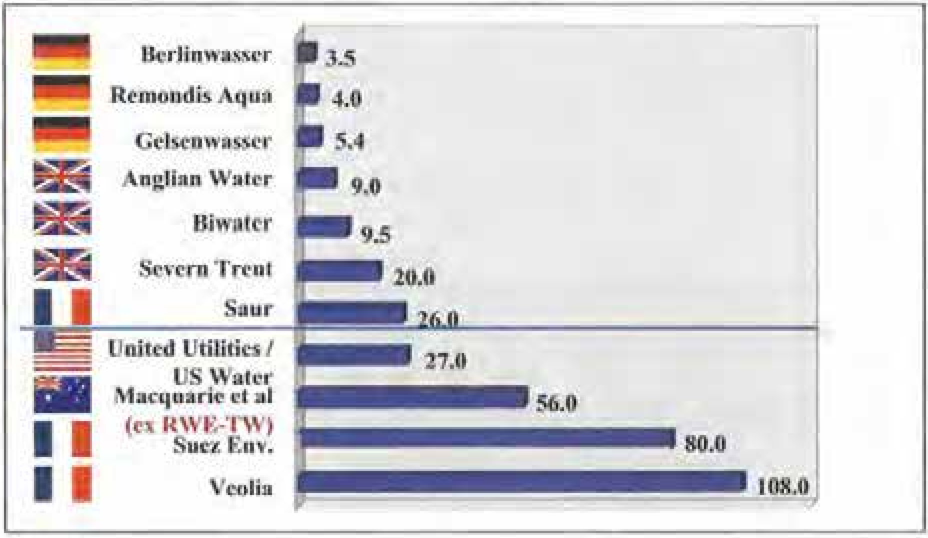

Figure 11

When the former VpA (Verband privater Abwasserentsorger, Association of Private Service Providers) was founded during the BOX blooming in Lower Saxony 1989 (to lobby the "Lower Saxony Operators Model" – Niedersächsisches Betreibermodell, **Figure 8** presents one of 29 of such projects realised), there were still 59 water service companies on the German market, mainly SMEs. That this situation has totally changed, as shown with Figure 11, is a strong disadvantage in terms of competition and regional water sector development. In macroeconomic terms it makes a difference, whether or not domestic companies are employed in the frame of donated or soft-loaned water projects.

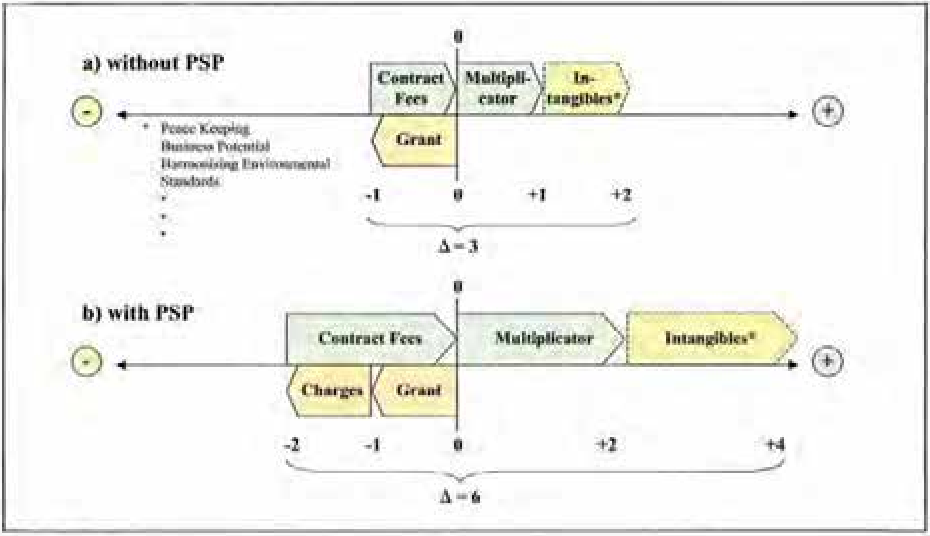

Figure 12

Whether in Asia, Latin America or Africa: Many mayors tell me that they would like to delegate technology management to professional service providers, if they could expect that local companies are involved, whom they can trust, who would allocate value added in the region, who would really contribute to capacity building and development et. al. But they see no such option to delegate services in water and sanitation, which makes them feel they have no safe choice than to rely on their public administration.

And now we can talk about Franchise.

The franchise idea and concept

Franchise basically means a link between a SME local service provider (LSP) and a large (often international) company - in the water sector a professional water company (PWC). Whenever a big and complex project is tendered, usually an international general contractor will win the job and make use of local sub-contractors. The contract would be governed from the headquarters (probably from abroad, which is no advantage under the view of developing and transition municipalities), and the local sub-contractor might be exploited and not really grow in his role. **Figure 13** visualises the change in the contractual scheme.

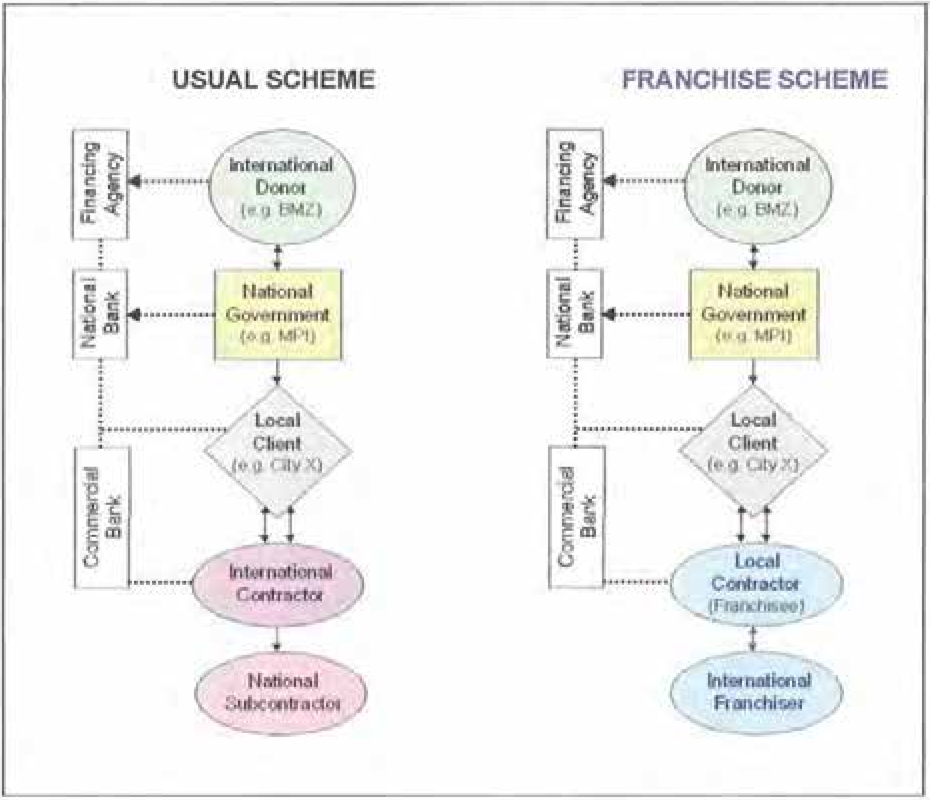

Figure 13

Franchise means a different relation. The LSP will directly do the job, contract and serve the client. But the LSP's capacity will be supported by the PWC, delivering tools and know-how etc. **Figure 14** shows the approach.

Local Service Providers (LSP)		Professional Water Company (PWC)	
STRENGTHS	• located near to the job • low staff costs	WEAKNESSES	• located far from the job • high staff costs
WEAKNESSES	• wastewater specific expertise limited • no financing power, short term business only	STRENGTHS	• professional wastewater expertise • sufficient financing power, mid- and longterm business possible

Figure 14

Figure 15 gives further explanations.

Stakeholder	Role in the Franchise Concept	Responsibilities/Tasks
Public service provider	Provision of sanitation services	• delivers sanitation services to costumers • gets paid by costumers • contracts out O&M to franchisees • pays franchisees for delivered O&M-services
Private service provider	Franchiser	• supervises recruitment process • trains franchisees (initially and throughout the project) • monitors franchisees' service quality • gives administrative support (taxes, accounting etc.) to franchisees
Local service provider	Franchisee	• responsible for O&M of sanitation services facilities in a specified area (suburb etc.) • pays a royalty fee (percentage share of annual turnover) to franchiser

Figure 15

The whole structure of real motivations and drivers is quite different in a Franchise scheme than with any PSP or other pure public option (like twinning, homostructural PPP = Public Public Partnership, intermunicipal networks, as described in the Asian Water Journal, June 2007, page 3). The strong response from different countries indicates a huge demand world-wide for new approaches to solve the water and sanitation problem in general, and potential for Franchise.

Under specific circumstances, different Franchise targets may be favoured, like

- Utility Franchise
  (A water and/or sanitation utility, be it public or private, might reach some protection from political wishes and better relations to its financing banks, if they can show a binding contract with a professional, international franchiser, making their business plan reliable, bankable etc.),
- Technology Franchise
  (The technology provider will, as franchiser to his client, make sure that the technology is equipped, operated and maintained in a sustainable way. The equipment may be a combination of local fabrication and the franchiser's products.),
- O & M Franchise
  (Where a municipality or else will delegate operations and maintenance of water and sanitation facilities to a private LSP, who will receive franchiser's support. This scheme may enable the municipality to get financial support and loans from sponsors, who might require a performance guarantee to be delivered by the LCP through the PWC, before they are willing to finance investments.),
- Selected Services Franchise
  (Quite common in EU are "full service contracts" e.g. for pumping systems, decentralised plants, water recycling units in industry, somehow similar to a Franchise.).

Perspectives

In most of the cases (South Africa, where the World Bank is supporting the first Franchise Pilot Project which had won the Global Competition in Water Management 2006, and in Vietnam, where the EU is sponsoring PSP and Franchise approaches), the responsible experts hope that Franchise might improve performance and thus the financial rating, to cut the vicious circle described above.

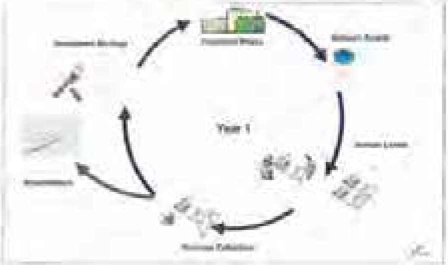

Figure 16

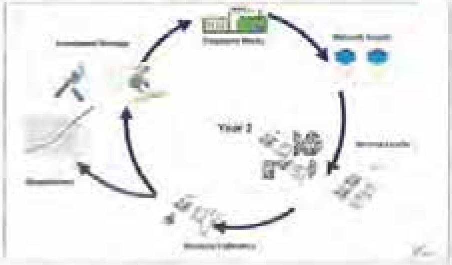

Figure 17

Summary, final remark

Under the working conditions especially in developing and transition countries, public utilities (working under political priorities) seem unable to deliver the necessary improvements needed for water and sanitation.

Twinning and homostructural PPP may help for a certain time with limited effects, but will not be able to heal the situation in most cases. The same applies to Benchmarking.

PSP approaches, like BOX, PPP, management contracts, concessions etc., have been successful in many cases, but are facing growing resistance.

Franchise might become a feasible solution, acceptable to municipalities and the local communities, because it does not delegate tasks and values added to global players from outside.

As local players see a chance for business development, linked to the decision makers in the towns, and as local players know much more about the local working conditions, the restraints etc., the potential for Franchising in the water sector seems attractive.

Anyhow, there is not yet much experience existing with Franchise models, although the basic components are well established (e.g. with contracting models), as is the overall scheme in the food trade and service sector (Mr Minit, McDonalds ...). The Author hopes to conclude the first "Water-Franchise-Pilot-Project" in South Africa until the next year, and to commence more projects in other regions in future. Then, it will be possible to evaluate, whether and under which conditions Franchise can be a favourable option.

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Prof. Dr. Karl-Ulrich Rudolph

»Das Wasser rauscht', das Wasser schwoll ...« – Wasser als Motiv in der Musik

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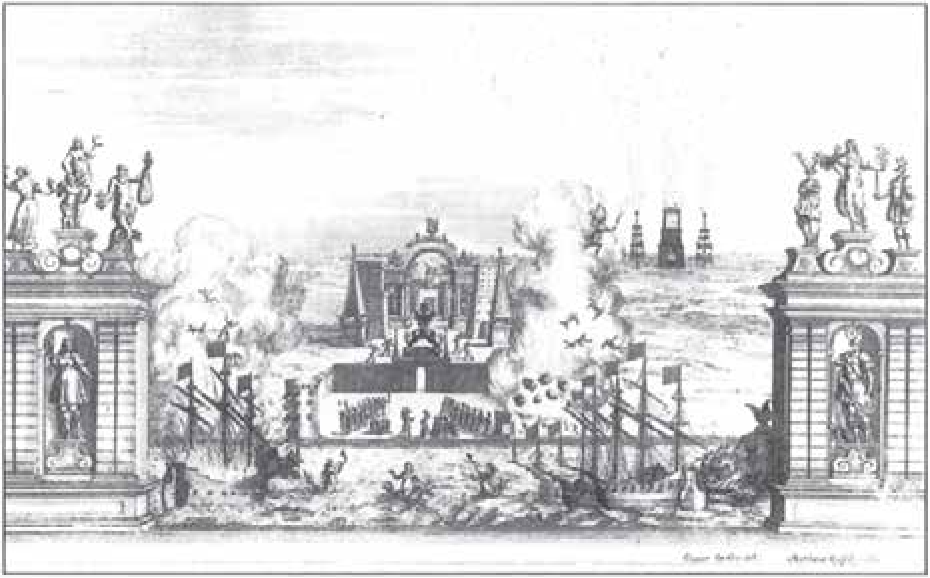
Das Wasser als rauschendes Bächlein, als Ort der Lorelei und anderer todbringend schöner Nixen, das Wasser als tobendes Meer, als Ort heiteren Glücks, als erquikkendes Wasserspiel – in allen musikalischen Gattungen, in Lied, Instrumentalmusik, Oper und Ballett, ist das Motiv Wasser anzutreffen. Und ist daher in der einen oder anderen Gestalt jedem schon einmal begegnet: als majestätisch strömender Fluß in Bedřich Smetanas Symphonie *Die Moldau* (1875); als erfrischende Wasserkünste in Franz Liszts Klavierstück *Les Jeux d'eau à la Villa d'Este* (1877); als die launisch springende Forelle, die eines Fischers Opfer wird, in Franz Schuberts *Die Forelle* (1817); oder als gottgesandter Sturm, der Unzähligen das Leben kostet, in Wolfgang Amadeus Mozarts Oper *Idomeneo, re di Creta* (1781).



Oder in Georg Friedrich Händels sogenannter *Water music* – ? Doch so berühmt das Stück, so irreführend der Titel. Denn Wasser ist hier gerade nicht das Thema, sondern der Aufführungsort – genauer: die Themse war der Ort, auf dem die Folge dieser so ungemein prägnanten und sogleich berühmt gewordenen Stücke dem englischen König Georg I. am Abend des 17. Juli 1717 während einer Prozession von etwa 50 Musikern dargebracht wurde.[i] Solch aufwendiges Spektakel zu Wasser war allerdings keineswegs ein singuläres Ereignis; vielmehr gehörte es zur höfischen Festkultur des Barock und schloß auch andere Formen des Wasserfestes ein. So hatte der kurfürstliche Hof in München schon 1662 – im Wettstreit mit den glänzenden Festen Ludwigs XIV. – die Taufe des Erbprinzen Max Emanuel, des späteren Türkenbesiegers, mit einem acht Tage währenden Fest gefeiert, dessen fulminanten Höhe- und Schlußpunkt das Feuerwerksdrama *Medea vendicativa* bildete. Hierbei handelte es sich um sechs, jeweils in einem Feuerwerk endende Bilder, die in der mythologischen Figur des Theseus den Mut und das strategische Geschick des neugeborenen Herrschers rühmen, der aus einer verheerenden Seeschlacht schließlich als Triumphator hervorgeht. Aufgeführt wurde das opernähnliche Stück auf einer aus Flößen erbauten Bühne auf der Isar; die Zuschauer waren auf Tribunen am Ufer untergebracht, die man während der Feuerwerksszenen in sichere Distanz ziehen konnte. Auch die Floßbühne ließ sich bewegen und wurde eigens vom Ufer weggezogen, um so für eine Seeschlacht Platz zu machen, die höchsten illusionistischen Ansprüchen genügte[ii] (Bild).

Gleichzeitig gab Kurfürst Ferdinand Maria, der Vater von Max Emanuel, dem Vorbild der Venezianer und der goldglänzenden Galeere des Dogen, des Bucintoro, folgend den Bau des berühmten Bucentaur in Auftrag, eines Prunkschiffs, auf dem eigens auch für Musiker Platz vorgesehen war und das der Münchner Hof zusammen mit einer ganzen Flotte von Schiffen bis zur Mitte des 18. Jahrhunderts für großartige Feste auf dem Starnberger See nutzte, zu denen selbstverständlich auch Musik gehörte. Spätere Herrscher hielten sich nur mehr ein ihrer Würde entsprechendes Schiff.[iii] Ludwig II. aber, der sein Dampfschiff Tristan auf dem Starnberger See liegen hatte, erinnerte noch einmal an die barocke Wasserfesttradition, indem er nach Richard Wagners Besuch in Hohenschwangau im Jahre 1865 die Ankunft des Schwans aus Wagners Lohengrin (1850) auf dem Alpsee inszenieren ließ. Währenddessen erklang die zugehörige Passage der Oper (allerdings ohne Gesang), in der das Erscheinen Lohengrins als Klangwunder gefeiert wird.

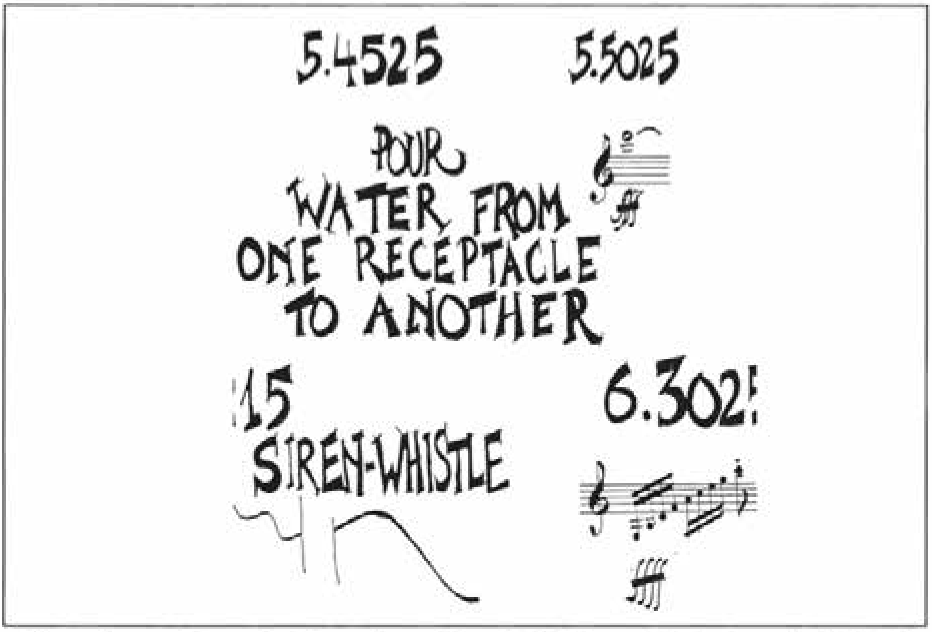
Von solchen geradezu als Events zu bezeichnenden Ereignissen unterscheidet sich, worum es hier im ersten Teil geht, das Wasser als Motiv in der Musik, ›Motiv‹ verstanden im Wortsinn: als das Movens zur musikalischen Gestaltung. Dabei gilt es zunächst zu unterscheiden zwischen einem Lied oder einer Opernnummer auf der einen Seite, in der das Thema oder auch nur das Motiv Wasser schon durch den Text benannt ist. In diesem Fall hat der Komponist zu entscheiden, ob das Wasser überhaupt seine musikalische Erfindung leiten soll, schließlich kann er es auch als nebensächlich für seine Komposition übergehen. Auf der anderen Seite gibt es symphonische Dichtungen und andere instrumentale Programm-Musiken, die von einem Titel begleitet sind, der auf Wasser hinweist. Hier ist der Titel nicht etwa als eine Erklärung der Musik zu verstehen, so als bestünde der Sinn darin, das Auf und Ab der musikalischen

Bewegungen, das Fortströmen der Motive oder das Anstürmen der Skalen als leichtes Wogen des Sees, als Heranrollen von Welle auf Welle oder als sturmgepeitschtes Meereswasser identifizieren zu können. Vielmehr gehören Musik und Titel zusammen, bilden sie gemeinsam die Chiffre einer poetischen Idee: etwa des ständigen Verfließens eines Geformten, des Aufglänzens einzelner Farben und Harmonien als musikalisches Gegenbild des Sonnenreflexes auf dem Wasser, des geräuschhaften Herandrängens einer unheilvollen Macht und von vielem anderen mehr.[iv] Denn die Motive, die die Komponisten zur Zeichnung der verschiedenen Erscheinungsformen von Wasser ge- und erfunden haben, stellen nicht etwa per se Wasser dar. Ganz im Gegenteil: Sie stellen eine musikalische Bewegung, einen Rhythmus, ein Klangspiel dar, die sich als musikalisches Äquivalent zu dem Naturphänomen begreifen lassen. Genau besehen ergibt sich dabei im Laufe der Geschichte folgender Widerspruch: Nirgends erscheint das Wasser so ausschließlich als alleiniger Darstellungsgegenstand wie in der Programm-Musik des späteren 19. Jahrhunderts. Nirgends aber geht es dem Komponisten in geringerem Maße konkret um Wasser, als vielmehr um die genannten abstrakten Parameter, die er, unter Rekurs auf das Wasser und seine besonderen Erscheinungsformen, zum Gegenstand seiner Komposition erhebt und so bisweilen Traditionen ausweitet und Grenzen der Tradition überschreitet. Insgesamt läßt sich wohl die allgemeine Behauptung wagen, daß die musikalische Charakterisierung des Wassers um so überzeugender gelungen ist, je gekonnter, ideenreicher und oft auch innovativer die abstrakten Parameter, die sich mit dem Wasser und seinen Erscheinungsformen assoziieren lassen, in genuin musikalische Parameter wie Bewegung, Rhythmus und Klang übertragen sind.

Oper

Daß sich das Motiv Wasser so häufig in der bildenden Kunst, der Malerei und auch der Musik findet, liegt nicht zuletzt daran, daß es wesentlich zum Topos des *locus amoenus* gehört, dem wichtigsten Element der Naturschildung seit der Spätantike: des heiteren Ortes, an dem sich Bäume, Wiesen und eben auch eine Quelle oder ein Bach und dazu oft Vögel und Blumen glücklich vereinen. Einen solchen Lustort galt es schon 1677 für Jean-Baptiste Lully, den Hofkomponisten Ludwigs XIV., in seiner tragédie lyrique *Armide* zu schildern. Nach der Befreiung der Ritter aus der Hand der Sarazenen will der Held Renaud zu neuen Taten aufbrechen, trotz der Warnung seiner Freunde vor der Zauberin Armide. Sie nämlich ist in ihn verliebt und setzt nun alles daran, ihn, der sie bislang achtlos überging, für sich zu gewinnen. So verhindert sie zunächst einmal seine Abreise und läßt ihn auf einer Blumeninsel am Ufer eines Flusses – einem *locus amoenus* – einschlafen, wo Najaden ihn lieblich umgaukeln, bevor sie ihn dann zusammen mit Armide ans Ende der Welt tragen und diese ihn wenigstens für kurze Zeit bezaubern kann. Das akustische Erkennungszeichen des Ortes, das leise Plätschern des Baches, diente dem Komponisten als das Naturelement, das er in eine gleichmäßige wellenförmige Melodie der Streicher übersetzte und über das der Opernbesucher zunächst Wasser und in einem zweiten Schritt, im Verein mit dem Bühnenbild und im gleichzeitigen Rekurs auf die literarische Tradition, die spezifische Atmosphäre des heiteren Ortes imaginieren konnte. Eine ähnliche Wellenbewegung durchströmt das wunderbare, zeitenthobene E-Dur-Trio in Mozarts *Cosi fan tutte* (1781), in dem Dorabella und Fiordiligi mit Don Alfonso ihren Verlobten Ferrando und Guglielmo angenehm süßen Wind und ruhigen Wellengang auf ihrer Schiffahrt in den Krieg wünschen. Dabei mag für manchen Hörer noch die Seefahrt als Sinnbild des Lebens mitgeschwungen haben, wie es in der barocken Oper gern verwendet worden war, wenn das Schicksal dem Helden nach mancherlei Irrung endlich doch ein gutes Ende beschert. So singt etwa Ariodante in Friedrich Händels gleichnamiger Oper (1734), als er seine Geliebte Ginevra heiraten kann: »Dopo notte, atra e funesta, / Splende in ciel più vago il sole, / E di gioia empie la terra. / Mentre in orrida tempesta / Il mio legno è quasi assorto, / Giunge in porto, / E'l lido efferra.«[v] Da es sich um ein Gleichnis handelt, mußte sich der Komponist allerdings nicht unbedingt um ein spezifisches musikalisches Motiv für das Meer, die stürmende See oder den ruhigen Port kümmern und tat es denn auch nicht. Ganz anders an der Wende zum 20. Jahrhundert, als Claude Debussy in *Pelléas et Mélisande* (1902) einen geheimnisumwobenen Ort tiefer Ruhe mit einem alten, erfrischend kühlenden Brunnen darzustellen hatte, gewissermaßen eine moderne Variante des *locus amoenus*, an dem sich Mélisande und Pélleas an einem heißen Nachmittag begegnen. Da malen aus der Höhe herabrieselnde Pianissimo-Sechzehntel der Violinen das perlend klare Wasser, kontrastierend mit langen, dunklen, vom Klang des Englischhorn getränkten Bläserakkorden, eine aufs Knappste gedrängte Klangvision des Ortes, der das Bühnenbild und gesungene Wort Konkretheit verleihen.

Wie sich für das Wasser als angenehmes Element ein recht fest umschriebenes Repertoire an Motiven herausgebildet hat, auf die die Komponisten bis zum 20. Jahrhundert zurückgriffen, so auch für den Seesturm mit Gewitter und dessen barocke allegorische und mythologische Verwandte wie das Seeungeheuer, das einen solchen Sturm entfacht. Mit deren Zeichnung sind seit Anfang des 18. Jahrhunderts wilde Skalen, Dreiklangsbrechungen, Tremoli, Fortissimo-Schläge des ganzen Orchesters und kurze Läufe in den hohen Flöten als Zeichen der grellen Blitze assoziiert. So, um nur zwei von vielen möglichen Beispielen zu erwähnen, in Philippe Rameaus *Dardanus* (1739), in dem ein Seeungeheuer die Gefangennahme des Göttersohnes Dardanus rächt, indem es die Küste mit einem Sturm verwüstet. Oder in dem gefährlichen Seesturm zu Beginn von Giuseppe Verdis *Otello* (1887), unter dessen Wüten der Kriegsheld Otello im Hafen von Zypern anlangt. Im Unterschied zu seinen Vorgängern hat Verdi aber auch das dröhnende Krachen des Sturms zu erfassen gesucht und dazu Klänge und Töne zu einem schrillen Cluster übereinandergeschichtet, in das die einzelnen Rufe derer am Ufer hineintönen. Als das Musiktheater nach dem Zweiten Weltkrieg stagniert, tritt an dessen Stelle bisweilen ein sogenanntes instrumentales Theater: der Spieler rückt als Akteur in den Vordergrund, während die Musik ins Geräusch erweitert ist. *Water music* (1952) von John Cage ist eines der programmatischen Stücke der Zeit und übersetzt nicht etwa den Klang des Wassers in Musik, sondern benutzt ihn als ›nature concrète‹: Sechs Minuten lang agiert da ein Pianist, spielt einzelne Akkorde und Motivfetzen auf einem Klavier, dessen Klang mit verschiedenen Objekten allmählich immer stärker ins Geräuschhafte verändert ist, stellt ein Radio an, läßt eine Spielente unter Wasser pfeifen, spielt wieder Klavier, läßt die pfeifende Spielente im Wasser versinken, schüttet Wasser von einem Behälter in einen anderen etc. (Bild).



Einen eigenen Typus der Wasserthematik stellt die Barcarole dar, das Arbeitslied der venezianischen Gondelführer. Denn hier steht von vornherein fest, daß die Motivik der Begleitung und der 6/8-Takt das sanfte Wiegen eines Kahns nachzuzeichnen haben, während sich das lyrische Ich mit seinen Worten gewöhnlich an seine Liebste wendet oder sie zu einem geheimen Stelldichein zu locken sucht. Gerade die pittoreske Situation machte die Barcarole zum beliebten Einlagelied in Oper wie Operette – so etwa in der Operette *Eine Nacht in Venedig* (1883) von Johann Strauß,[vi] während selbständige Barcarolenlieder – wie bei Felix Mendelssohn-Bartholdy (op. 57/2) oder auch Richard Strauss (op. 17/6) – eher selten sind.

Lied

Überblickt man das Liedrepertoire, so will es scheinen, als fände sich die Wassermotivik besonders häufig unter den von Schubert vertonten Gedichten, sind es bei ihm doch zum Teil sogar die berühmtesten Lieder, deren Figuren im, am oder um's Wasser situiert sind:

Der Fischer, Johann Wolfgang von Goethes Gedicht, das auch Richard Strauss vertonte, *Fischerweise*, *Die Forelle*, *Der Jüngling am Bach*, *Am See* – diesen Titel teilen zwei verschiedene Kompositionen –, *Am Meer*, *An eine Quelle* oder auch *Lorelei*, zu welchem Motiv der Rhein und die von Loreleis Stimme verführten Schiffer zwingend dazugehören. Die Reihe ließe sich leicht fortsetzen. Unter Robert Schumanns Liedern finden sich zum Beispiel: *Abends am Strand* (op. 45/3), innerhalb der *Dichterliebe* (op. 48) die Vertonung von Heinrich Heines deutschnationalem Gedicht *Im Rhein, im heiligen Strom*; Johannes Brahms setzte *Auf dem See* und *Regenlied* in Musik, beide vereint im Opus 59, weiter *Meerfahrt* (op. 18/4) und *Vom Strande* (op. 69/6), um allein Lieder anzuführen, in denen das Wasser bereits im Titel genannt ist. Hugo Wolf besingt das ferne, meerumspielte Orplid im Gesang Weylas; und in Ernst Kreneks Zyklus *Reisebuch aus den österreichischen Alpen* (1929) sind auch das unbeständige, oft regnerische Wetter, ein Gewitter und ein heißer Tag am See bedacht.

Vorherrschende Bilder in all diesen Liedern sind das Strömen von Fluß und Bach, die grenzenlose, bewegte Fläche von See und Meer; des Lebens Fülle, die sich von dem auf dem Wasser gemächlich auf- und niedersinkenden Kahn in Muße erschauen läßt. Nicht selten verschwimmen dem so der Natur ausgesetzten Ich Nähe und Ferne, Gegenwart, Vergangenheit und Zukunft. Ströme und Bäche können aber auch Boten der Liebe sein, und immer und immer wieder sind sie Sinnbilder des παντα ρει (panta rei), der verfließenden Zeit und der Vergänglichkeit, wie überhaupt die Seefahrt und ihre Fährnisse Abbild des Lebens und seiner Unwägbarkeiten sind – ein Motiv, wie es insbesondere die Maler der deutschen Romantik liebten. Doch nicht alle Wasseransichten sind friedvoll, freudig oder melancholisch nachdenklich. In Schuberts Forelle steht – der Titel sagt es schon – die Forelle im Vordergrund, deren launischen Sprüngen – ein übermütiger Sextolenlauf im Klavier zeichnet sie nach – der Fischer ein Ende bereitet. Und wo das Wasser Wohnsitz der Undinen und Nixen ist, kann das Abenteuer Wasser für den Menschen gar tödlich enden: »Das Wasser rauscht', das Wasser schwoll, ein Fischer saß daran [...] aus dem bewegten Wasser rauscht ein feuchtes Weib hervor«, dichtete Goethe, und die Faszination für diese Erscheinung zieht den Fischer schließlich in den Tod. Schuberts Klavierpart vollzieht den Gang der Erzählung mit, so kurzatmig, heiter und ahnungslos dem Tod entgegen laufend, wie das distanziert beobachtende Gedicht das Ereignis mitteilt. Ähnlich im ersten Lied von Schuberts *Schwanengesang*, in dem die hell herausragenden Spitzentöne der Klavierbegleitung das Plätschern des Bächleins darzustellen scheinen, wie es als Bote »munter und schnell« zur Geliebten forteilt.

Gerade Schubert liebt es, wenn er denn das Motiv Wasser in Musik übersetzen will, das immerwährend Gleiche, die gleichsam stehende Bewegung der Wellen mit einer gleichmäßig dahinrollenden Bewegung zu malen und wie in einem Klangteppich auszubreiten. Immer neue und doch ähnliche Motive hat er dazu erfunden und diese nicht selten auch in seine Instrumentalmusik übernommen (ohne daß sie dort allerdings mit Wasser zu assoziieren wären). Dann wieder gibt es wie in der Oper wellenförmige

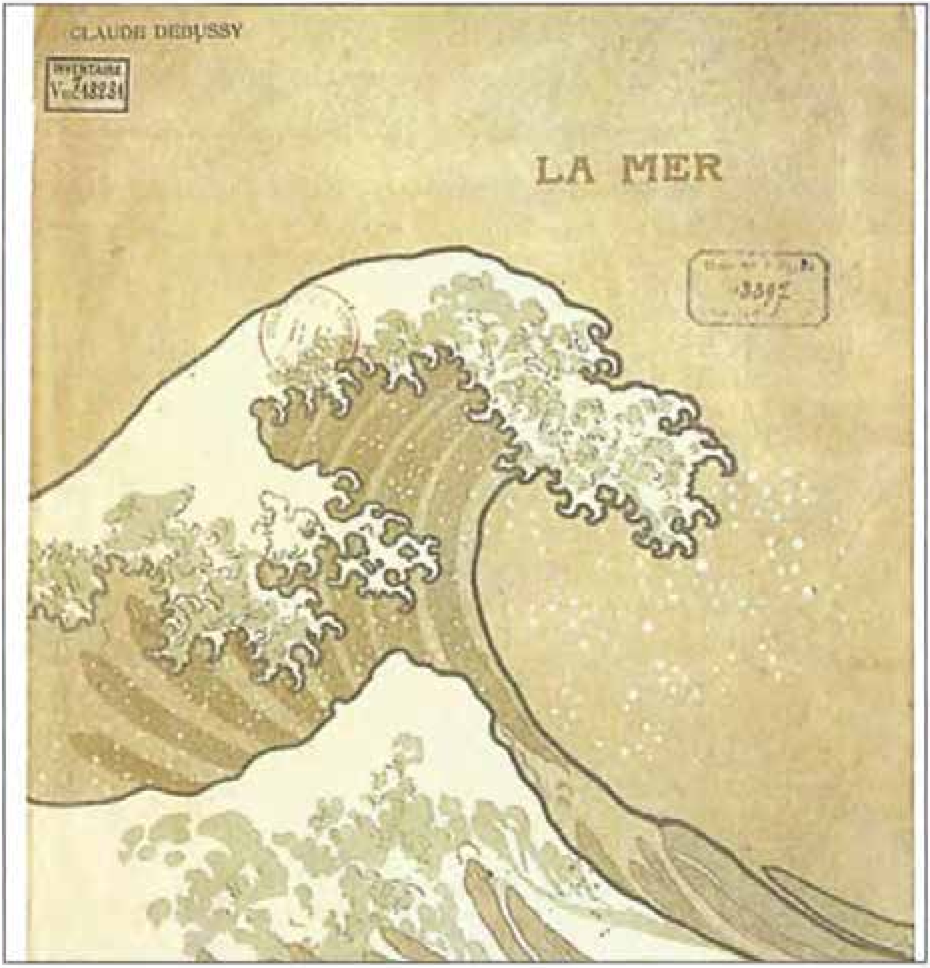
Motive, meist in leiser Dynamik, die optisch im Notenbild und akustisch wie Wellen auf- und niedersinken – so geradezu emblematisch formuliert in Schuberts berühmtem, an die Barcarole anspielenden Lied *Auf dem Wasser zu singen*. Vermutlich aus genau diesem Grund ließ sich Franz Liszt von ihm zu einer Transkription für Klavier solo (1838) inspirieren, deren Virtuosität aufgeht im Dienst für die Liedmelodie. Von Strophe zu Strophe steigt sie höher auf und vollzieht so das Entschwinden der Zeit und des Ichs in der Zeit als ein Entschwinden in immer höhere Höhen nach. Andere Komponisten haben das Wasser im Grundsatz kaum anders dargestellt, wohl aber im Detail Veränderungen eingeführt. So sind bei Brahms gegenüber Schubert die weitausholenden Gesten neu, die das Stürmen des Herzens – in *Auf dem See* (op. 59, 2) – widerspiegeln oder den Wellenschlag – in *Vom Strande* (op. 70, 2) – einfangen.

Unter den zu Lebzeiten Schuberts erschienenen Opera findet sich auch eines der ganz wenigen, in dem drei Lieder unter der Thematik Wasser zu einem kleinen Zyklus geeint sind. Das 1817 erschienene Opus 21 zeigt das Wasser in drei verschiedenen Ansichten: Im ersten Lied, *Auf der Donau*, rollen, so ist der Klavierpart zu verstehen, mächtig schwere Wellen dahin, sich verdüsternd und in bedrohliche Tiefen gleitend, – und verweisen den Menschen in seinem kleinen Kahn auf Vergänglichkeit und Untergang. Die heitere Quirligkeit der Musik des zweiten Liedes, *Der Schiffer*, soll zum einem wohl die Wellen des Flusses porträtieren – eine ununterbrochene Sechzehntelfolge im Klavier sorgt für ein wassertypisches stetes Vorwärtsfließen –, mindestens ebenso aber des Schiffers »himmlische Lust«, wenn er und sein Kahn, zum Spiel der Wellen geworden, ihnen zu trotzen vermögen. Innerhalb dieser siegesgewissen Haltung gleitet die Klavierbegleitung in jeder Strophe einmal unmerklich und für wenige Takte hinüber in ein Bild von Sturm und gefährlichem Wellenschlag und bereitet vor auf das letzte Lied. Der kleine Zyklus endet nachdenklich, düster, schließt in Moll: *Wie Ulfruh fischt* läßt den Fischer leer ausgehen, wobei im Gegensatz zu den vorangegangenen Gedichten nun das feste Land das unsichere Element ist: Sturm, Hagel und Frost zerstören die schöne Natur, dem Fisch im Wasser aber können sie nichts anhaben. Zwar handelt das Gedicht vom Wasser; doch Schubert hat es nicht zum kompositorischen Thema erhoben. Umgekehrt verfährt Brahms in seiner Vertonung des Gedichtes *Dein blaues Auge* (op. 59, 8): Wie der Text gleich zu Beginn an ein Gewässer denken läßt – »Dein blaues Auge hält so still, ich blicke bis zum Grund« – und das am Schluß mit den Worten »und wie ein See so kühl« bestätigt, so hat Brahms es zum bestimmenden Element des gesamten Liedes gemacht und sowohl mit der eigenständigen auf- und abwogenden Klaviermelodie als auch mit den sie begleitenden Achteln eine typische musikalische Vergegenwärtigung von Wasser gewählt.

Programm-Musik

Wie das Motiv Wasser in der Malerei der Moderne um 1900 bei Camille Pissarro, Alfred Sisley und vor allem Claude Monet immer großformatigere Bilder beanspruchte –

wobei nach zeitgenössischem Verständnis Formatgröße und Bedeutung in Relation zueinander stehen –, so gewann es auch in der instrumentalen Programm-Musik einen prominenten Platz. Doch selbst wenn die Titel in der Musik nicht anders als in Malerei das Wasser in den Vordergrund rücken – *Les Jeux d'eau à la Villa d'Este* von Liszt, *Reflets dans l'eau* (1905) in Debussys *Images* oder dessen drei symphonische Skizzen für Orchester *De l'Aube à midi sur la mer*, *Jeux des vagues* und *Dialogue du vent et de la mer* unter dem Gesamttitel *La Mer* (1905), die Tondichtung *Fontane di Roma* (1916) von Ottorino Respighi –, so steht damit doch keineswegs fest, ob Wasser denn überhaupt konkret gemeint ist. Schon George Sand, Frédéric Chopins Geliebte, berichtet, wie empört dieser war, als sie in seinem sogenannten *Regentropfenprélude* (1839) tatsächliche Regentropfen zu hören glaubte, während er selbst erklärte, daß das Stück zwar voller Regentropfen sei, die auf den Ziegeln der Kartause widerhallten (in der er das Stück komponiert hatte), daß sie sich in seiner Phantasie jedoch in Tränen verwandelt hatten, die vom Himmel herab auf sein Herz fielen. Ebenso lehnte auch Debussy die Idee einer direkten Illustration ab. Was Chopin jedoch als Chiffre für ein Seelisches versteht, das ist dem Impressionisten Debussy eine Parallele zu musikalischen Phänomenen, selbst wenn oder gerade weil er angab, wie sehr ihm die Natur immer wieder zur Inspirationsquelle wurde und ihm neue Horizonte eröffnete: »Je l'aime [die Musik] passionnément, moi, et c'est par amour pour elle que je m'efforce de la dégager de certaines traditions stériles qui l'engoncent. C'est un art libre, jailissant, un art de plein air, un art à la mésure des éléments, du vent, du ciel, de la mer.«[vii] Was das technisch bedeutet, hat Paul Cézanne von seinem Medium der Malerei her 1871 so erklärt: »La nature j'ai voulu la copier, je n'arrivais pas. Mais j'ai été content de moi lorsque j'ai découvert que le soleil, par example, ne se pouvait pas reproduire, mais qu'il fallait le représenter par autre chose … par de la couleur.«[viii] Ebensowenig wie man Cezanne einen Landschaftsmaler nennen kann – weil der gegenständliche Vorwurf für ihn nebensächlich geworden ist –, so sind auch für die Komponisten die Gegenständlichkeit das Wasser, die Meereswogen, die glitzernden Wasserspiele eines Brunnens in ihrer Gegenständlichkeit nicht wirklich von Interesse, sondern Chiffre für jene poetische Idee, die aus dem Zusammenspiel von Musik und programmatischem Titel hervorgeht. Und zugleich Umschreibungen dessen, was der Komponist kompositionstechnisch beabsichtigt: Bewegungen und Rhythmen, die nicht mehr unbedingt in den Grenzen des taktbildenden Metrums gedacht sind; Klangfarben und Harmonien, die mit Pentatonik und Ganztonskalen die tradierte Dur-Moll-Tonalität verlassen; sowie Themen, die nicht Formteile markieren, sondern diese verschleiern. Eben darin lagen Reiz wie Herausforderung gleichermaßen. Bei Liszt mögen die niederfallenden Wasserschleier des d'Este-Brunnens noch sozusagen ›gegenständlich‹ klingen und gemeint sein, so klar und präzis sind Motive und Klangfarben konturiert; Debussy hingegen hat sich die polyphone Farbvielfalt des Orchesters gewählt, hat die Motive im Sinne des Kunstgeschichtlers Heinrich Wölfflin eher flächig angelegt denn skulpturartig herausgestellt und sie aus einer vibrierenden Bewegung auftauchen und



wieder versinken lassen. Der berühmte Farbholzschnitt des Japaners Katsushika Hokusai, den Debussy als Titelbild für den Druck von *La Mer* wählte, paßt allenfalls seiner Thematik, seiner monochromen Farbgebung und seiner Flächigkeit wegen; die Macht der sich überschlagenden, gischtenden Welle – *Die große Woge* ist der Holzschnitt von 1825 denn auch benannt – ist nicht gleichermaßen typisch für Debussys Musik (Bild).

10 Jahre später beschäftigte sich Respighi mit den Brunnen Roms, wobei er dem Hörer seiner *Fontane di Roma* zur Überschrift auch eine Art Programm mitlieferte. Danach stehen neben verschiedenen berühmten Brunnen Roms antike Bukolik und Götterwelt im Vordergrund, hat der Hörer sich vorzustellen, wie Schafherden an diesen

Orten vorüberziehen und Najaden und Tritonen auf ein Signal herbeieilen, – Handlungselemente, wie sie typisch sind für eine italienische Komposition und die zudem markante Zäsuren sowie formgebende Themen zulassen und so dem Stück eine klar profilierte Form verleihen.

Das Problem Trinkwasser – historische Realitäten und deren Reflexe in der Oper

So vielfältig und unterschiedlich Wasser in der Musik seit etwa 1650 repräsentiert ist, nirgends stößt man auf das Alltagsproblem jeden damaligen Großstadtbürgers und jeden Reisenden: das Trinkwasser. Obgleich dem keiner – auch kaum einer der hier genannten Komponisten – entgehen konnte. Im Blick auf das Thema des Kongresses sei hier auch darauf eingegangen, soweit es Komponisten real betraf und soweit es als fehlendes Wasser in einem Werk manifest wird.

Paris etwa zählte um die Mitte des 18. Jahrhunderts 650 000 Einwohner und 20 000 Wasserträger, eine Erscheinung, die so prägnant war, daß der »marchand de l'eau« auch von den Pariser Bronziers in ihren Uhrenskulpturen porträtiert wurde (Bild) und in den Lithographien der *Tableaux de Paris* (1821-23) von Jean Henri Marlet nicht fehlt (Bild).

Einmal, in Luigi Cherubinis europaweit gespielter opéra comique *Les deux Journées* (1800), begegnet dieser Beruf auch auf der Opernbühne: Hier verhilft ein Wasserträger in seinem Wasserfaß einem Grafen zur Flucht vor Mazarin. Die Wasserträger verkauften in erster Linie Trinkwasser, wenn sie nicht warmes Wasser für ein Bad in ein Haus lieferten. Doch bestand das übliche Getränk in den Großstädten nicht unbedingt aus purem Wasser, vielmehr war es durchaus Usus, Wein mit Wasser zu mischen oder überhaupt auf Wein oder Bier auszuweichen. Daher konnte man denn auch trunkenen Reisenden begegnen, wie man aus den Briefen Leopold Mozarts erfährt. Auf der dreijährigen Reise, die er zu Bildungszwecken mit seinen Kindern Wolfgang Amadeus und der viereinhalb Jahre älteren Schwester, dem Nannerl, von 1763 bis 1766 unternahm und die vor allem den Zielen Paris und London galt, gehörte das Trinkwasser – neben Pferden und Kutschen, Ausgaben und Einnahmen sowie den Unterkünften – zu den wesentlichen Problemen des Reisealltags.[ix] Am größten erwiesen sie sich zwar in Paris und London, doch setzten sie bereits in der Gegend um Mannheim, Mainz und Frankfurt ein, wo man, so Mozart, »nichts als Schwalbacher und Selzerwasser« trinkt, da »die brunnenwasser meistens schlecht, matt, stinckend, oder trüb sind«. In dieser Gegend begegneten sie daher auch einer Reisegesellschaft, deren Mitglieder von ihren Weinvorräten, die sie statt Wasser mit sich führten, so betrunken waren, daß man sie bei ihrer Ankunft an einer Poststation an der Hand geleiten mußte. In Paris stellte das Trinkwasser ein Problem für jedermann dar, das auch in der berühmten Schilderung des *Tableau de Paris* behandelt wird, dem zwischen 1781 und 1789 erschienenen Stadtporträt von Louis-Sébastien Mercier, das schon 1790 ins Deutsche übersetzt erschien und unter anderem von Friedrich Schiller und Goethe begeistert gelesen wurde.

Hier heißt es, daß das Wasser aus den Brunnen nicht trinkbar und man daher auf das Seinewasser angewiesen sei. Und weiter: »Quand la rivière est trouble, on boit l'eau trouble : on ne sait trop ce qu'in avale; mais on boit toujours. L'eau de la Seine relâche l'estomac, pour quiconque n'y est pas accoutumé. Les étrangers ne manquent presque jamais l'incommodité d'une petite diarrhée : mails ils l'évoteroient, s'ils avoient la précaution de mettre une cuillerée de bon vinaigre blanc dans chaque chopine d'eau.«[x] Mozarts waren offenbar besser unterrichtet: Sie kochten ihr Trinkwasser ab. Drei Wochen nach der Ankunft in Paris schreibt Leopold Mozart, nachdem er über die dortigen Geldsorten berichtet hat, ganz unvermittelt: »Das abscheulichste ist hier das trinckwasser, so aus der Seine |:so abscheulich aussieht |: geholt wird. Es sind einige Wasserträger, die das Privilegium haben, und etwas an den König bezahlen müssen;folglich mus alles Wasser bezahlet werden. Wir haben es im Hause, Es wird auf der gasse ausgeruffen: de l'eau. Wir sieden uns alles Trinckwasser, und lassen es abstehen, dann wird es schöner.« In London angekommen bevorzugen Mozarts Wein, generell aber trinkt man dort statt Wasser Bier: »Die Kinder und die Magd«, so berichtet Leopold, »trinken leichtes Bier, und haben die Freyheit nach belieben zu dem fässe zu gehen den ganzen Tag hindurch; denn hier trinckt niemand Wasser, Herr und Frau trincken Starckbier.

Im übrigen wurde das Trinkwasser als zentrales Problem des Alltags nirgends thematisiert. Mit Ausnahme des erwähnten *Tableau de Paris*. Und mit Ausnahme der Oper *Messidor* (1897). Themen dieser Oper, der der Name des Erntemonats im französischen Revolutionskalender den Titel gab, sind: die Industrialisierung und infolgedessen die Entstehung armer Schichten, die bisher sich selbst zu ernähren vermochten; und im Zusammenhang damit fehlendes Trink- und Bewässerungswasser als Folge einer Flußumleitung. Autoren sind der Librettist Emile Zola, der Urheber des naturalistischen Romans, und der Komponist Alfred Bruneau. Uraufgeführt wurde das Ende 1893 begonnene Werk im Februar 1897 an der Pariser Opéra. Zwar stellte sich kein bedeutender Erfolg ein, zumal Zola in dieser Zeit gerade in die Dreyfuß-Affäre verstrickt war, immerhin aber gelangte *Messidor* im folgenden Jahr auch in Brüssel zur Aufführung und wurde 1903 in deutscher Übersetzung in München gezeigt.

Die Handlung spielt in der Gegenwart um 1890, in einem Bergdorf der Pyrenäen im Gebiet des Flüßchen Ariège, das seinen Namen vom Lateinischen ›aurigera‹, die Goldführende, erhielt. Zu Beginn von Akt I trifft bei der alten Véronique und ihrem Sohn Guillaume Gaspard mit seiner Tochter Hélène ein und bittet um Wasser. Die Sommerhitze hat die Ernte auf den Feldern verdorren lassen, der Fluß ist trocken, die Bevölkerung hungert: Weil Gaspard sich des Wassers bemächtigt, ein Bergwerk zur

Goldgewinnung erbaut und dazu den Fluß umgeleitet hat. So wurde er selbst zwar reich, stürzte die Bevökerung aber ins Elend. Daher verweigert Véronique nun jede Hilfe für die dürstende Hélène. Guillaume jedoch, der sie seit Kindertagen liebt, reicht der Erschöpften ein Glas Wasser. Véronique verachtet diese Liebe ihres Sohnes, weil sie glaubt, Gaspard habe ihren Mann wegen eines Goldstücks in den Tod gestürzt, das er gefunden hatte und aus dem sie sich später eine Kette arbeiten ließ. Auch weiß sie von der Legende des Goldes zu erzählen. Danach kommt das Gold aus dem Golddom, der sich an unbekannter Stelle in dem Berg befinde. Dort sitze die Gottesmutter mit dem Christuskind auf dem Schoß, das mit dem Sand spiele und ihn als Gold in das Wasser gleiten lasse. In Akt II trifft Wilhelm allein auf Hélène. Sie gestehen sich ihre Liebe, gestehen sich, daß der eine ohne den anderen nicht würde leben können, müssen aber auch erkennen, daß Hélènes Reichtum zwischen ihnen steht. Akt III beginnt mit einem allegorischen Ballett, in dem der Kampf zwischen menschlicher Liebe und Herrschsucht, die dem Gold dient, dargestellt wird. Das Gold sieht das Elend der Welt, sieht, daß es mit seiner Macht Barmherzigkeit zu üben hat und söhnt sich mit der Liebe aus, freilich nicht ohne am Schluß in einer Apotheose gefeiert zu werden.[31] Im Winter sind Gaspard und Hélène plötzlich der von einem blindwütenden Bauern angeführten Menge ausgesetzt, die Gerechtigkeit und Gleichheit fordert, Gaspard das alleinige Recht auf die Schätze der Erde abspricht und schließlich das Bergwerk zu zerstören ansetzt. In diesem Moment greift die Natur ein, Schneefall tobt, eine Lawine geht nieder, und ein Fels zerstört das Bergwerk mit seiner Flußumleitung und damit den Reichtum seines Besitzers. Akt IV zeigt die Landschaft im Frühling. Die Felder tragen reiche Ernte. Der Bauer Mathias besucht Véronique, gesteht ihr seinen endlosen Haß auf alle, auch, daß er es war, der ihren Mann vor Jahren zu Tode brachte. Nun richtet er sich selbst und stürzt sich einen Felsen hinab. Eine Prozession nähert sich, Gott um Segen für die Felder zu bitten. Aus der Ferne kommen, verarmt und verzweifelt, Gaspard und Hélène herbei und begegnen Guillaume. Als er Hélène jetzt wieder seine Liebe anträgt, ist sie sicher, daß er sie nicht des Geldes wegen liebt. Die Beiden schwören sich ewige Liebe; die Prozession zieht vorüber.

Zu unterscheiden ist in diesem Libretto zwischen den realistischen oder zumindest scheinbar realistischen Elementen und sozialen Aspekten einerseits und den symbolischen anderseits, beide eingebunden in eine aus der ersten Jahrhunderthälfte ererbte Kontrastdramaturgie. Im Zusammenhang mit dem Thema des Kongresses ist nun interessant, mit welchen Argumenten Zola innerhalb der realistisch dargestellten Verhältnisse die Frage ›Recht auf Wasser‹ verhandelt. Als erste resümiert Véronique das Problem: »Te souviens-tu des jours, où nous étions riches? Et tout le village, avec nous, était riche, tandis que maintenant, la misère et la faim sont partout. Des ruisseaux, venus des grands rocs, là-bas, coulaient devant nos portes, roulant de l'or. Chaque famille avait sa part du torrent, dont elle lavait la sable.« Der Bau des Bergwerks, hier stellvertretendes Symbol der Industrialisierung, brachte das jetzt herrschende Elend: »Et il [Gaspard] a tari nos ruisseaux, et il n'y a plus d'or que pour lui.« (Akt I / Szene 2). Seit-her kann die Bevölkerung nicht nur kein Gold mehr waschen; auch das Wasser zum täglichen Leben muß sie sich aus zwei Meilen Entfernung holen (I/3). So fordern die verarmten, hungernden Menschen in der zentralen Auseinandersetzung (III/3): »Nous voulons qu'un seul n'ait pas le droit de prendre aux autres la fortune de la terre, qui est notre mère à tous.« Ein Vorwurf, den Gaspard anfangs noch mit dem Hinweis auf die ungleiche Verteilung von »intelligence« und »activité« unter den Menschen abzuwehren sucht: »Et-il défendu d'avoir plus d'intelligence et d'activité que les autres?« Und weiter: »Mais c'est l'eau qui, d'elle même est venue à moi [...]«. Darauf aber antwortet man ihm: »Vous l'avez retenue, vous nous l'avez volée.«[xii] Hier fällt das entscheidende Wort ›Diebstahl‹. Auch wenn dies nicht in Worten mit der Qualität des Wassers als wichtigstem Lebenselement begründet wird, so machen doch gerade der Handlungsverlauf und – mindestens ebenso eindringlich – das Optische des Bühnenbildes die lebensbedrohliche Situation ohne Wasser an den hungernden und dürstenden Figuren und an den vor Trockenheit starrenden Feldern anschaubar. Damit kontrastiert die Ansicht der prangenden Äcker im letzten Akt – dank der Rückkehr zu den naturgegebenen Verhältnissen, ein Bild, das Zola zu einem Symbol der Fruchtbarkeit überhöht hat.

Für ein derart realistisches Verständnis gibt der Text, wie dargestellt, genügend Anhaltspunkte, auch wenn sich Zola selbst gegen diese Lesart mancher seiner Zeitgenossen ausdrücklich gewehrt und einerseits den lyrischen Charakter, anderseits den sozialen und zugleich philosophischen Gehalt seines Librettos betont hat.[xiii] Auch in seiner Erklärung des Werkes, die er zusammen mit Bruneau am 20. Februar 1897 in der Zeitung *Le Figaro* erscheinen ließ, führt er das Thema Wasser mit keinem Wort an: »Ce que j'ai voulu faire?«, fragt er eingangs und fährt fort: »Donner le poème du travail, la nécessité et la beauté de l'effort, la foi en la vie, la fécondité de la terre, l'espoir aux justes moissons de demain. Imaginer, dans notre pays de France, un village, des montagnes où les habitants ont vécu jusqu'à ce jour de la récolte de cet or ; et, là, faire qu'un d'eux ait capté tout l'or, en détournant les ruisseaux, ce qui a ruiné le village entier ; et dans une catastrophe, anéantir l'or, rendre l'eau à la terre pierreuse et inculte, d'où monte l'auguste moisson du blé, lorsque, de laveurs d'or qu'ils étaient, les hommes sont devenus des laboureurs.«[xiv]

Allerdings kommt dieser Deutung nicht etwa kein besonderer Status zu, weil sie von Zola stammt und durch ihn autorisiert ist. Gerade das Wort eines Künstlers über sein eigenes Werk ist nur eine von vielen Interpretationen. Vielmehr ist dieses selbst nach seinen immanenten Themen und Botschaften zu befragen; und danach ist Wasser – Wassermangel – sehr wohl eines der Themen dieses Librettos. Bedenkt man zusätzlich, daß alle naturalistischen Romane Zolas Tatsächliches und Mythisches verbinden, daß also ein so bildhaft überhöhter Roman wie *Au Bonheur des dames* (1883) auf dem historischen Übergang des mittelalterlichen Paris in das moderne Stadtbild aufgebaut ist, die ungemein konstruierte Geschichte in *L'Argent* (1891) auf den Börsenkrach von 1871 rekurriert, und schließlich, daß Zolas Vater Ingenieur war und den Kanal von Aix en

Provence baute, so dürften auch die dargestellten Verhältnisse in *Messidor* nicht bloße Vorstellung Zolas sein, auch wenn er es selbst so suggeriert, sondern mindestens teilweise auf reale Tatsachen zurückgehen. Konkret erhebt sich so die Frage, ob die Goldgewinnung oder – allgemeiner – das Umleiten eines Flusses tatsächlich bereits am Ende des 19. Jahrhunderts einmal zum Vertrocknen der Felder und damit zu allgemeinem Elend in dem betreffenden Gebiet geführt hat. Auch wenn aus dieser Zeit – bislang – kein derartiges Ereignis bekannt ist, bleibt als Wesentliches Zolas Frage nach dem Recht auf Wasser als Grundelement jeden Lebens.

Befassen sich Komponisten mit Wasser, so ist das Thema: wie das Wasser rauscht und strömt, wie es plätschert und tropft, wie es bei Gewitter und Sturm wütet und tobt, und nicht zuletzt, wie es in seinem scheinbar endlosen Fortströmen zum Sinnbild des Lebens wird. All dies in seiner Vielfalt übersetzt und übertragen in musikalische Motive und Klänge. Und wenn es zum Wesen der Kunst gehört, Fragen an die Wirklichkeit, die sozialen Verhältnisse zu stellen, nicht aber, sie unbedingt auch zu beantworten, so haben das Zola und Bruneau in ihrer Oper *Messidor* getan – noch bevor das Problem des umgeleiteten und also anderen dringend fehlenden Wassers ernsthaft und prominent in die Realität trat. Das zu lösen anderen aufgetragen ist.

Wenn jemand daher an dieser Stelle wie der Romancier Théophile Gautier im Jahre 1835 die provokative Frage stellen sollte: »Zu welchem Zweck die Musik? Zu welchem Zweck die Malerei?«, dann läßt sich dem mit Gautier entgegnen: »Il n'y a de vraiment beau que ce qui ne peut servir à rien ; tout ce qui est utile est laid ; car c'est l'expression de quelque besoin ; et ceux de l'homme sont ignobles et dégoûtans, comme sa pauvre et infirme nature.« und die Antwort mit seinen Worten prägnant so abschließen: »L'endroit le plus utile d'une maison, ce sont les latrines.«[xv]

Abstract: Composers of all musical genres invented motives, found harmonies and rhythms that illustrate and paint water, that sound like falling water drops, that give the impression of the gentle murmuring of a sprightly brook, that let arise the image of a majestic river or give the horror driven picture of a terrible storm at sea. In its first part the essay follows up these pictures and their musical representations along the different genres; in the second part the accent lies on the opera *Messidor* (1897) by Emile Zola (libretto) and Alfred Bruneau (music). Here the inventor of the naturalistic novel poses for the first and single time in the history of musical theatre the case of ›theft of water‹ as well as rises the fundamental question of the ›right to water‹ – long before it gained its urgent presence in national and international policies.

i Zu den zeitgenössischen Berichten über das Ereignis Howard Serwer, The World of the Water music, in: Händel-Jahrbuch 1996/97, S. 101-111.

ii Zu diesen Feierlichkeiten in jüngster Zeit Jürgen Schläder, Das Fest als theatrale Fiktion von

Wirklichkeit. Über die Bühnenästhetik der Münchner Applausus festivi von 1662, in: Basler Jahrbuch für historische Musikpraxis (23) 1999, S. 41-57.

iii *S. dazu Gerhard Schober, Prunkschiffe auf dem Starnberger See, München 1982.*

iv *Vgl. dazu Carl Dahlhaus, Thesen über Programmusik (zuerst 1975, wieder) in: Ders., Klassische und romantische Musikästhetik, Laaber 1988, S. 365-385.*

v *»Nach schwarzer und düsterer Nacht / scheint die Sonne strahlender am Himmel / und erfüllt die Erde mit Freude. / Während in dem fürchterlichen Sturm / mein Schiff fast unterging, / ist es nun in den Hafen eingelaufen und hat das Ufer erreicht.« Die Übersetzung von Klaus Scharff im Beiheft der Archiv-Aufnahme der Oper unter der Leitung von Marc Minkowski, Deutsche Grammophon 1997, S. 134/136.*

vi *Über 50 Opern-Barkarolen wurden untersucht von Herbert Schneider, Die Barkarole und Venedig, in: L'opera tra Venezia e Parigi, hrsg. von Maria Teresa Muraro, Florenz 1988, S. 11-56.*

vii *Claude Debussy, Monsieur Croche et autres écrits, hrsg. von François Lesure, Paris 1971, S. 296. »Ich liebe die Musik leidenschaftlich, und gerade weil ich sie liebe, bemühe ich mich, sie aus gewissen unfruchtbaren Traditionen zu befreien, die sie einschnüren. Musik ist eine freie Kunst, frei hervorsprudelnd, eine ‚Pleinair'-Kunst, eine Kunst nach dem Maß der Elemente, des Windes, des Himmels, des Meers.« Die deutsche Übersetzung nach Wolfgang Dömling, Debussy. La Mer, München 1976, S. 26.*

viii *Nach Maurice Denis, Cézanne, in: Ders., Theories 1890-1910. Du Symbolisme de Gaugin vers un nouvel ordre classique, Paris 1907. »Ich habe die Natur kopieren wollen, es gelang mir nicht, von welcher Seite ich sie auch nahm. Aber ich war mit mir zufrieden, als ich entdeckt hatte, daß man sie durch etwas anderes repräsentieren muß, durch Farbe als solche. Man muß die Natur nicht reproduzieren, sondern repräsentieren.« Die deutsche Übersetzung nach: Walter Hess, Dokumente zum Verständnis der modernen Malerei, bearbeitet von Dieter Rahn, Reinbek bei Hamburg 1988, S. 21f.*

ix *Das Folgende nach Josef Mançal, der auf die vier genannten Problembereiche eingeht: Josef Mançal, Leopold Mozart und seine Familie auf Europareise, Augsburg 2006, S. 85-87. Zitiert wird aus: Mozart, Briefe und Aufzeichnungen, hrsg. von Wilhelm A. Bauer und Otto Erich Deutsch, Kassel / Basel / London / New York, Band 1, 1962, Brief vom 20. August, 8. Dezember 1763 und 13. September 1764.*

x *Louis-Sébastien Mercier, Tableau de Paris, Band 1, Amsterdam 1782 (reprint Genève 1979), S. 154f. »Ist der Fluß trübe, trinkt man trübes Wasser. Man weiß nicht genau, was man da schluckt, aber man trinkt immerhin: demjenigen, der es nicht gewöhnt ist, entkräftet das Seine-Wasser den Magen. Den Fremden bleibt fast nie die Unpäßlichkeit einer leichten Diarrhöe erspart; sie könnten sie aber vermeiden, wenn sie als Vorsichtsmaßnahme einen Eßlöffel guten weißen Essigs jedem Schoppen Wasser beimengten.« Die deutsche Übersetzung übernommen von: Louis-Sébastien Mercier, Tableau de Paris. Bilder aus dem vorrevolutionären Paris, Auswahl und Übersetzung aus dem Französischen von Wolfgang Tschöke, Zürich 1990, S. 173.*

xi *Das Ballett wurde schon in der Uraufführung an den Beginn der Oper versetzt. Darauf verweist Zola selbst in seiner Erklärung des Werks, die am 20. Februar 1897 in der Zeitung Le Figaro erschien.*

xii *In dem deutschen Libretto, das im Verlag Albert Ahn, Berlin, Köln, Leipzig, um 1900 erschien, lauten die zitierten Passagen so: Veronika: »Denkst du der frohen Zeit, wo wir glücklich waren und mit uns das ganze Dorf reich und zufrieden? Doch jetzt, jetzt ist das Elend, der Hunger bei uns eingekehrt. Große Bäche stürzten einst vom Fels herab, flossen vor unseren Thüren und brachten Gold. Jeder behielt den Ertrag, den er mit seiner Hände Arbeit gewonnen. [...] Unsere Bäche versiegten, und für ihn [Gaspard] allein fließt das Gold.« (I/2) – Wilhelm: Wir wollen, dass einer nicht allein das Recht hat, die Schätze der Erde zu heben, sie ist unser aller Mutter.*

Gaspard: So, lieber Freund, ist es denn verboten, mehr Umsichtigkeit und Fleiß als andere zu haben? [...] das Wasser, wißt ihr doch, kam von selbst zu mir.« Wilhelm: »Ihr habt es abgeschnitten, Ihr habt es uns gestohlen.« (III/3)

xiii *In seiner Entgegnung an den Musikkritiker Louis de Fourcaud, der ihn am 20. Februar 1897 in der Zeitung Le Gaulois unter anderem wegen des Realismus und der Modernität des Librettos, die zur Musik nicht paßten, angegriffen hatte. Zolas Antwort in derselben Zeitung am 23. Februar 1897, wieder in: Emile Zola, Correspondance, hrsg. von Bard H. Bakker, Band 8, Montréal 1991, S. 390f.*

xiv *»Was ich machen wollte? Ein Werk der Arbeit geben, die Notwendigkeit und Schönheit der Anstrengung darstellen, den Glauben an das Leben, die Fruchtbarkeit der Erde, die Hoffnung auf die gerechte Ernte von morgen. Sich ein Bergdorf in unserem Land Frankreich vorstellen, wo die Bewohner bis zu diesem Tag von der Goldwäsche gelebt haben; und dort einen von ihnen alles Gold gewinnen lassen, indem er die Bäche umleitet, was das ganze Dorf ruiniert; und in einer Katastrophe das Gold vernichten, das Wasser an die steinige und unbestellte Erde zurückgeben, woraus die glückliche Getreideernte hervorgeht, wenn die Menschen, die Goldwäscher waren, Arbeiter geworden sind.«*

xv *Théophile Gautier, La Préface de Mademoiselle de Maupin, hrsg. von Georges Matoré, Paris 1946, S. 31f. »Es gibt nichts wahrhaft Schönes außer dem, was keinen Zweck erfüllt. Alles Nützliche ist häßlich. Denn dies ist der Ausdruck eines Mangels. Und die Leute [zu ergänzen: die so fragen] sind gemein und widerlich, wie die armselige und schwache Natur des Menschen. – Der nützlichste Ort eines Hauses, das sind die Toiletten.«*

Priv.-Doz. Dr. Manuela Jahrmärker

Session IV – Central to Decentral
Introduction

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Semi-Centralized Supply and Treatment Systems for Urban Areas

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Abstract: Mega cities with rapid growth are challenged by two main problems concerning water supply and sanitation. One is water scarcity, because local demand always exceeds local supply. The other is that the infrastructure for water supply likewise the collection and treatment of wastewater can not keep up with the rapid growth of the mega cities. The transfer of conventional centralized water and wastewater systems from industrialized countries to mega cities seems not appropriate, because of the rapid and almost unpredictable growth of mega cities on the one hand and the regional shortage of water which requires an economical use and reuse wherever possible on the other hand. The transition from centralized to Semi-centralized Supply and Treatment Systems may be one method of resolution to the grave discrepancy between the rapid city growth and the provision of supply and treatment infrastructure. Semi-centralized Supply and Treatment Systems can be realized with different treatment technologies. An example of combined waste and sewage sludge treatment in combination with separate greywater treatment and reuse is given. Options for greywater treatment are presented and first preliminary results are introduced. One important aspect of planning semi-centralized wastewater and waste collection and treatment infrastructure including intra-urban water reuse is the assessment of the optimal size (inhabitants, catchment area etc.). Therefore, factors and indicators are mentioned, which have an effect on the scale of semi-centralized sanitation systems. They have to be further developed.

Keywords: Semi-centralized supply and treatment system, Intra-Urban Water Reuse, Mega Cities, Greywater treatment.

Introduction

The rapid city growth has a tremendous effect on the infrastructure for supply, disposal, and treatment of water, wastewater, and waste. Looking at today's wastewater situation, e.g. in China, the increase of problems related to insufficient supply, disposal, and treatment in the next couple of years can be predicted [Wilderer et al., 2003].

In order to find a solution for these needs, two main objectives have to be pursued. On the one hand the environment has to be protected from pollution; on the other hand the resources have to be managed in a sustainable manner. To achieve these objectives, the manifold intra-urban reuse of water - where applicable - is indispensable.

The transfer of conventional centralized supply and treatment systems from industrialized countries to mega cities in newly industrialized and developing countries seems not appropriate, as intra-urban water reuse fosters decentralized systems, which avoid the manifold transport of (different) wastewater out of the city borders to the centralized wastewater treatment plant and the transport of miscellaneous service waters from the far away treatment plants to the consumers. Household-based self-sustaining systems (de-centralized systems), such as rainwater collection, urine-separation or compost toilets, have already been proposed as possible solutions. These systems give valuable information, however, in urban areas with high population densities aspects such as (monitoring) quality standards and surveillance, hygiene, maintenance and performance doubt a wide spread use as stand-alone solutions. To overcome the shortcomings of centralized on the one side and household-based de-centralized systems on the other side semi-centralized, town-district based supply and disposal facilities are proposed.

Semi-centralized supply and treatment systems

Figure 1 shows central and semi-centralized supply and treatment systems in comparison. These systems, referred to as "Semi-centralized Supply and Treatment Systems", are combined treatment facilities for water, wastewater, and (organic) waste, which provide service water for household use and intra-urban irrigation for an entire district within a city. The combined treatment offers new technical possibilities such as mass and energy flows within the facilities, e.g. the co-treatment of organic waste and wastewater and the direct use of biogas. These techniques lead to an increase in system efficiency and a decrease in the amount of residues to be disposed. Another characteristic is the proximity between consumers and treatment facilities, which allows short sewer and pipe systems, resulting in an economic reuse of water. Treated wastewater can be used for intra-urban irrigation or toilet flushing without any need of long distance transport to and from outside the city borders. Close-by waste treatment facilities minimize the traffic and optimize the recycling of resources. Furthermore, supply and disposal are carried out by qualified personnel, thus assuring maximum reliability in achieving high quality standards, hygiene in water distribution and water reuse, and control of material flows and disposal. In addition to these advantages, planning and design are much more reliable as it comprises smaller and manageable frames in time and space.

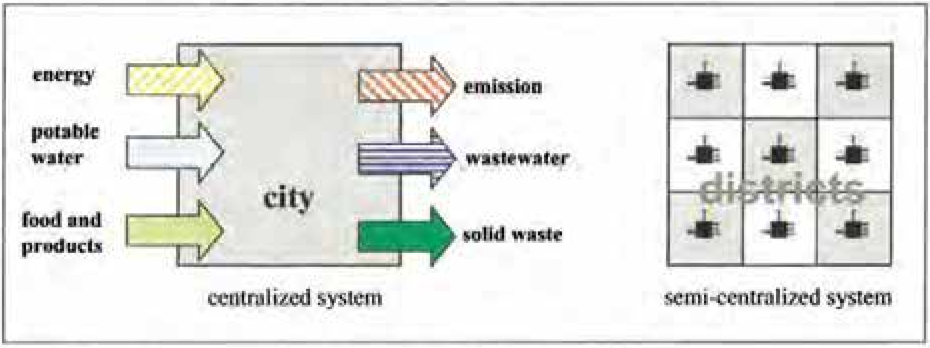

Figure 1: Centralized and semi-centralized system in comparison

In comparison with centralized and decentralized units, the following advantages can be addressed:

Compared with conventional centralized systems:

- sustainable reuse of water, dual piping feasible
- splitting of industrial and municipal wastewater possible
- higher flexibility (planning, technical adaptation on specific conditions)
- better over all economy (water treatment and supply, sewer system, wastewater treatment plants, waste disposal)
- incremental growth (modularization)
- individual awareness

Compared with decentralized systems:

- professional operation and maintenance
- monitoring of and compliance with quality standards
- use of advanced and energy-efficient technologies
- holistic approach for water, wastewater and waste
- best over all economy

Semi-centralized Supply and Treatment Systems can be realized with different technologies. The use of reclaimed greywater as process water is one possibility. Figure 2 shows the results of a survey on the water consumption of private households in the city of Qingdao (Shandong province, P.R. China) [Bi, 2004]. Greywater from shower/bathing and washing machines sums up to 41 L/(C·d), which is almost 40 % of the total water demand of 109 L/(C·d). 33 L/(C·d) thereof are used for toilet flushing and could be replaced by processwater, e.g. adequately treated greywater.

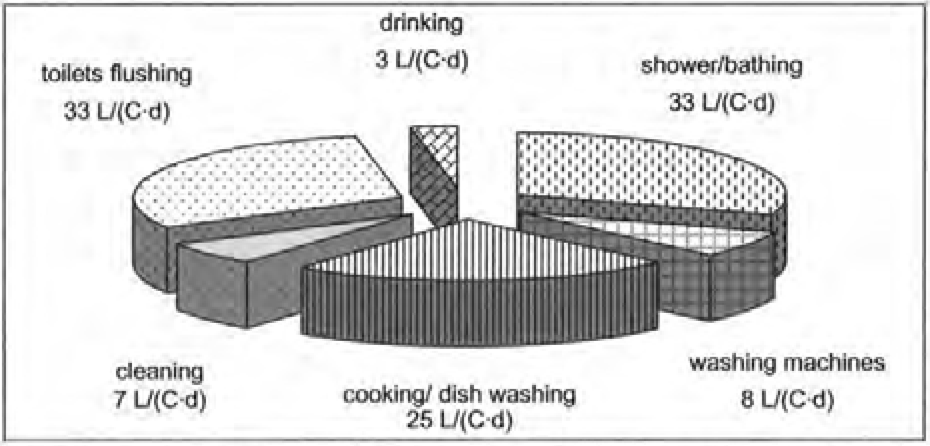

Figure 2: Specific water consumption of private households in he city of Qingdao [Bi, 2004]

Figure 3 demonstrates how water treatment can be combined with mechanical /anaerobic/aerobic treatment of waste and sewage sludge. First of all, about 250 g of paper, plastic material etc. out of 1 kg waste per capita and day, can be separated as so-called refuse derived fuel (RDF). The combined anaerobic/aerobic treatment of the remaining waste and surplus sludge reduces the amount of residual waste to 600 g/(C·d) and generates electrical surplus energy of about 65 Wh/(C·d), which can be used for wastewater treatment.

Such an integrated approach allows an almost energy autarkic operation, as material and energy balances indicate. At least the greywater can be treated without additional electrical energy. Figure 3 shows the material flow in a general overview for the example Qingdao.

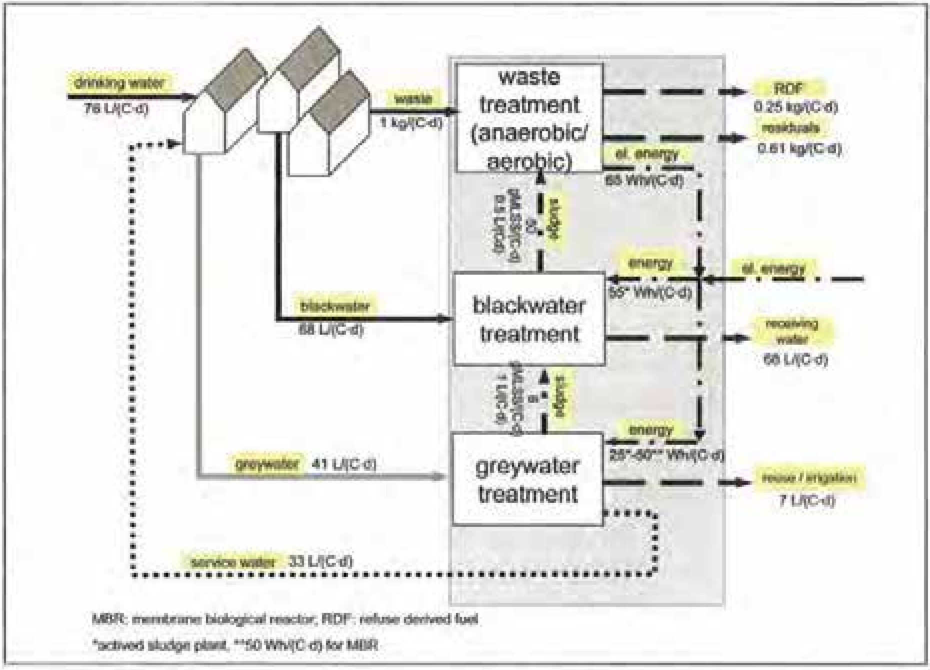

Figure 3: Material and energy flow in a semi-centralized treatment system (example City Qingdao)

For comparison, Figure 4 shows the scheme of conventional treatment. In the given case, fresh water demand is more than 40 % higher (109 instead of 76 L/(C·d)), less waste has to be transported from the settlement and only treated wastewater leaves the treatment plants. Compared to semi centralized treatment, the energy balance is less favourable. Thus, the semi-centralized concept leads to sustainable conservation of resources, smaller sewer systems and shorter sewers, as treated effluent can be discharged to the nearest receiving water body.

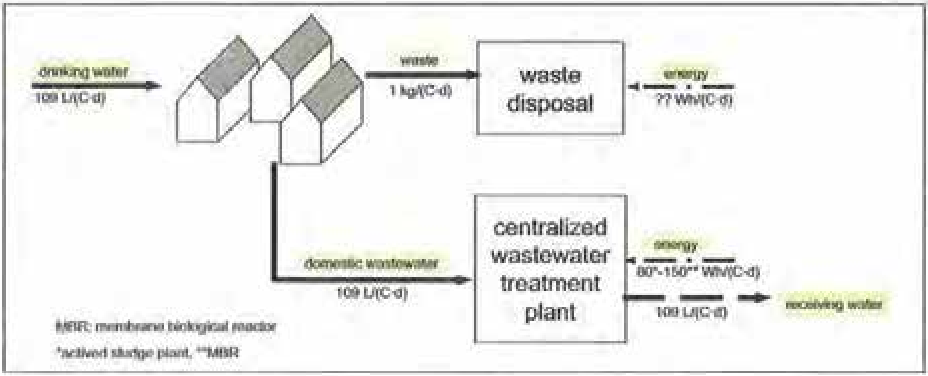

Figure 4: Material and energy flow in a conventional system (example City Qingdao)

Decentralized greywater treatment

Within a research project funded by the German Federal Ministry of Education and Research different reclamation techniques for greywater are developed and compared - in pilot-plant scale - with five different treatment systems. The aim of the treatment is to reach the standards for service water in China [Final report, 2006]. Table 1 shows the Chinese quality standard of service water for intra-urban reuse.

Table 1: Parameters for water quality of service water, [CECS: 61-94] (abstract)

	toilet flushing, street cleaning, fire fighting	irrigation of public greens	car washing	use at construction sites
odour	no displeasing odour			
SS [mg/l]	≤ 15	≤ 30	≤ 15	≤ 15
BOD_5 [mg/l]	≤ 15	—	≤ 15	—
COD_{Cr} [mg/l]	≤ 50	≤ 60	≤ 50	≤ 60
anionic surfactants[mg/l]	≤ 1	≤ 1	≤ 0.5	≤ 1
E. coli [amount/l]	≤ 100		≤ 1,000	

For the experiments, synthetic greywater is used, which consists of commercially available sanitary products, such as washing powder, toothpaste, shower gel, shampoo etc.. The composition of sanitary products is based on the statistical consumption per capita and day in the Federal Republic of Germany. Additionally, about 3 to 5 % of raw wastewater from a municipal treatment plant is added to the synthetic greywater to simulate particulate and microbial matter. This synthetic greywater has a concentration of COD of about 300 to 400 mg/L, anionic surfactants of about 60 to 80 mg/L and suspended solids of about 100 to 150 mg/L, which is similar to real greywater from household bathing/showers and washing machines.

The pilot plant consists of a unit for the preparation of synthetic greywater, a pre-treatment unit with flocculation and micro-sieve (10 and 50 µm), two storage tanks for the five treatment units after pre-treatment, one CONTIFLOW® biological sand filter (Hans Huber AG), two membrane biological reactors (ITT Flygt Pumpen GmbH, Hans Huber AG), one rotating ceramic membrane filtration unit, and one sequencing batch reactor (ITT Flygt Pumpen GmbH). The effluents of the biological sand filter, one of the two MBRs and the SBR are disinfected by UV. Nutrient elimination is not focused on because of the low nutrient concentrations. The total influent of the pilot plant is 3 m³/h. Figure 5 gives an overview of the investigated techniques.

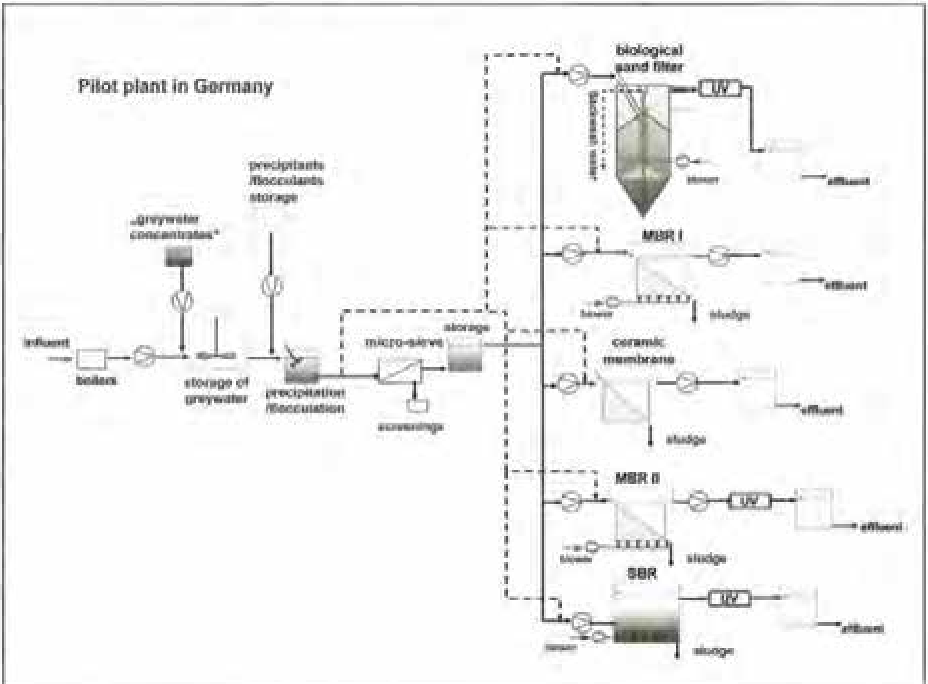

Figure 5: Scheme of the pilot plant

Summarized first results of the pilot plants

- Design and operation have to take in account that untreated greywater has a tendency to foam.
- C:N:P ratio in the synthetic greywater is about 100:1:0.1. Thus, the nutrient content is very low compared to municipal wastewater (100:10:1 or 100:5:1).
- Flocculation/precipitation combined with micro sieving (50 µm) can reduce COD about 30 %, anionic surfactants about 35 %, and suspended solids about 35%. Beside the large amounts of sludge, the high backwash water demand is a severe drawback.
- Micro sieving (10 µm) without flocculation/precipitation might reduce COD by 20 – 30% and anionic surfactants by about 10%. Anyhow, about 15% of the filtrate water is needed as backwash water.
- With a Membrane Bioreactor (MBR) the quality requirements of service water in China can be reached. Energy demand and fouling/scaling have to be optimized. Lack of nutrients seems to cause disintegration of flocs resulting in higher fouling potential. The impact of the nutrient content on fouling/scaling of membranes needs to be further investigated.
- First results of sequencing batch reactors (SBR) indicate that the COD requirements can be reached, however, to fall below the required values for anionic surfactants and suspended solids might be challenging. Nutrient supply might be critical, phosphorus in particular. Too low P concentrations jeopardize floc formation and SVI.
- Enhanced mechanical treatment with a rotating ceramic membrane alone resulted in a rapid flux decrease of about 75% within 24 hours from 61 $L/(m^2 \cdot h)$ down to 16 $L/(m^2 \cdot h)$.

Parameters to be considered for evaluating the scale of semicentralized sanitation systems

What is the optimal scale of semi-centralized systems? Beside the local boundary conditions and the chosen technologies, many other factors, criteria, and indicators affect the scale of decentralization.

The ideal scale of a system is not defined by the amount of serviced households (supply and disposal) alone. The optimal system in design and scale takes into consideration various factors, criteria, and indicators, such as population density, acceptance of the users, sustainability, water reuse, investment expenses, operating cost and maintenance (see Figure 6). For example, the specific energy demand might be higher in small treatment plants compared to large plants, however, the acceptance of using appropriately treated wastewater as service water within the households increases the smaller the catchment area, the area of origin of the wastewater, is. For the assessment of the ideal scale of a system, all these factors have to be weighted according to the given goals, such as sustainability, low cost, operating safety, and social equity. By these means, one may be able to determine the best-adapted sanitation system with an optimal scale of the system for the given respective local conditions [Cornel et al., 2004, Cornel et al., 2005].

Figure 6: Factors for the scale of semi-centralized sanitation systems

Some important factors, criteria, and indicators and their effects on the scale of sanitation systems and the scale of the catchment areas, respectively, are discussed hereafter.

Summary and conclusion

The rapid city growth, e.g. in China, is a challenge for future infrastructure systems. The planning of semi-centralized supply and treatment systems, which realize water reuse, may be one method of resolution to the grave discrepancy between the rapid city growth and the water scarcity on the one side and the provision of supply and treatment infrastructure on the other. In comparison with central units, it can be expected that semi-centralized supply and treatment systems can be built faster. At the same time they will be more flexible, and can be planned and adapted better to the given conditions. A sustainable reuse of water can easily be realized, dual piping is feasible, and a splitting of industrial and municipal wastewater is possible. In comparison with decentralized systems, semi-centralized systems have professional operation and maintenance, monitoring and compliance with quality standards are guaranteed, and advanced and energy efficient technologies can be used.

Material and energy balances show that about one third of the freshwater can be replaced by service water. The gain of electrical energy from anaerobic waste treatment, for example, could be almost sufficient for wastewater treatment, at least for service water production and distribution. Semi-centralized supply and treatment systems are not inevitably linked to one special treatment technique. First results of comparative studies of different treatment techniques make us expect that biological treatment will meet the service water standards, whereas mechanical treatment alone – consisting of a fine sieve followed by ceramic UF unit seems not to be reaching the treatment goal.

In order to assess the optimal scale of a sanitation system, various criteria have to be taken into account. The most important aspect of the evaluation, by which the specific optimal scale can be determined, lies in the emphasis of each factor. If the main weight is placed on environmental concerns, which imply water reuse, then the weight of the other factors will be lower than if the main concerns are economical aspects.

Ackowledgements

This ongoing research project – Semi-centralized Supply and Disposal System for Urban Areas in China (project part I: 02WD0398, project part II: 02WD0607) – is supported by the German Federal Ministry of Education and Research.

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Source Control – An Efficient Alternative to End-of-Pipe Treatment

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Abstract: This report compares the efficacy of conventional end-of-pipe technology in water pollution control with source control as it developed over many decades. For most of the relevant pollutant categories source control has contributed more to water pollution control than end-of-pipe technology. Case histories for non biodegradable detergents, refractory organic compounds, heavy metals, phosphate in laundry detergents, water savings in households and household appliances, garbage grinders, etc. demonstrate that careful planning of source control provides efficient alternatives to extended end-of-pipe technology

Keywords: source control, hard detergents, heavy metals, phosphate ban, garbage grinders, urine separation, water saving, infiltration.

Introduction

Mackenbach (2007) argues that sanitation has been the greatest medical advance since 1840 and 15.8% of 11'300 readers of the British Medical Journal (BMJ) followed his arguments and preferred his suggestion over 15 others (antibiotics 15%, anaesthesia 14%, vaccines 12%, see Ferriman 2007). Flushed sewers and piped water started their globally successful career in London roughly 175 years ago. Central wastewater treatment to protect our water resources was the required consequence of this development and today a similar poll among environmental professionals would possibly yield the answer that wastewater treatment is the single most effective development in water pollution control. In this contribution I like to challenge this assumption.

The basic hypothesis of this report is: *As compared to central end-of-pipe wastewater treatment for water pollution control, source control has in the past been (i) more efficient and (ii) the rule rather than the exception.*

For solid waste handling source separation has become the rule in recent decades (Figure 1) and is generally accepted as an efficient contribution towards a more sustainable economy. In my household I am expected to separate more than 15 waste streams (Figure 2) and separate storage of some of them becomes a problem. Contrary to solid waste, wastewater seems to contain whatever we want to get rid of in liquid form exactly at the time we want to discharge it. Is this a correct analysis of the situation?

In the 19th century, when population density in the cities rapidly increased and deadly epidemics caused by polluted drinking water endangered urban life (Figure 3) it must have been a big relief, to be connected to well treated drinking water and flushed sewers (Figure 4). Under these circumstances it was nothing but understandable that sewers were used to flush whatever made life miserable. But is this notion still valid today?

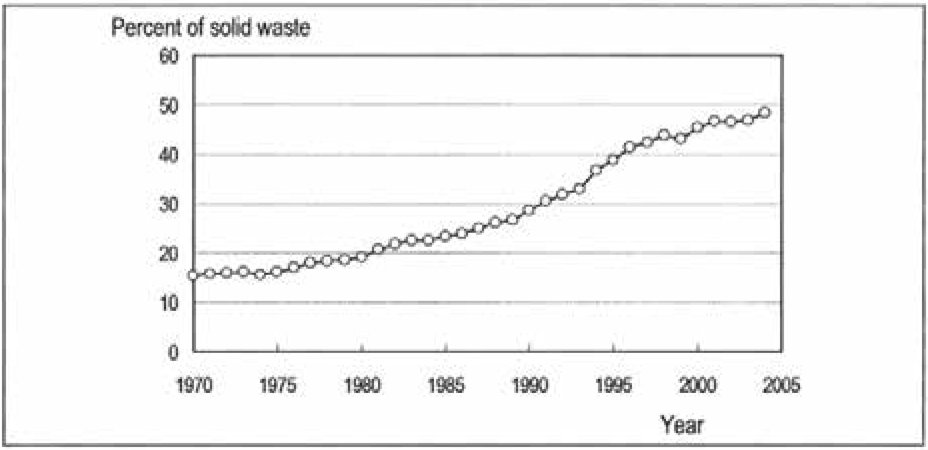

Figure 1: Separately collected solid waste in Switzerland (Data Swiss Federal Environmental Protection Agency, BAfU)

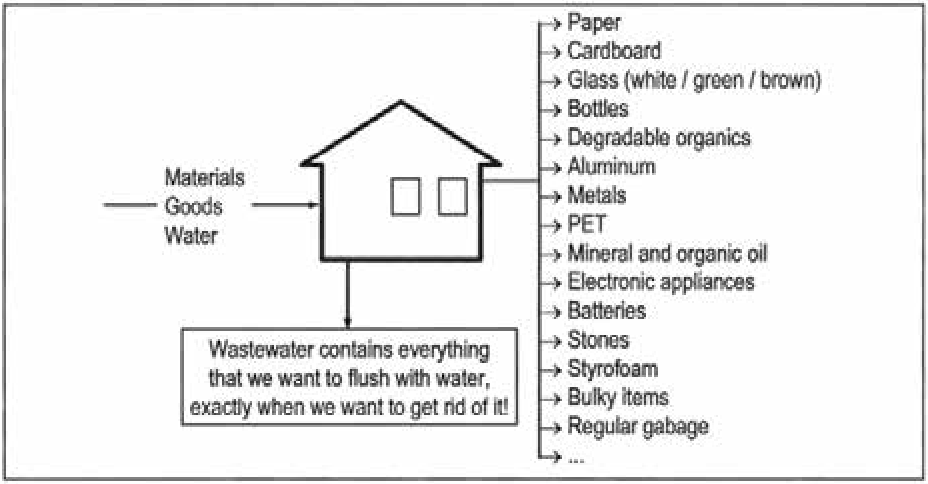

Figure 2: Solid waste is separated into many different streams whereas wastewater is produced and discharged whenever it is convenient

Source control

Definition of source control

In this report *Source Control* includes all activities which affect the amount and the composition of the domestic wastewater in a desirable way. It leads towards a wastewater which is easier to treat and supports fulfilling discharge requirements by wastewater treatment plants. The term *waste design* relates to the formulation of specifications for the composition and time of discharge of the wastewater in view of treatment possibilities.

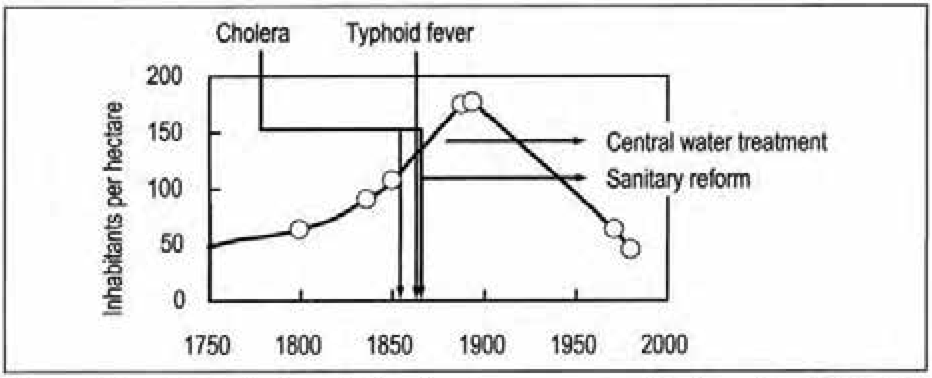

Figure 3: Development of population density, appearance of water related epidemics and begin of sanitary reform and central drinking water treatment in the city of Zurich

Figure 4: Drainage of wastewater along the river Birsig in Basel, Switzerland (Photo taken in 1880)

Why is source control desirable?

Flushed sewers caused massive pollution in receiving waters and made water pollution control a necessity; for decades this meant wastewater treatment. A never ending story was started on a grand scale:

- Sedimentation was introduced and later became primary treatment
- Biological treatment soon was named secondary treatment
- Chemical phosphorus precipitation was termed tertiary treatment
- Only politicians proudly announced sand-filtration as quartenary treatment, professionals stopped to count.

In the mean time we have added:

- nitrification
- denitrification
- biological phosphorus removal
- disinfection

and we are discussing:

- removal of micropollutants
- how to efficiently deal with virus
- how to make sure that microbial resistance to antibiotics does not enter natural cycles
- nano-particles may become a major threat
- and so on, and so on …

This endless story cannot really be fully effective. Our sanitary systems are full of holes rather like a Swiss cheese than an engineered technical system (Figure 5):

- Households are largely uncontrolled in the amount and properties of waste they discharge through the sewers
- poorly maintained sewers are known to leak to the underground
- combined sewers regularly must overflow during rain and storm events
- some inhabitants are not connected to sewers at all but release wastewater into the
- environment
- wastewater treatment plants are never 100% effective
- sludge loaded with pollution may end up on agricultural soil.

As a summary: End-of-pipe treatment is a bold venture which cannot really be entirely successful. Source control tries to reduce pollution at the source and thereby does not suffer from leaks in the system. But this route too, will never end and requires significant effort.

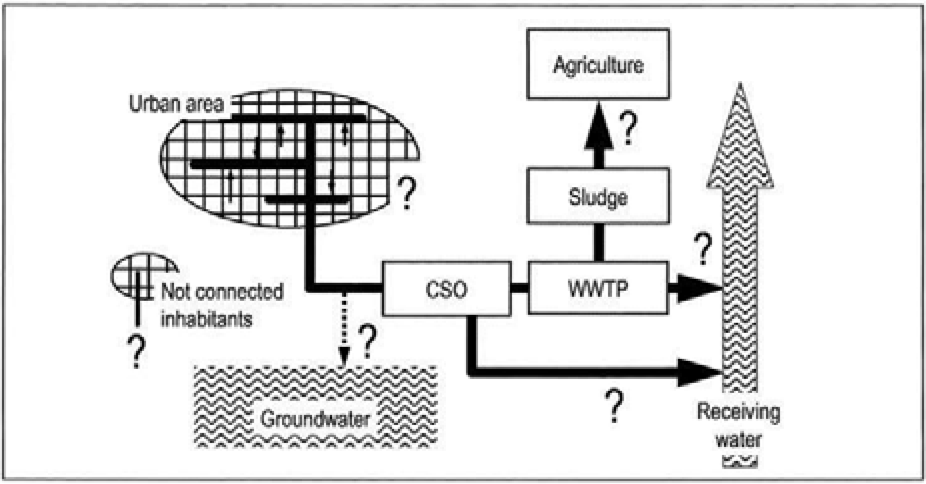

Figure 5: Urban drainage systems have many leaks: House connections, leaky sewers, CSO, only partially effective treatment plants, pollutants in agriculturally used sludge, unconnected inhabitants, ...

Effective cases of source control

The following cases will demonstrate that source control has been and may be an effective and efficient contribution to water pollution control.

The case of branched alkylbenzene sulfonates (BABS)

With the introduction of automatic washing machines for cloths after world war two new detergents came into use. The first generation of these detergents consisted of branched allkylbenzene sulfonates (BABS) which turned out to be non biodegradable in biological wastewater treatment plants. In the raw wastewater these detergents were adsorbed to the pollutants and hardly caused any harm. But after the degradation of the pollutants the detergents became active again and caused excessive foaming in aeration tanks (Figure 6, left) and leaked out into the receiving waters (Figure 6, right). In 1964 BABS had to be replaced by the biodegradable, linear alkylbenzene sulfonates (LAS). This helped to alleviate and latter solve the problem. This procedure changed the properties of several grams of pollutants per capita per day, they became biodegradable (at least their surface activity was rapidly lost by aerobic microbial activity) and could then be handled by aerobic biological treatment; a case of waste design.

Figure 6: Excessive foaming in an aeration tank (left) and in receiving waters (right) due to nonbiodegradeable detergents (branched alkylbenzene sulfonates). Pictures taken around 1964 before the introduction of LAS (archive Eawag)

The case of BABS was later repeated, when nonylphenol, a metabolite of nonylphenol-polyethoxylates (NPnEO) turned out to be more toxic and less degradable than the original compound. In Switzerland use of NPnEO in laundry detergents was banned in 1986. Other surfactants followed. For a summary see Giger and Alder (2002).

Refractory organic carbon

Initial tests for biodegradability only tested for the loss of activity (surface activity in the case of detergents) but not for degradation of intermediary metabolites and complete degradation to CO2 and H2O (for a critical discussion see Wuhrmann, 1976). Thus, some metabolites remained in the treated wastewater and contributed to an increase of refractory (non biodegradable) organic carbon. In the early 1970ties stringent discharge requirements were postulated for the biggest wastewater treatment plant in Switzerland. An international contest for the design of the treatment plant clearly demonstrated that the limits for refractory compounds could only be fulfilled with the aid of physical chemical processes, especially activated carbon adsorption.

Confronted with this result, the federal administration released an ordinance for wastewater treatment which required industry to carefully reduce refractory compounds within its premises. Definitely the eternal increase of ever more and refractory organic compounds was slowed and even partially reversed primarily by source control procedures. Predictions of ever increasing DOC (Dissolved Organic Carbon) concentrations in surface waters (Roberts, 1976) did not become reality (also because many production facilities have in the meantime been realized elsewhere).

In the 1970ties research concentrated to a large extent on physicochemical methods of wastewater treatment and only later was this trend directed towards the optimization of biological treatment. The Lake Tahoe Advanced Wastewater Treatment Facility was built in this period as an entirely physicochemical plant.

Heavy metals in sewage sludge

Around 1980 it became clear that the agricultural use of sewage sludge would in a long term perspective result in the accumulation of heavy metals in the agricultural soil. Many countries introduced strict limits for the heavy metal content of the sludge. In Switzerland a national quality control program was started. Systematic source control programs were necessary to reduce the load of heavy metals in the wastewater; industrial and trade waste had to be upgraded at the source and alternative materials, low in heavy metals, started to be used in sanitary house installations. Larger cities hired chemists which had as their single task to trace and reduce heavy metals in wastewater. Today metal plating, automotive repair shops, dentists, etc. all maintain their own equipment to hold back heavy metals at the source. These programs were largely successful as illustrated by the decrease of heavy metals in sewage sludge over the years (Table 1).

Table 1: Decrease of heavy metal content of sewage sludge in Switzerland. The values are national averages from a quality survey program (Candinas et al. 1991 and 1999, adapted)

Heavy metal	Units	1984	1989	1999
Lead (Pb)	g Pb t^{-1} TS	409	232	94.5
Cadmium (Cd)	g Cd t^{-1} TS	5.7	4.0	1.7
Chromium (Cr)	g Cr t^{-1} TS	207	129	74
Cobalt (Co)	g Co t^{-1} TS	10.4	10.2	9.8
Cupper (Cu)	g Cu t^{-1} TS	447	388	341
Molybdenum (Mo)	g Mo t^{-1} TS	11.3	7.0	5.8
Nickel (Ni)	g Ni t^{-1} TS	77.7	42.6	31.9
Mercury (Hg)	g Hg t^{-1} TS	3.6	2.6	1.7
Zinc (Zn)	g Zn t^{-1} TS	1859	1378	929

One, very significant unsolved problem remains: Copper and Zinc used for roofing, gutters and cladding contributes significantly to the heavy metal content of sewage sludge. The loss of copper from roofs depends strongly on the relative contribution of copper surfaces to the roof areas (Figure 7). Recommendations for sustainable construction advise not to use large fractions of either copper or titanium-zinc surfaces for roofs, gutters or cladding (Table 2).

Biocides in roof protection and cladding paint

Gravel covered flat roofs and cladding paint contain biocides in order to reduce the growth of algae and fungi on these surfaces. These biocides are extremely stable and long lived, they must however be released slowly from protected surfaces in order to be active. They are washed off during rain and end up in surface runoff.

Today research is expected to yield less harmful surface protection systems. Definitely biocides protecting from algae growth do not belong into our aquatic ecosystems. Only source control can solve these problems.

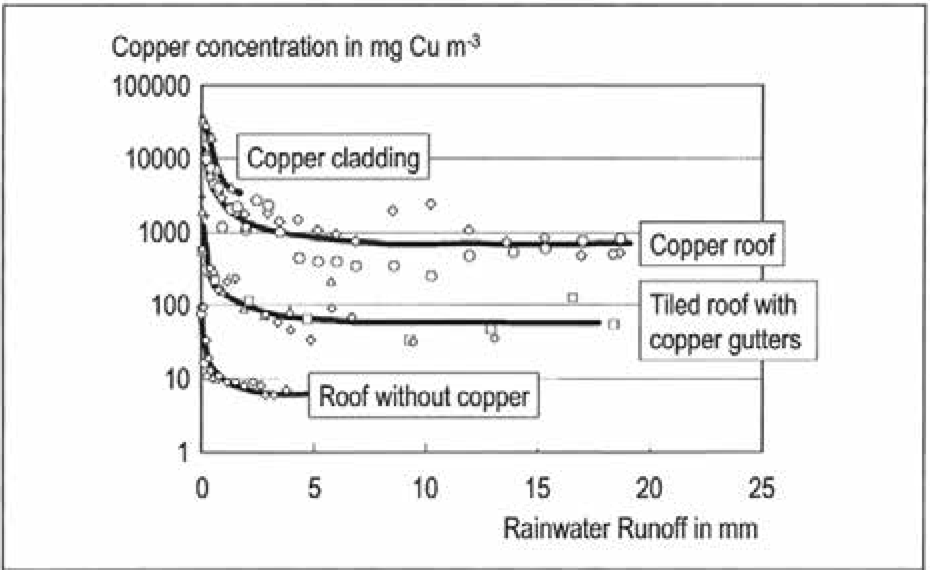

Figure 7: First flush behaviour of Copper in the runoff from surfaces containing different amounds of Cu surface (Boller 2004)

Table 2: Contribution of 3 m² of different metal sheets per capita to the heavy metal content of sewage sludge (KBOB/IPB, 2001)

Type of metal sheet	Contribution to sewage sludge	Mean content of sewage sludge (1999)	Units
Copper	175	341	$g\ Cu\ t^{-1}\ TS$
Titanium Zinc	315	929	$g\ Zn\ t^{-1}\ TS$
Aluminum alloy	1	13'600	$g\ Al\ t^{-1}\ TS$
CrNiFe	Cr: 7 Ni: 6	Cr: 74 Ni: 32	$g\ Cr,Ni\ t^{-1}\ TS$

Reduction of BOD and particulate organic material

In most European countries garbage grinders (appliances which grind organic kitchen waste and flush the waste into the sewer) are not allowed even though there is continuous pressure from industry to introduce them. This is in contrast to North America, where such apparatus is the rule rather than the exception.

Table 3 quantifies the substantial increase in pollutant loads that must be expected when garbage grinders are introduced in a community. Together with this increase goes an extension of the required capacity of the wastewater treatment plant. All elements which depend on pollutant load rather than hydraulic load would have to be extended: Activated sludge reactors and all types of sludge handling processes. In addition somewhat more water would have to be treated (and delivered).

Table 3: Increase of pollutant load due to garbage grinders (USEPA, 2007)

Parameter	Increase in pollutant loading (%)
Suspended Solids (TSS)	40 – 90
BOD	20 – 65
Fats, oil and grease	70 – 150

Reduction of nutrients at the source

Substitution of phosphates in detergents

With the replacement of soap by artificial detergents after world war two, polyphosphates were added to laundry detergents in order to deal effectively with water hardness. These phosphates invariably ended up in the wastewater and caused a severe increase of the phosphate concentration and thus eutrophication in many freshwater lakes (Figure 8). In the 1960ties technology became available (simultaneous precipitation with iron salts) to effectively deal with these phosphates. The trace of the phosphate concentration over the years looks rather like a success story of end-of-pipe treatment (Figure 8). However it was not until the ban of phosphates in laundry detergents in 1986 that truly low residual concentrations could be reached. This ban later turned out to be economically efficient for both sides – treatment plant operation and detergent manufacturing.

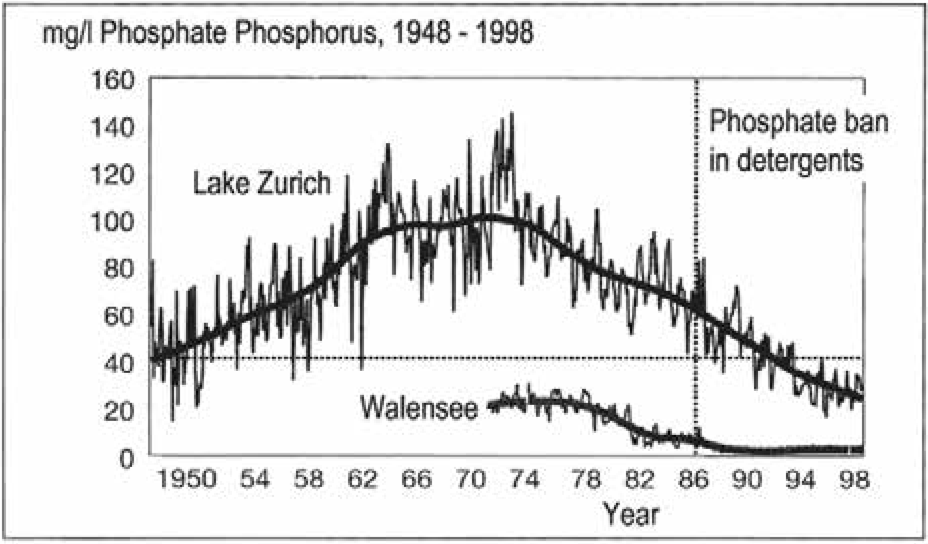

Figure 8: Moving average of phosphate concentration in Lake Zurich and Walensee. Use of simultaneous precipitation of phosphorus in wastewater treatment started in the 60ties. Starting in 1981 phosphate was reduced and in 1986 phosphate was banned in detergents (Data WVZ)

In Switzerland, a continuous, compulsory reduction of the phosphorus content of laundry detergents started in 1981 and resulted in a drastic decrease of the P/TOC ratio in wastewater and thus simplified treatment (Figure 9). Since chemical treatment is costly, due primarily to the additional sludge produced, phosphorus precipitation was implemented only in the catchment area of lakes. In the river Rhine source control had a drastic and rapid beneficial effect (Figure 9). Many wastewater professionals were surprised to see these positive effects of source control even though effective technology was employed end-of-pipe.

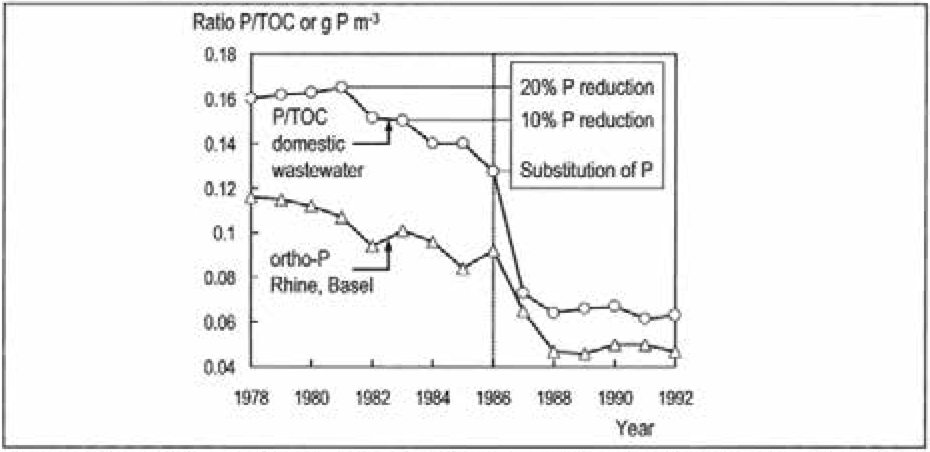

Figure 9: Typical ratio of Phosporus to TOC in primary effluent of a domestic wastewater treatment plant in Switzerland as a function of successive phosphate substitution in detergents (Siegrist and Boller, 1999). Observed concentration of ortho-P in the river Rhine in Basel (data NADUF, BUWAL, adapted)

Reduction of nutrients: nomix technology

As compared to the removal of BOD, removal of nutrients (Nitrogen, phosphorus) requires very large wastewater treatment plants. As an example activated sludge systems for BOD removal are typically designed with a solids retention time of 3 days whereas nitrification, denitrification and biological phosphorus removal may easily require an SRT of 15 days or reactors approx. 4 to 5 times larger.

Without phosphate in laundry detergents, most of the nutrients in domestic wastewater stem from urine, thus it would be advantageous to separate urine at the source and treat it in concentrated form rather than after dilution by a factor of over 100. Figure 10 shows the situation for domestic waste: The wastewater contains approx. 10 g N per capita per day. One quarter of this load is necessary to build up the required biomass for biological treatment of the wastewater and is then removed via excess sludge, 50% are typically removed by denitrification and the rest appears in the effluent and is discharged to receiving waters. Since more than 75% of this load stems from urine, separation of urine would make denitrification and even nitrification obsolete and in addition would reduce the amount of nitrogen discharged to receiving waters. The situation for phosphorus is comparable; given there are no phosphates in detergents, precipitation could become obsolete if urine were separated at the source.

NoMix technology allows separating urine at the source (Larsen and Gujer, 1996) and today there is a variety of technologies available for the removal of nutrients from concentrated urine (Maurer et al., 2006). In addition a significant fraction of pharmaceuticals and their metabolites can be separated from wastewater and treated in concentrated form (Lienert et.al., 2007).

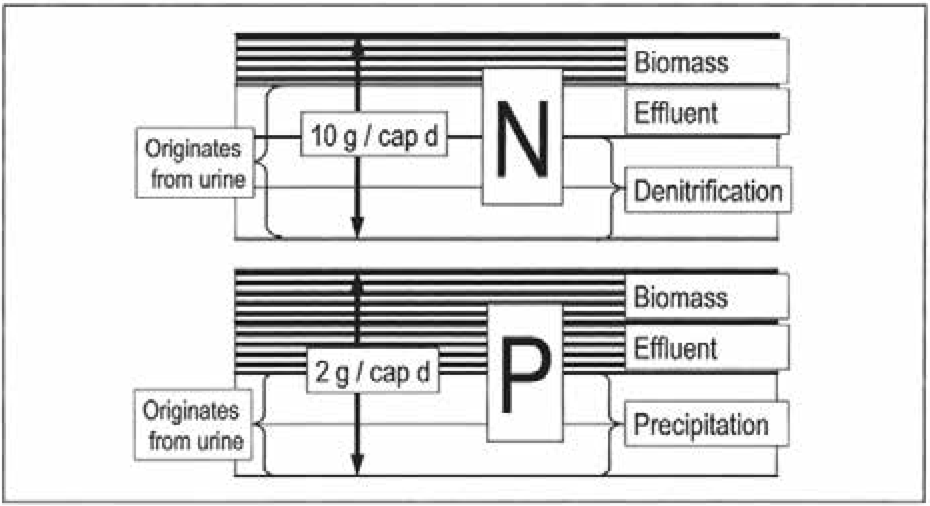

Figure 10: Approx. 75% of total nitrogen and 50% of total phosphorus in domestic wastewater originate from urine. Biomass (excess sludge) and effluent account roughly for 50% of the incoming nutrients. 50% of the nitrogen must be denitrified and 50% of the phosphorus must be precipitated (removed)

Separation of micropollutants at the source

As indicated above, pharmaceuticals can partially be separated from wastewater and treated in concentrated form by separate collection of urine. In addition separate treatment of wastewater from hospitals, asylums and nursing homes could enhance this potential since a large fraction of medication is consumed in these locations.

Reduction of wastewater flow: will we eliminate wastewater all together?

Combined wastewater in the influent of central wastewater treatment plants is composed of three fractions: (i) Polluted wastewater from households, trade and industry, (ii) Clearwater inflow/infiltration from groundwater, spring water, drainage, running fountains, etc and (iii) rainwater and snowmelt from impervious areas. Today, all three contributions are subject to systematic reduction.

Reduction of water consumption

Changes in pricing of drinking water together with technical advances in water saving installations and household appliances led to a decrease of specific water consumption since about 1980 (Figure 11). A trend which is still ongoing but may soon reach its limits (s.a. Table 4) as household water consumption has dropped substantially below 200 l/cap/d in western Europe and has reached an average of only 126 l/cap/d in Germany for household and local trade. In Switzerland total production of drinking water decreased from more than 450 l/cap/d in the 1980ties to less than 400 l/cap/d in the 21st century (Figure 11).

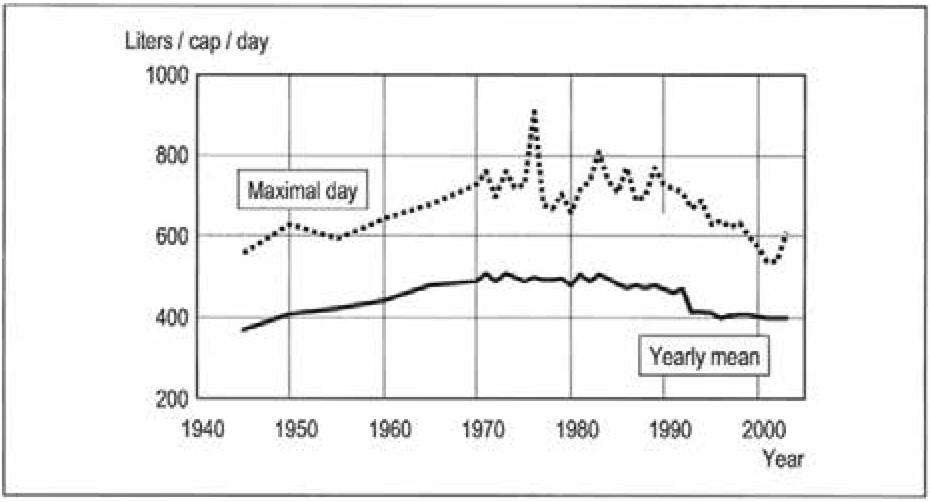

Figure 11: Development of specific water production for households, trade and industry in Switzerland (statistical information SVGW, 2003)

Table 4: Water consumption of household appliances for a single normal cycle (according to Merkblatt W410 of DVGW). Dishwashing by hand would require 30 – 40 liters per cycle

Production year of appliance	Water requirement of a washing machine l / cycle	Water requirement of a dishwasher l / cycle
1980	125 – 175	45 – 55
1985	100 – 125	30 – 40
1990	70 – 125	20 – 30
1992	< 50	20 – 22
2005	< 40	10 – 15

Table 5: Contributions to unpolluted wastewater in Zurich. Today (2007) the remaining mean dry weather flow is approx. 2000 l s-1

Source	1985 l s-1	2002
Spring and river water	250	90
Running fountains	65	50
Cooling water	105	90
Drain and groundwater	450	120
Total unpolluted wastewater in main sewer	**870 l s-1 100%**	**350 l s-1 40%**

Reduction of unpolluted wastewater flow

The city of Zurich maintains a systematic program to reduce the amount of unpolluted wastewater in the influent of its main wastewater treatment plant. Table 5 is a summary of what has been achieved over the last 20 years. More than 500 l s-1 of unpolluted wastewater or approx. 20% of dry weather flow has been eliminated. This allowed activating significant amounts of wastewater treatment capacity by increasing the activated sludge concentration in the biological treatment step (Dominguez and Gujer, 2006). In addition it allows storing a larger fraction of combined sewage and feeding it to the treatment plant after rain and storm events, resulting in better protection of receiving waters at no extra cost.

Reduction of rainwater

Since 1991 the Swiss federal law on water pollution control (GSchG, 1991) requires that whenever it is ecologically sound as well as hydro-geologically and technically feasible non polluting surface runoff must locally be infiltrated into the underground. This option must be checked for all new buildings and pavements and whenever significant renovation of property is foreseen. In the meantime most communities maintain plans and design information for surface runoff infiltration. The result is an overall net decrease of surface runoff rather than an increase in parallel with the ever increasing impervious areas.

Rainwater use remains rather limited

The substitution of drinking water by rainwater for toilet flushing or in cloths washing machines has the effect, that overall less wastewater has to be treated. Contribution of this substitution is however still rather limited.

Discussion

Conventional, central wastewater treatment plants are explicitly designed for the removal of solids, bulk organics and the nutrients nitrogen and phosphorus. Definitely the success of water pollution control in many industrialized countries would not have been possible without such central wastewater treatment since bulk pollutants can all be controlled end-of-pipe. However source control is a decisive element of effective water pollution control, since many problem pollutants can only be controlled at the source. In addition source control provides substantial contributions to the control of bulk pollutants as well.

Without

- requiring (true) biodegradability for detergents and other man-made organics,
- controlling the amount of solids and organics by not allowing garbage grinders,
- limiting nutrient discharge by banning phosphates in laundry detergents,
- controlling discharge of heavy metals,
- reducing different contributions to the volume of wastewater flow,

the cost of central treatment would explode and overall be significantly less efficient. These source control procedures have either changed the composition of the wastewater such that treatment became possible (waste design, Larsen and Gujer, 2001) or they have reduced the discharge of the pollutants such that further treatment became unnecessary. In addition today's research tries to make additional alternatives available which will help to introduce new approaches to difficult or expensive treatment options (micropollutants, biocides, urine separation).

Table 6 summarizes an evaluation of different aspects of water pollution control. So far source control has very positive effects on all aspects except hygiene and treatment of faeces. With today's rapid development of membrane technology it should be possible to develop on-site technology, which can effectively deal with the stabilization and decontamination of faeces. Together with efficient operation schemes, such technology would be key for source control procedures to fully out-compete end-of-pipe technology.

Conclusions

Source control proves to be more versatile than end-of-pipe treatment. Most of the deficiencies of central treatment could be corrected by source control. On the technical side, it is the efficient cooperation of three elements which leads to efficient water pollution control: (i) alleviation of pollution and volume of wastewater, in order to reduce required treatment; (ii) change of wastewater composition, in order to facilitate treatment; and (iii) final treatment of residual problems. Given the efficacy of source control for a broad spectrum of water pollution control problems, it is well possible that in the future these techniques will dominate water pollution control in urban areas.

Today we lack efficient technology which allows dealing on-site with problems of hygiene. Since hygiene is one of the top benefits of flushed sewers, this is a serious limitation which deserves intensive research and development.

Table 6: Summary and evaluation of the effect of source control and End-of-Pipe treatment on different pollutants

Pollutant or Loading	Effect of source control	Effect of end of pipe treatment	Source control approach
Suspended solids	++	+++	Garbage grinders
BOD	++	+++	Garbage grinders
Refractory organics	+++	1)	Biodegradability
Heavy metals	++	2)	Removal at source
Phosphorus	++	++	Substitution, urine separation
Nitrogen	+++	++	Urine separation
Wastewater production	++	0	Water savings, prizing
Clear water separation	++	0	Sewer maintenance
Storm drainage	++	0	Infiltration
Hygiene	?	++	No solution yet

[1)] Refractory compounds either end up in the effluent or are adsorbed to the sewage sludge depending on their physico-chemical properties

[2)] Heavy metals are partially removed from the wastewater, but they end up in the sewage sludge

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Prof. Dr. Willi Gujer

Separate Discharge and Treatment of Urine, Faeces and Greywater – EU Demonstration Project (SCST)

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Introduction

Sustainable water management is a basic concern of Berliner Wasserbetriebe and Veolia Eau. In this context, not only issues with regard to the long-term use of water and other resources, but also concerning their reuse and the environmental consequences have to be considered. But also from the economic point of view, the highly capital-intensive facilities for water supply and disposal are inflexible as to their long-term and safe use and have to be critically scrutinized due their necessary maintenance expenditure. "Out of sight – out of mind" says a German proverb. If wastewater is not regarded as part of our responsibility, it may be managed improperly. To what extent the social benefit of urban hygiene has in the meanwhile turned into a socially unfavourable thoughtlessness, was not the object of the following project "Sanitation concepts for the Separate Treatment of Urine, Faeces and Greywater". This project was realised by Kompetenzzentrum Wasser Berlin, financed by BWB and Veolia Eau and, as a demonstration project, funded within the EU LIFE programme.

Project scope and goals

Centralised, conventional water supply and wastewater treatment systems that have been developed and implemented for decades in industrialised countries are not sufficiently sustainable, especially not regarding their implementation in developing countries as they involve high costs, high water consumption, and a low reuse of nutrients. Sustainable concepts should aim to reuse as much as possible the treated wastewater and the nutrients, and to lower the overall energy consumption. Alternative concepts and technologies have been around for a long time and have been implemented; however, further developments and plausibility checks are necessary. For this reason, the Berlin Centre of Competence for Water (KompetenzZentrum Wasser Berlin, KWB), together with the Berliner Wasserbetrieben (BWB) and Veolia Water carried out an EU-demonstration project in this field (Sanitation Concepts for Separate

Treatment (SCST)). In this project, two different sanitation concepts were tested in buildings of the BWB on the grounds of the wastewater treatment plant Stahnsdorf. The project goal was to test if these new sanitation concepts prove to have advantages over conventional sanitation systems with water-carrier method of wastewater discharge and wastewater treatment plant (end-of-pipe-system) in terms of environmental impacts as well as economic efficiency.

Technologies used / methodology

The new sanitation concepts for the separate discharge and treatment of yellowwater (urine), brownwater (faeces without urine but with flushing water), and greywater (wastewater from kitchen and bathroom) were installed and implemented in previously existing buildings (one office building and one apartment house) on the grounds of the wastewater treatment plant Stahnsdorf nearby Berlin. The new sanitation concept in the office building was installed in 2002 / 2003, when the building was being renovated. In spring 2005, the new concept was extended to the apartment house **(Fig. 1).**

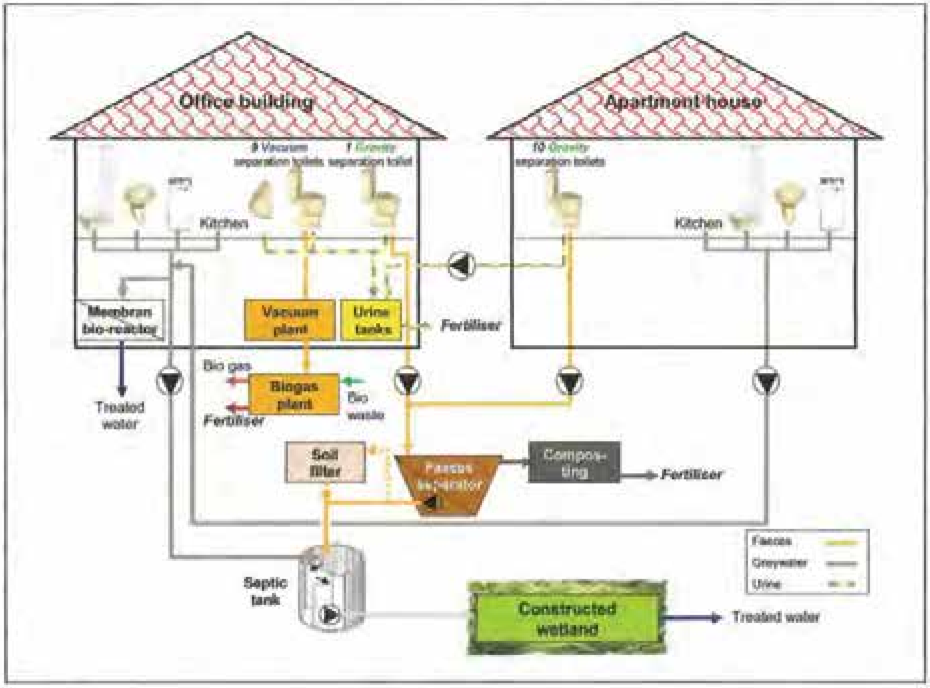

Figure 1: Tested sanitation concepts (left: vacuum separation toilets; right: gravity separation toilets)

In the sanitation concept featuring gravity separation toilets **(Fig. 2)**, the brownwater was discharged by gravity, dewatered in filter bags, and subsequently thickened.

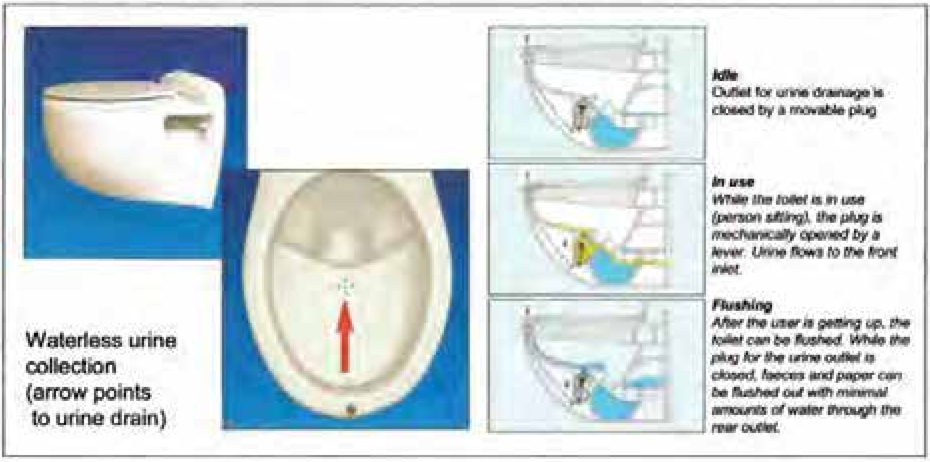

Figure 2: Gravity separation toilet (No Mix-Toilet) of the company Roediger

The thickened faeces were then composted. Afterwards, the filtrate was channelled into a two-chamber septic tank for pre-treatment. The greywater was also pre-treated mechanically in the septic tank. The mixture of mechanically treated greywater and faeces filtrate then underwent biological treatment by means of a constructed wetland. Simultaneously, the biological treatment of the greywater by a membrane bio-reactor was tested. The treated greywater from both installations (constructed wetland, membrane bio-reactor) can be used e.g. for irrigation purposes.

The yellowwater was discharged into tanks through a separate pipe. As part of the project, the Humboldt University Berlin (HUB) carried out tests regarding fertilising potential with the yellowwater. In addition to these tests, other technical procedures for the treatment of yellowwater (vacuum evaporisation, steam stripping, precipitation, ozonisation, UV irradiation and process combinations) were investigated at the Technical University Hamburg-Harburg (TUHH). The aim of these tests was to gain marketable products.

In the sanitation concept featuring vacuum separation toilets, yellow- und greywater were also discharged by gravity, but the brownwater was transported by a vacuum system. The yellowwater was treated as described above. The brownwater from the vacuum separation toilets was treated in a two stage thermophile biogas plant; at times, bio-waste was added. The digested sludge generated in this process can, on the whole, be used as fertiliser. The further use of the biogas produced in this process was not tested in this project.

The sanitation concept using the gravity separation toilets was tested in the office building in a preliminary project phase from October 2003 to April 2005. For these purposes, 10 gravity separation toilets and 5 waterless urinals from 3 different producers were installed. Based on the insights gained in this project phase, in spring 2005, gravity separation toilets were installed in 10 apartments in the apartment house. Simultaneously, starting in October 2003, the gravity separation toilets in the office building were gradually replaced with vacuum separation toilets.

The project was accompanied by a Life Cycle Assessment (LCA) undertaken by the Technical University Berlin. This LCA intended to find out whether the new sanitation concepts have ecological advantages over conventional systems. All relevant processes in the sanitation systems were modelled by a Life-Cycle-Assessment software. The data required for this were taken from pilot projects, the literature or data-bases. Apart from the operation of the sanitation systems, the LCA took into account the construction expenditures. The thus obtained substance-flow model for energy resources, nutrients and heavy metals was evaluated statistically with a series of environmental indicators.

Looking at the economic aspects, a cost comparison between the new sanitation concepts tested in the project and conventional concepts was undertaken. The calculations were made according to the German directive on dynamic cost comparisons (Deutsche Richtlinien der Dynamischen Kostenvergleichsrechnungen) of the Länderarbeitskreis Wasser (LAWA). A settlement in Berlin with a conventional sanitation system was chosen as a case study. The different aspects of the project are laid out in the following table **(Tab. 1)**. They were tested at different times, in different project phases, and in various combinations.

Table 1: Structure and aspects of the project

		material flow		
		urine	faeces	greywater
technique conception	sanitary technique	gravity separation toilets vacuum separation toilets waterless urinals	gravity separation toilets vacuum separation toilets	
	transport	gravity main force main	gravity main vacuum main force main	gravity main force main
	treatment facilities	storage, vacuum evaporation, stripping, precipitation etc.	coarse filter settling tank biogas plant	sedimentation and constructed wetland membran bio-reactor
utilisation		agricultural utilisation		
assessment	life cycle assessment, cost comparison calculation			

Results

Sanitation technology

In 6 out of the 10 toilets in the apartment house, the urine effluents were blocked by precipitants. The toilets, however, continued to work. But from then on, the yellow- and the brownwater were not discharged separately any more. In order to use the gravity separation toilets as a large-scale alternative to conventional toilets, their geometry and flushing mechanism need to be optimised.

When evaluating the vacuum separation toilets, one has to bear in mind that they are modified gravity separation toilets equipped with a vacuum valve at the reduced flush outlets. They are tailor-made, unique models that have to be seen as prototypes. The installed toilets require a flushing water volume of one to two litres per flush. For serial production, the toilet should require less than a litre of flushing water per flush.

User surveys showed that the separation toilets were on the whole accepted. However, as mentioned before, improvements in the flushing mechanism are necessary for both toilet types.

Collection of yellowwater

The yellowwater of the users of the toilets in the office building was collected in four tanks located in the cellar of the building. From there, it was pumped down to be used in the tests on agricultural use and technical treatment. The mean volume of yellowwater from the office building was 7 L/d, and the one from the apartment house approx. 60 L/d. The concentration levels for nitrogen, COD etc. were much lower than the values documented in the literature, especially in the case of the yellowwater from the apartment house. One reason for this could be the dilution of the yellowwater with greywater, resulting from not completely closed valves in the urine effluent of the separation toilets. An analysis of micro pollutants such as pharmaceutical residues was undertaken as well. Given the non-representative sample of users, the concentrations found were very low. A detailed description of the findings shall not be given here as this information can be found in the comprehensive final report (www.kompetenz-wasser.de\ research\ SCST).

Greywater treatment

In **Tab. 2** the influent and effluent flows of the constructed wetland in two operation periods are depicted.

Table 2: Influent and effluent values of the constructed wetland

Parameter		Unit	Greywater from office building and apartment house			
			with faecal filtrate		without faecal filtrate	
			29.6.2005 - 1.7.2006		1.9. - 16.11.2006	
			Infl.	Effl.	Infl.	Effl.
Flow	Q	L/d	5,191		4,334	
Chemical oxigen demand	COD	mgO_2/L	402	27.6	318	18.6
Total phophat-phosphor	P-total	mgP/L	6.7	1.7	4.7	0.5
Totel nitrogen	N-total	mgN/L	33.4	19.6	11	3.5
Ammonium	NH_4-N	mgN/L	20.4	2.6	5.8	0.1

In one period, the constructed wetland was operated with greywater from the office and the apartment house, including the faeces filtrate; in the other period, it was operated without the latter. In the first period, the volume of the flow was higher, in the second period, lower than the volume of 4.580 L/d that had previously been estimated. When looking at the concentrations of the different chemical parameters such as COD, P-total etc. in the influent and effluent, the impact of the faeces filtrate is clearly detectable. In the first period, the concentration levels were much higher than in the second period. In both cases, however, the COD-concentration levels in the effluent are much lower than e.g. in the wastewater treatment plants of Berlin, where they amount to 40 – 50 mg/L.

When the greywater was treated with the membrane bio-reactor, effluent concentration levels similar to those of the constructed wetland in the second period were obtained. Yet, in this case, the greywater was additionally disinfected.

Brownwater treatment

The brownwater from the gravity separation toilets flowed by gravity into pits. From there, by means of a cutting pump, it was pumped into the faeces separator for dewatering and storage. The soil filters are polyethylene filter bags that were installed to hang in the pit. The largest share (79 %) of the suspended solids of the brownwater from the apartment house was captured by the filters. But because of the high concentration of these suspended solids in the effluent (faeces filtrate), the filtrate was at times channelled into the two-chamber septic tank, and, together with the greywater, mechanically pre-treated before it was treated biologically with the constructed wetland.

Regarding the operation and handling of the faeces separator, it has to be stated that this method of dewatering faeces is only adequate for small units. For larger settlements, a continuously operating installation that can reduce the concentration of suspended solids even further is required.

In order to produce compost from the thickened faeces, Eisenia fetida worms were added to the faeces in the soil filters. These were then stored in a room with a temperature of approx. 20 oC for several months (four to six) and composted – with a very satisfactory result (vermicomposting). This compost was subsequently used for the tests on fertilising potential at the Humboldt University Berlin.

The two stage biogas plant for the treatment of the brownwater from the vacuum separation toilets could only be put into operation in July 2006. Consequently, the results based on this plant can only be seen as tentative findings. With a hydraulic retention time of seven days, quantities of biogas similar to those of digested sludge in municipal wastewater plants were produced.

Assessment of source separation

In order to determine to which extent the measured percentage shares of different substances in the yellow-, brown-, and greywater corresponded to values recorded in the literature, a mass balance was calculated. By the way of an example, the results for total nitrogen (N-total) are presented in **Tab. 3.**

Table 3: Comparison of measured values of nitrogen in yellow-, brown-, and greywater to values found in the literature

			Yellowwater		Brownwater		Yellowater		Sum
Apartment house	N-total	%	33	87	57	10	10	3	100
Office building	N-total	%	41	87	40	10	19	3	100
cursive = literature values									

Looking at the values for yellowwater, it becomes obvious that the percentage of N-total in the urine of the users of the toilets in the apartment house is much smaller than the values documented in the literature. The percentage in the brownwater, by contrast, is much higher than the percentage given in the literature. This is equally true for the greywater. As the tenants of the apartment house reportedly sat down to urinate, the reason for these results are not likely to be found in an incorrect use of the toilets. A more likely explanation is the low separation capacity of the toilet, which is further reduced through the precipitations at the valve of the urine effluent. In order to clear the blockages, to this day, the valves of 6 of the 10 toilets had to be replaced.

The separation capacity of the gravity separation toilets tested in the office building was similar to that of the toilets in the apartment house; the percentage of N-total, by contrast, was much higher. The reason for the latter is most likely the fact that the urine of the male users was collected mostly through the waterless urinals.

Reuse of products

In order to determine the fertilising potential of urine, composted faeces and untreated faeces, the Humboldt University Berlin carried out the corresponding pot and field trials. The exemplified results from pot trials with spring wheat which was not fertilised, fertilised with mineral fertiliser, and fertilised with yellowwater, respectively, is depicted in **Fig. 3**.

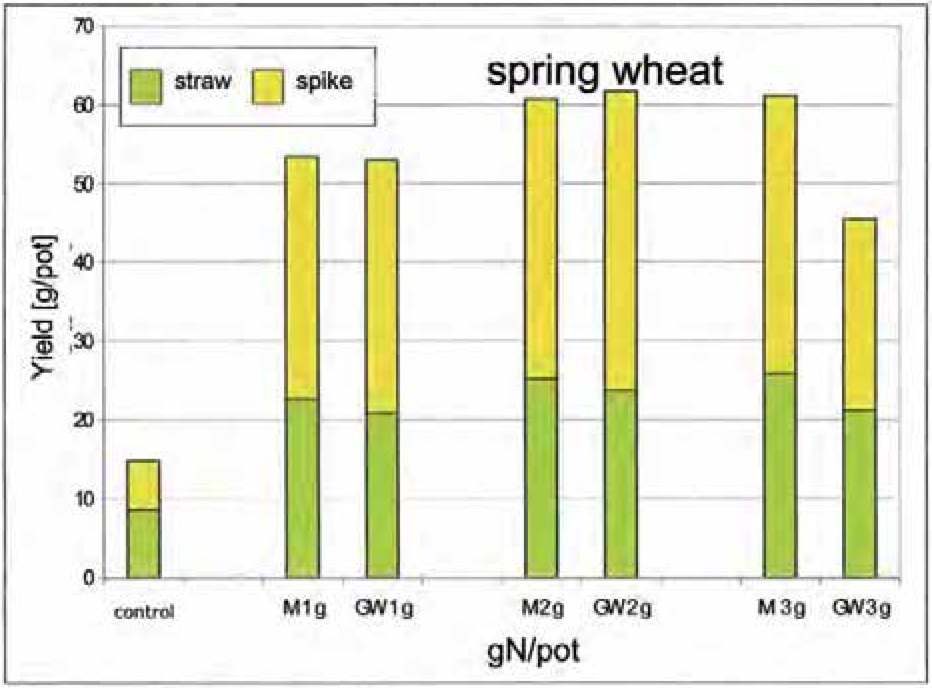

Figure 3: Yields of spring wheat after fertilisation with mineral fertiliser (M) and with yellowwater (GW) (1 - 3 g N/pot)

As can be seen from these results, the yields of the spring wheat fertilised with yellowwater are similar to those resulting from fertilisation with mineral fertiliser. The example shows the high fertilising-potential of yellowwater. It has been estimated that the yellowwater of the inhabitants of Berlin and Brandenburg could replace 40 % of the nitrogen currently used in Brandenburg. The quantity of phosphorus that could be replaced by fertilising with yellowwater even amounts to 75 % of the total amount of fertiliser used in the economic year 2003/2004.

The tests of the TU Hamburg-Harburg regarding the treatment of urine revealed that, on the whole, all tested processes are technically feasible.

By the way of an example, the steam stripping resulted in an ammonia solution with a concentration of more than 15 %. Trough using evaporation, 20 L concentrate could be produced from 1 m³ urine, which correspondents to a 50 times volume reduction. The phosphor contained in the concentrate crystallized out in the subsequent storage. Stripping and concentration in the consecutive precipitation did not result in a noteworthy change in precipitation-efficiency. Pharmaceutical residues could be completely removed with ozonisation.

Life cycle assessment

The Life Cycle Assessment (LCA) undertaken by the Technical University Berlin showed that the new sanitation concepts have fewer negative impacts on the environment than the conventional sanitation system. This finding is presented in **Fig. 4**.

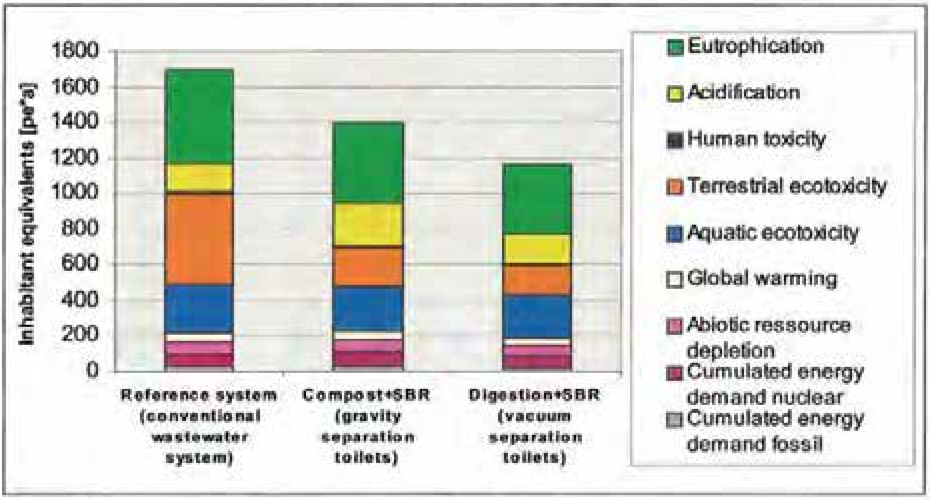

Figure 4: Normalised eco-profiles as inhabitant equivalents (environmental impact) of conventional system and of the two alternative sanitation concepts tested

The less negative environmental impacts of the new concepts are mainly a result of two factors: first, a lower degree of heavy metal enrichment on farmlands (terrestrial ecological toxicity) by using urine, composted faeces and digested brownwater as fertilisers instead of mineral fertilisers; second, a lower eutrophication of the receiving water bodies. The results obtained were based on the assumption that the urine is not treated to be used as fertiliser. If it should prove necessary to treat the urine with different processes for the concentration of nutrients such as nitrogen and phosphorus as well as for removing micro pollutants such as micro pollutants (pharmaceuticals, steroids), in the worst case, the two columns in **Fig. 4** would increase by approx. 100 inhabitant equivalents. Even in this case, the new sanitation concepts would still be less environmentally harmful than the conventional system. A further assumption for the LCA was that 75 % urine can be separated with the separation toilets. Unfortunately, this separation could not be reached with the toilets used in the project. The actual separation rate obtained was between 30 % and 40 %.

Costs

The results of the cost comparison carried out by the Otterwasser GmbH (a consultant to the project) showed that the costs involved in the new concepts depend considerably on the special needs and circumstances in a given settlement. Accordingly, the costs can be either higher, the same as, or lower than the costs involved in conventional sanitation systems.

Impacts on the environment

The results of the Life Cycle Assessment laid out above demonstrate that the new sanitation concepts have fewer negative impacts on the environment than the conventional sanitation system. The sanitation concept featuring gravity separation toilets causes approx. 20 % (12 % with urine treatment) less environmental damage, and the concept using vacuum separation toilets approx. 30 % (25 % with urine treatment) less damage. This is based on the condition that 75 % of the collected urine can be separated. This separation rate, however, could not be achieved (see above). In order to achieve this rate, the separation toilets need to be improved considerably.

Cost-benefit analysis

As has been pointed out in the section "results/costs", it is difficult to give a final assessment of whether the new sanitation concepts tested in the project are more expensive, more economical or just as expensive as conventional sanitation systems. The costs depend heavily on the specific situation. This fact renders it difficult to provide a final cost-benefit analysis. If the costs are the same, the new sanitation concepts come with the advantage that they are more beneficial in environmental terms than the conventional sanitation system. If the costs are lower, the new concepts bring the advantage of fewer negative environmental impacts on top of the cost advantage.

Transferability of project results

The overall results of this project provide evidence for the fact that, on the whole, the sanitation concepts tested work, and that they have potential for further development. In order to use them on a larger scale, improvements are necessary. This concerns in particular the separation toilets and the dewatering and thickening of the brownwater (faeces plus greywater). Moreover, the problem of how to avoid or minimise incrustations in the urine effluents, especially in the sanitary installations, needs to be tackled. Another challenge remains regarding the use of the different products (urine, composted faeces, anaeorobically treated faeces) as fertiliser. As these products contain micro pollutants (pharmaceuticals, steroids), the impacts of which are uncertain, it will be difficult to gain acceptance and permissions, respectively, for their use as fertilisers. Many experts dealing with new sanitation concepts, however, consider the benefits that can be derived from the use of these products as being far bigger than the damages that can be caused by these micro-pollutants. Given the increasing importance of topics such as saving water and energy, water reuse, and nutrient recycling, further endeavours in these areas need to be undertaken, which is what is happening in many places. The DWA (German Association for Water Management, Wastewater and Waste) e.g. founded a special commission of experts called "Neuartige Sanitärsysteme / Innovative Sanitation Systems", which collects and publishes up-to-date knowledge on the topic. Examples of the application of innovative sanitation concepts are Solar City in Linz (Austria), House Griesbach of the EAWAG (Water Research Institute of Switzerland) and, in Germany, apart from the SCST-project, the settlement Flintenbreite (Lübeck) of the company Hans-Huber (Berching), the Lambertsmühle (Burscheid), and the German Agency for Technical Cooperation (GTZ, Eschborn). In Berlin, there are no applications planned at present, mainly because the problems and uncertainties detailed above.

Last but not least, it should be highlighted that there has been and still is a strong interest in this demonstration project. To this day, the project has been presented on-site to national and international visitors (approx. 500) about 68 times. This vivid interest can be seen as a result of the internet presentation of the project provided by the KompetenzZentrum Wasser Berlin (www.kompetenz-wasser.de\research\SCST), numerous publications in specialised journals as well as information presented in radio shows (17), and presentations given at national and international conferences (31).

Acknowledgements

The scientific investigations were carried out at the Technical University of Hamburg-Harburg, the Technical University of Berlin and the Humboldt University of Berlin. Through its provision of expert advice, the company Otterwasser GmbH substantially contributed to the project's success. Particular thanks go to the authors of the Final Report, Dr. Anton Peter-Fröhlich, Alexandre Bonhomme, Dr. Martin Oldenburg, Boris Lesjean and Ms Regina Gnirß. The reports can be downloaded from KWB's web site www.kompetenz-wasser.de.

Mr. Ludwig Pawlowski

Application of the Concept of Decentralisation and Reuse for Designing a Sustainable Urban Water System in Water Deficient Area

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Abstract: Northern China is suffering from a problem of chronic water shortage and therefore wastewater treatment and reuse is recognised to be an important countermeasure to mitigate water shortage especially in the urbanised area where water demand is increasing. A centralised wastewater treatment and reuse system, as has been practiced in several large cities, often requires vast investment for the construction of large scale pipelines or network for supplying the treated water. In contrast to this, a decentralised wastewater treatment and reuse system shows its advantages of cheaper investment and flexibility of application, particularly for small towns, communities, residential areas where onsite treatment and onsite reuse can be practiced. This paper introduced three examples in Xi'an – a large city in northern China, the 1st being a college, the 2nd being a residential area, and the 3rd being a newly developed tourist district. The wastewater treatment and reuse system designed for each of them consists of independent wastewater collection, wastewater treatment, treated water storage and reuse facilities. Environmental lake/pond is also an important component of the system which receives the treated wastewater and performs the functions of water storage/regulating, water quality stabilisation, and improvement of local environment. Water is pumped from the lake/pond for onsite gardening. Such kind of decentralised urban water environmental system is considered to be sustainable for cities of the future in northern China.

Keywords: decentralisation, northern China, urban area, sustainability, water reuse, water shortage.

Introduction

The total renewable water resource in China as of 2004 was 2,413 x 10^9 m^3 (Ministry of Water Resources, 2005). This ranked as number 6 in the world following Brazil, Russia, United States, Canada and Indonesia (World Resources Institute, 2005). However, due to its large population of 1.29988 billion (National Bureau of Statistics of China, 2005), the per capita water resource became 1,856 m^3/year which was only 22% of the world average as about 8,500 m^3/year (World Resources Institute, 2005). China possesses a large territory with geographical and meteorological conditions varying from the north to the south and from the east to the west. In the northern part of China, especially the Yellow River, Haihe River and Huaihe River basins, the per capita water resource is less than half of the national average (565, 227 and 365 m^3/year, respectively for the three basins as of 2004) and water shortage is the main problem affecting the development in these areas. Due to limited availability of water resources, over withdrawal of surface water or groundwater becomes a common problem in northern China, especially in the densely populated city area or extended irrigation area. The direct result of over withdrawal is a decrease of water flow in the river channel and/or a decline of groundwater table (Wang and Jin, 2006). This further results in deteriorated water quality because of insufficient water quantity for diluting pollutants. In 2004, about 40% of the surface waters in the whole country could not be used as source water for drinking water supply, but in the northern basins the percentage was as high as 55 to 70% (Ministry of Water Resources, China, 2005).

Under such conditions, reuse of the treated wastewater becomes more and more important as a countermeasure to mitigate water shortage. Ministry of Construction and Ministry of Science and Technology of China (2006) has recently put forward a "Technical Guidance for Urban Wastewater Reclamation and Reuse". It sets a goal of direct reuse of 10% to 15% of the total wastewater quantity in the water deficient northern cities by 2010, and 20% to 25% by 2015. In accordance with this, the Ministry of Construction has further requested that all wastewater treatment plants newly installed have to supply the treated water for domestic, industrial or agricultural reuse, especially in the water deficient northern regions.

As will be discussed in the following section, the water and wastewater systems in a city are commonly managed in a centralised manner under the principle of "supply of high quality drinking water, collection of sewage and storm water and advanced treatment of the collected water prior to discharge into natural water bodies to meet the needs of the public health, industrial growth and prosperity of the society." (Wilderer, 2001). In such a system, all the water to be distributed in the urban area is purified at discrete locations, and the wastewater collected in the area is sent to a discrete plant for treatment and discharge. Therefore, practice of treated wastewater reuse with such a system often becomes difficult unless there are potential consumers near the wastewater treatment plant (this may not always be the case) or a long distance pipeline and distribution network are constructed. Comparing with this, a water and wastewater system managed in a decentralised manner has drawn wide attention (Crites and Tchobanoglous, 1998; Wilderer, 2001). The principle of decentralisation can mainly be characterised as (1) an independent collection system covering a smaller service area, (2) onsite treatment and onsite reuse, and (3) avoidance of long distance transfer of both the collected wastewater and the treated wastewater. The last point is the most attractive from an economic viewpoint. Because northern China is still a developing region, the economic affordability is one factor we have to consider in planning wastewater reuse projects. In this regard, decentralised management of wastewater treatment and reuse may be more favourable.

In recent years, discussions have also moved to the sustainability of an urban water system where water supply, wastewater collection and treatment, and treated wastewater reuse are important components. Tambo (2004, 2006) has proposed the concept of "urban water district" which is a water metabolic space within the hydrological cycle. It stresses the harmony of artificial facilities with water environment in the urban area and draws a clear distinction between the water areas that should be conserved and those to be utilised. In fact, comparing with water works which bring "clean water" in, sewage works which bring "dirty water" out, and natural waters which are accepted as part of our intimate environment, the treated wastewater still belongs to a completely new category which may be somewhat foreign not only to ordinary people but also to environmental engineers to a certain extent. How to locate the position of the treated wastewater in a hydrological cycle may thus be the key point for the design of a sustainable urban water system.

In this paper, the author is going to introduce his idea on configuring a sustainable urban water environmental system by applying the concept of decentralisation and reuse. Case studies of three newly implemented projects in Xi'an, a large city in northern China, will also be presented.

Basic considerations on the configuration of a sustainable urban water system in water deficient area

Treated wastewater reuse based on a conventional urban water system

Before considering a sustainable urban water system, it is necessary to review a conventional urban water system with a general configuration as shown in Figure 1. Such a system may have the following characteristics: (1) It is a large scale artificial water cycle consisting of source water, water treatment to meet the drinking water quality, water supply network to distribute drinking water for domestic, industrial/commercial and environmental consumption, wastewater collection and treatment, and final discharge. (2) The system is related to natural water bodies only at the beginning and end points of the system, i.e. the source water which locates at upstream of the city and the water body which locates at downstream of the city to receive urban discharge. (3) As the city is developed, the system may need expansion to meet the increasing demand. (4) If water reuse is required, an additional network has to be constructed for distributing the treated wastewater back to the city area for various purposes of reuse.

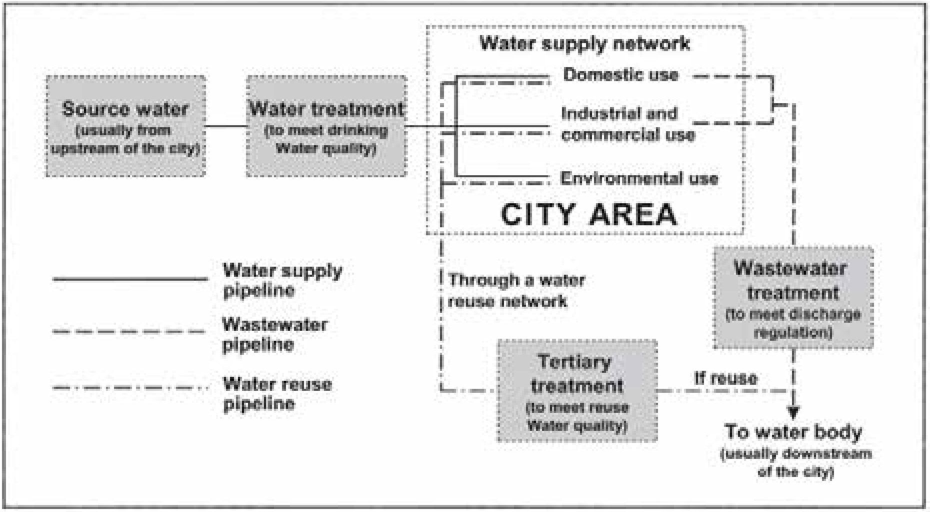

Figure 1: A conventional urban water system which composes of water supply network, wastewater treatment and additional water reuse network as treated water reuse is practiced

In such a system, the facilities for treated wastewater reuse (including the tertiary treatment and water reuse pipelines) are apparently additional to an originally "supply – use – discharge" system. In a city where an old wastewater collection and treatment system is in existence but wastewater reuse project is newly planned, such a system configuration may have to be adopted though the added "patch" does not harmonise with the whole system. But it can not be recognised in any sense as a reasonable solution for a new city or a newly developed district where treated wastewater reuse is to be practiced from the beginning of wastewater facility construction.

Principles for sustainable urban water system design

We herein propose the principles for designing an urban water system which can be considered sustainable from the viewpoints of resource and energy consumption, economy and environment. The so called sustainable urban waster system should be suitable to a new city or a newly developed district in a water deficient region.

Minimisation of fresh water supply and maximisation of treated wastewater reuse

We put this as the first principle for sustainable urban water system design under a consideration that wastewater is no longer "waste" but recyclable water resource (Asano, 2005). In a water deficient area, such as northern China, renewable fresh water resource is very limited. Therefore, minimisation of fresh water supply to a city is extremely important to the sustainable development. Any water consumption that can utilise the treated wastewater should be covered by this alternative resource if only feasible.

Decentralisation as the basic philosophy of system design

What we stress here is onsite treatment and onsite reuse which is the most important characteristic of a decentralised system (Fane et al, 2002). Comparing with treatment facilities, the construction of a large network for wastewater collection and reuse water supply is usually more expensive. This often becomes an economic obstacle of treated wastewater reuse.

Priority given to environmental reuse

A water deficient region may also characterised by low rainfall and dry climate. This is especially the condition in northern China. A rough estimation indicates that in a large city such as Xi'an, China, daily water consumption for gardening and sprinkling in the urban area may take about 8-10% of the total water supply (Wang and Jin, 2006). In an area with high green coverage and artificial water bodies, environmental water consumption can be as high as 20-25%. Comparing with in house reuse such as toilet flushing, environmental reuse may not require pumping the treated wastewater to higher elevation. The health risk may also be lower especially that relates to unpleasant smell or odor inside a building. Therefore, among various reuse purposes in an urban area, environmental reuse should be given priority in the system design.

Introduction of the "principle of ecological design"

Over the past decades ecological design has been applied to an increasingly diverse range of technologies and innovative solutions for the management of resources (Todd et al, 2003). There are a set of principles of ecological design which give insight, inspiration, and guidance for a radical redesign of our way of life (Ludwig, 2003) among which the followings are thought to be the most important ones related to the design of a sustainable urban water system.

- *Follow nature's example.* Natural systems are always in dynamic balance with the whole. They serve to keep us connected with nature and to remind us what is natural. Following this principle, we have to consider how to configure a system as closely connected with nature as possible.
- *Moderate and efficient resource use.* We have to put our resource and/or energy use in a human, comprehensible perspective, and try to keep our consumption within the renewable extent. Insufficiency of resource/energy supply can only be solved by increasing the efficiency of resource/energy use.

- *Appropriate technology.* We have to choose from varieties of available technologies the one which may consume less energy and materials, perform effectively and efficiently, and render less negative impact on the environment.
- *Green living inspiration.* This principle primarily relates to human attitude toward resource/energy consumption but it can be enlarged to creating more comfortable and ecologically sustainable environment. Therefore, it can be described by a simple formula of "green consumption + green creation".

System configuration

Following the above mentioned principles, a sustainable urban water system can be proposed as shown in Figure 2. Comparing with the conventional urban water system, this system has the following features: (1) It is an enclosed water system with minimised supply of fresh water and minimised discharge of wastes across its boundary. (2) The primary objective of wastewater treatment is for water reuse. Therefore, as long as economically and technically feasible, source separation is recommended in the system. (3) Where applicable, natural or artificial water bodies (lakes, ponds, streams) can be introduced into the system. These water bodies use the treated wastewater as source for water replenishment, and meanwhile play the functions of regulation basin and water quality polishing before being used for various purposes.

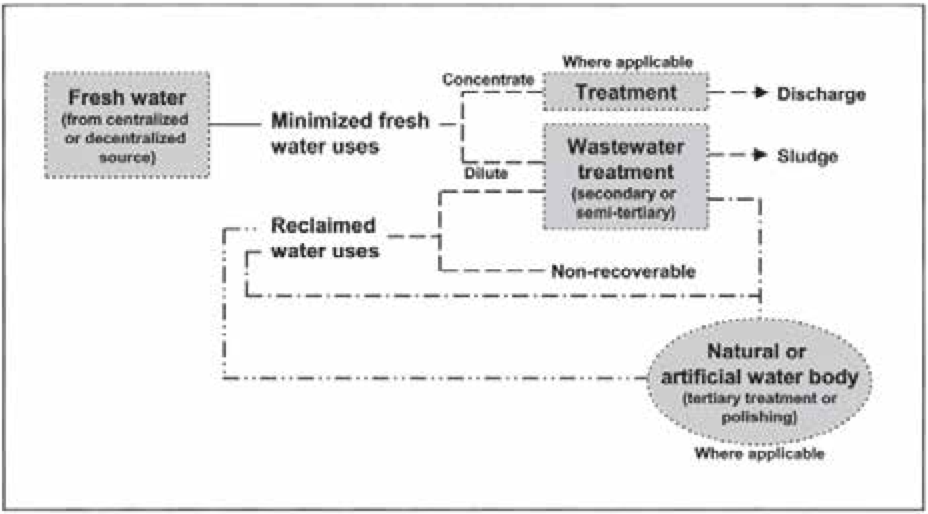

Figure 2: General configuration of a sustainable urban water system under the concept of decentralisation and reuse

Case studies

Case studies were conducted for implementing sustainable urban water systems of varied scales and varied conditions in the urban or suburban area of Xi'an, China. Details are given in the following sections.

Case 1: A college with zero discharge of wastewater

General condition

The technical college for this case study is located in the eastern suburb of Xi'an city. The campus is on top of a hill covering an area of about 87 hectares of which 45 hectares are green belts. About 25 thousands students are living in the campus. The college is away from the centralised urban water supply system and urban drainage system. Available water source is only several groundwater wells with a maximum water supply capacity of 3000 m^3/d.

System composition

Figure 3 shows the system we designed for this college. Because the groundwater from these wells can only cover part of the daily water consumption, we decided to use the treated wastewater mainly for toilet flushing in the whole campus, as well as road washing and gardening. An artificial pond with a water surface about 4000 m^2 is constructed in front of the college's main building. It receives about 600 m^3/d of the treated wastewater for replenishment. From the pond water is pumped for gardening of the green belt over the campus.

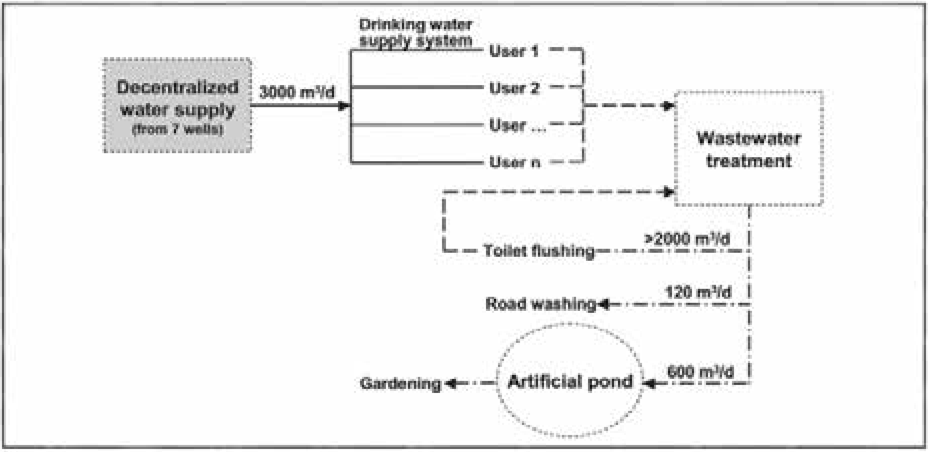

Figure 3: Composition of the system designed for a college in Xi'an suburban area

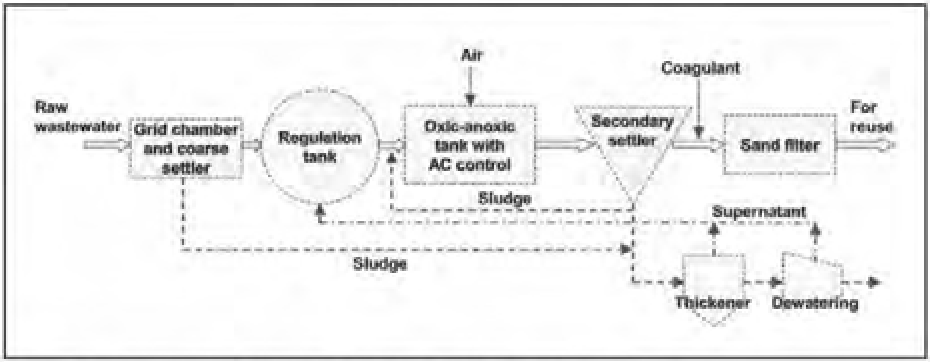

Figure 4: Wastewater treatment system applied for the college

Wastewater treatment system applied

The wastewater treatment system designed for the college is shown in Figure 4. Under the cooperation of Marche Polytechnical University, Italy, we utilised an oxic-anoxic tank with "alternate cycle" (AC) control as the main facility for organic decomposition and nitrogen removal (Battistoni et al, 2003). A sand filter with contact coagulation is provided for further treatment of the secondary effluent. It also assists phosphorus removal from the re-circulated water.

Case 2: A residential area with grey water for environmental reuse

Requirement of system design

This case study is for a pilot project in a newly developed residential community in Xi'an Urban area for grey water reuse. Environmental use, including replenishment of an artificial pond and green belt gardening, is the main purpose of treated wastewater reuse. The basic data for system design are as below:

- Served population: 1200 – 1600 residents of 400 households in 6 residential buildings
- Green belt area: 6400 m^2
- Artificial pond: water surface area 6500 m^2, average water depth 0.5 m

System composition

Figure 5 shows the system designed for the residential community. In the 6 residential buildings, dual pipe collection system is installed for separate collection of black water and grey water. The black water is treated by a septic tank system while the grey water is treated for environmental reuse. The treated grey water is led to the artificial pond for water replenishment. It also performs the function of a regulation tank for other reuse purposes. In order to control the pond water quality, part of the stored water is circulated. The average retention time of the pond water is about 15 days.

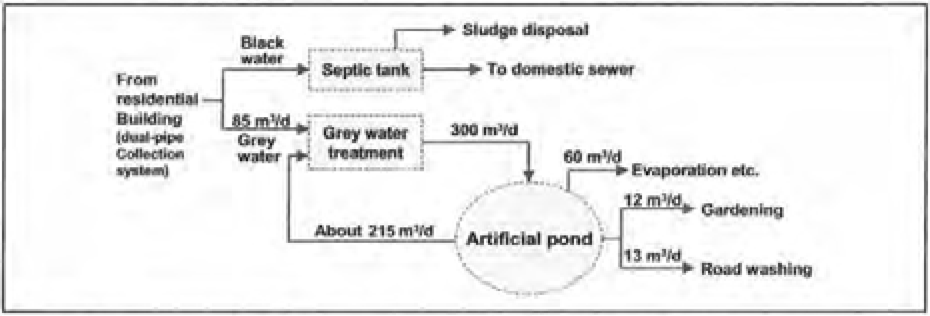

Figure 5: Composition of the system designed for a residential area in Xi'an urban area

Grey water treatment system applied

As shown in Figure 6, the grey water is treated by a process combining enhanced primary treatment with ozone enhanced flotation. The enhanced primary treatment is performed by a fluidised pellet bed bioreactor which is a specially designed wastewater treatment device for onsite wastewater treatment and can perform chemical coagulation, biological degradation, particle pelletisation and separation in one unit (Wang et al, 2007). The ozone enhanced flotation is performed by a dispersed-ozone flotation separator which is a compact device combining coagulation, ozonation and flotation in an integrated unit (Jin et al, 2006). As for the circulated pond water, it only enters the ozone enhanced flotation unit for treatment.

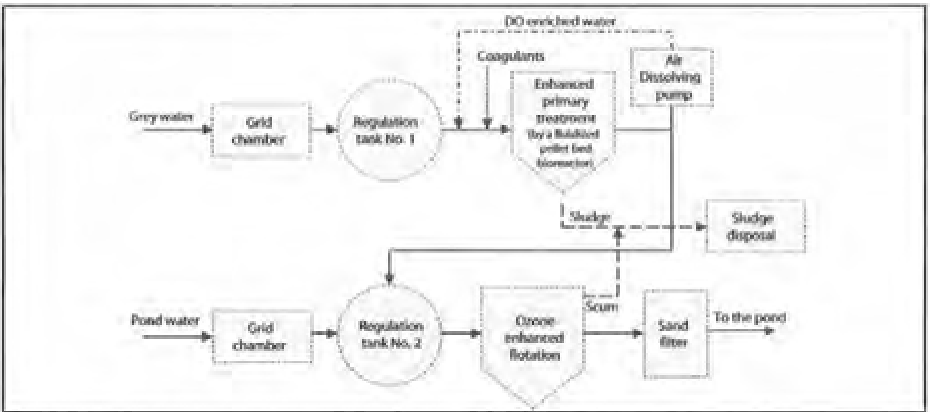

Figure 6: Grey water treatment system applied for the residential area

Case 3: A newly developed district as an independent water district

Characteristics of the district

The third case study is for a newly developed district in the southern part of Xi'an city. In short term (up to 2010) the district will cover 15.88 km^2, and in long term (up to 2030) it will cover 47 km^2. The main objective of development in this district is for tourism and entertainment because this district is rich with historical remains such as the Greater Goose Pagoda and the Tang Paradise dating back to the 7th century. The district is characterised by large water area. The North Lake with a water surface of 20 hectares has been restored recently, and the South Lake with a water surface up to 45 hectares is under restoration. The main problems related to the development of this district include allocation of water sources for lake water replenishment and construction of an environment and ecology friendly water and wastewater system.

Configuration of an independent water district

The water environmental system proposed for the district is shown in Figure 7. It is an independent water district which includes a district wastewater network for wastewater collection, a district wastewater treatment plant, an associated wetland system that performs tertiary treatment of the secondary effluent as well as storm water, and the two lakes as receivers of the treated wastewater and storm water and also regulation lakes for storage of water for various purposes of reuse in the district. Such a system fully utilizes the local geographic feature that with the two lakes at the center, an independent catchment basin is formed. Water balance calculation result (Wang et al, 2006) indicates that the quantity of the wastewater and storm water treated will be sufficient to replenish the two lakes under any season and to supply reclaimed water for environmental uses such as gardening, forestation, car washing and other miscellaneous usages. The two lakes can also provide sufficient volume to accommodate storm water in flooding season.

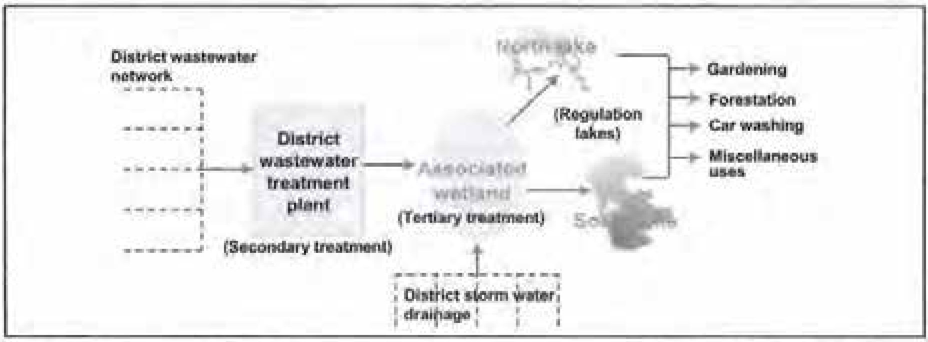

Figure 7: The water environmental system proposed as an independent water district

Summary and conclusions

In the former sections, the author explained the basic considerations on the formulation of a sustainable urban water environmental system. Such a system should have the following characteristics:

- Minimisation of fresh water supply and maximisation of treated wastewater reuse;
- Decentralisation as the basic philosophy of system design;
- Priority given to environmental reuse;
- Introduction of the "principle of ecological design" such as follow nature's example, moderate and efficient resource use, appropriate technology and green living inspiration.

Following the above mentioned principles, a sustainable urban water system was proposed as an enclosed water system with minimised supply of fresh water and minimised discharge of wastes across its boundary. As long as economically and technically feasible, source separation is recommendable and where applicable, natural or artificial water bodies are introduced into the system. These water bodies use the treated wastewater as source for water replenishment, and meanwhile play the functions of regulation basin and water quality polishing before being used for various purposes.

These considerations were realised in three case studies of sustainable urban water systems in Xi'an city, which show the advantage of such a system for mitigating water shortage and improving urban environment in the water deficient area.

Acknowledgement

The study is supported by the National Natural Science Foundation of China (Grant No. 50621140001).

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Dr. Xiaochang C. Wang

De-Central Treatment of Source Separated Urine to Enhance Central Wastewater Treatment and Protect Sewers

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Abstract: Many central wastewater treatment plants are overloaded in South-Africa. This is exacerbated by directing service delivery mostly at the provision housing and drinking water. In a case study, average wastewater inflow of 18 ML/d, with 550 gCOD/m³ and 65 gNtot/m³ is found. The activated sludge reactor does not nitrify well, and effluent nitrogen of 35 gNtot/m³ is largely in the form of ammonia (denitrification occurs mostly in clarifiers).

Urine contains up to 80% of the nitrogen load in wastewater, and around 50% of the phosphate load. In other words, the ammonium-N load from urine to this plant is almost one ton per day. Separate collection and treatment of urine can improve the effluent quality considerably. If percentages of 20%, 30% and 40% of urine were collected separately (instead of flushed and diluted with the rest of the wastewater) and treated biologically to denitrify via nitrite instead of nitrate, then the final effluent quality would improve to concentrations of 28, 25 and 22 gNtot/m³ respectively.

It has been found that nitritation (instead of full nitrification) of urine in suspended sludge bioreactors is effective at relatively long sludge ages (4 days) as compared to a SHARON process for instance. It is believed that the high concentrations of free ammonia and nitrous acid inhibit nitrite oxidising bacteria more than ammonia oxidising bacteria. Nitritation firstly means that less oxygen is required, as compared to full nitrification. It also has the advantage that less COD is required for denitrification (stoichiometrically 1.71 gCOD/gNO_2^--N vs 2.86 gCOD/gNO_3^--N, based on the catabolic half reactions). If biomass yields of 0.4 - 0.5 were assumed, 0.29 - 0.35 gNO_2^--N/gCOD could be removed via nitrite, compared to 0.17 - 0.21 gNO_3^--N/gCOD via nitrate. Denitrification also adds additional alkalinity to improve nitritation. If 9.2 gN/person.day is produced in urine, one can assume a COD load of the same quantity in urine, of which 15 – 18% is not readily biodegradable. Based on the available COD, the effluent composition from a nitritation/denitritation reactor would be 2.5 gN_2/p.d, 3.4 g NO_2^--N/p.d and 3.4 g NH_4^+-N/p.d. If this effluent is released into the sewer, denitritation will continue in sewers were biological sulphate reduction normally occurs. As long as nitrite is present alongside sulphate, it is likely that bacteria growing in a sewer biofilm will utilise this electron donor before sulphate reducers In some systems,

nitrate is actually added to sewers to prevent biological sulphate reduction which leads to sewer crown collapse, i.e. sulphate reduction leads to volatilisation of hydrogen sulphide, which dissolves in the moisture on the sewer walls and oxidises to sulphuric acid. However, external dosing of nitrate often requires external carbon dosing in a post-denitrification unit. Through the separate collection and biological treatment of urine as described, we can kill two flies with one swat. Normal urinals have already been retrofitted not to use flush water in many buildings to save drinking water. This would be the obvious place to start the implementation of separate treatment of urine. The design of a reactor is discussed in the paper.

Reconfiguration of the treatment plant can also improve the effluent quality, but a hybrid scheme of treating some urine locally, plus reconfiguring the treatment plant can improve the effluent quality dramatically. This pushes back the building a new treatment plant. The separate collection and treatment of urine is this way is a good transition technology towards greater implementation of other source control options.

Dr. Jac Wilsenach

Central to Decentral
Quantitative Monitoring of Progress Using a Rating System

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Abstract: It is important for us to be able to measure progress towards decentralisation. This is particularly so for land or real estate developments. A rating tool has been developed for determining the water use performance efficiency of land developments. The rating score also measures how well the land development is towards implementing decentralised water system. Land developments can draw supply from scheme water and dispose of wastewater through a centralised sewerage system, or they can rely on rainwater harvesting and reuse water entirely within the land development, or anywhere in between from a centralised to a decentralised system. The rating tool quantifies the volumes of water drawn from all sources and wastewater disposed or reused through all routes, compares these with best practice water use volumes and arrives at a score out of 10 (equivalent to best practice) for the land development. The algorithm for the rating tool is implemented using Excel workbook/ worksheets prompting users to enter required input values. Application to four case study land developments is presented. The rating tool will assist land developers in improving the water use efficiency of the development, in promoting their water efficient real estates to consumers, and for consumers in choosing alternative real estates, and for regulators in facilitating more efficient use of water for land development.

Keywords: land development, progress towards decentralisation, rating tool, real estate, water use efficiency.

Introduction

It is important for us to be able to measure progress towards decentralisation. This is particularly so for land developments. Land or real estate developments are clearing or re-clearing of land for building of houses and associated infrastructure (roads, school, shopping, commercial or professional centre) and they provide an opportunity for a decentralised water system to be implemented. For an urban or peri-urban setting in a developed country there is an expectation, and this is normally reinforced by government regulations, for the land development to be supplied with scheme water and for wastewater to be conveyed to a centralised sewerage system.

There are advantages and disadvantages in having a centralised water system. We have outlined these for urban wastewater (Ho and Anda, 2006). Protection of public health is a primary reason for having a centralised sewerage system, and it was the reason why it was introduced about a century ago. Cities in developing countries still experience the cost burden from endemic water-borne diseases where a proper sewerage system is lacking. Modern decentralised systems can now achieve the same public health outcome, and there are numerous examples of decentralised technologies that when maintained and operated properly can readily achieve or better the performance of centralised systems. Jamieson et al. (2006) identified and developed a data base of over 160 decentralised technologies, following the earlier work of Green & Ho (2005). Costs appear to be similar for both centralised and decentralised systems with the investment costs dominated by pipes and pumps in a centralised system and by the treatment system in a decentralised system. The distinguishing feature between the two systems is their environmental impact and sustainability. I use the term sustainability to refer to what is commonly termed the triple bottom line ofsocial, economic and environmental considerations. Having shown that the public health and economic factors are about equivalent I believe that decentralised systems have environmental advantages over centralised systems.

A centralised water system based on surface water usually relies on building a dam across a river, and consequently river water flow beneath the dam suffers. The lack of what is now termed environmental flow affects ecosystems along the river below the dam. Collected wastewater in a centralised sewerage system is generally discharged to rivers and the sea, and consequently polluting the receiving environment. Discharge effluent standards have become more stringent and this adds costs to the treatment system for the removal of the pollutants. And if treated wastewater is to be reused, for example for agriculture, then the water has generally to be transported long distances to where it is needed.

Decentralised systems have advantages when contrasted to the above for centralised systems. If water supply is derived from rainfall collected in rainwater tanks locally, then we do not affect environmental flows elsewhere. Wastewater can also be treated locally and contamination from industrial effluents can be minimised or avoided. Nutrients can be recycled locally through irrigation of parks and gardens or if desired for growing food (urban agriculture).

Much progress has been made in the development of technologies for decentralised systems. Reference has been made above of the data base developed by Jamieson et al. (2006), and management systems have also evolved. The latter has clearly shown that centralised management of decentralised systems is necessary to deliver outcomes equivalent to centralised systems. In contrast to the dominant of the activated sludge process in centralised treatment of wastewater, there are numerous treatment technologies for decentralised wastewater systems. It remains to be seen whether with maturity several decentralised technologies will predominate.

While the emphasis on research and development of decentralised technologies is commendable, we have not examined their impact on the environment and sustainability, for which decentralised systems have their advantage. For the application of a decentralised system in a land development what this emphasis has meant is that we have examined in greater detail what is within the square box of Figure 1, labelled LAND DEVELOPMENT. In other words we have attempted to apply the best technologies, for example, for rainwater harvesting, or wastewater treatment and reuse, but we have not quantitatively assessed their impact on the water streams going into and coming out of the LAND DEVELOPMENT box. The latter in fact provides the basis for determining not only the impact of a decentralised system (and its technologies) on the environment, but also the water use efficiency of the land development. Both of these measures form the basis of a water rating efficiency of land development and hence how well a decentralised system in land development performs (Hunt et al., 2006).

In this paper we describe the development of the water rating tool and illustrate its application for a number of land developments.

Methods

We have given our water rating assessment tool the term LADERS-H_2O, being an abbreviation of **La**nd **De**velopment **R**ating **S**cheme for water. We are also developing LADERS for energy to assess the energy use efficiency of a land development. LADERS-H_2O consists of 3 main steps.

1. Ranking and assigning weighting values for water flows into and out of a land development
2. Determining best practice figures for volumes of water flows into and out of a land development
3. Determining actual or projected values for volumes of water flows into and out of a land development and assigning a score compared with best practice.

Ranking and assigning weighting values for water flows into and out of a land development

Figure 1 shows the flows of water into and out of a land development. Three sources of water are available to supply water to the land development and five means for wastewater disposal. Scheme water and reticulated sewer are options for a land developer if a centralised system is desired.

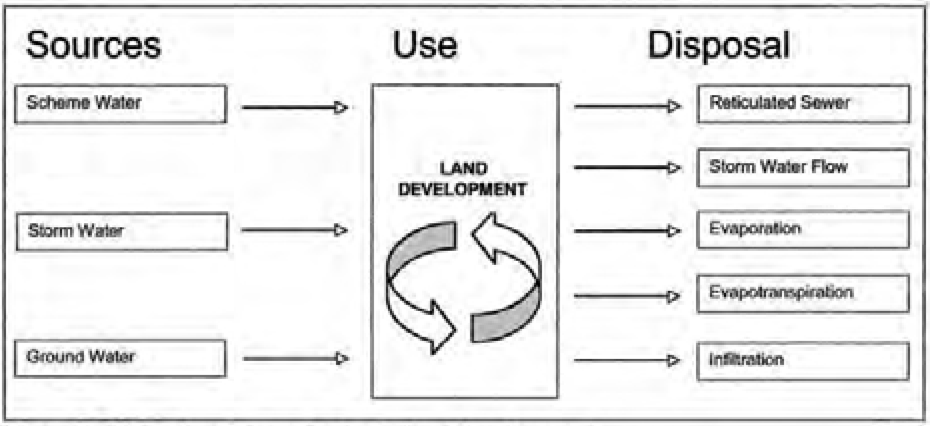

Figure 1: Water flow into and out of a land development

It may be necessary to draw water from scheme water if local rainfall, roof catchment or space for rainwater tanks is not adequate. Disposal of excess wastewater during the rainy season to a centralised sewerage system may also be necessary. If the objective of a decentralised system is to minimise impact outside the land development, then we want to minimise or avoid drawing water from scheme water or discharge wastewater to a centralised sewerage system.

For water supply we may give water from local rainfall the highest priority, followed by local groundwater which is replenished by rainfall and water from a centralised scheme the lowest priority.

For wastewater disposal our first priority can be evapotranspiration, because this is through plants and hence a means of maintaining a vegetated landscape (parks and gardens) or for growing food locally if desired. The next priority can be infiltration to the ground, because this is the means for recharging the local groundwater. Stormwater run-off can be next, because this will contribute to stream and river flow, although we may want to retain as much stormwater onsite, mimicking natural systems and may prevent flash flooding in streams and rivers. Evaporation from excessive irrigation and disposal to a centralised reticulated sewer are least desirable when we wish to minimise impact on the environment and increase water use efficiency in a land development.

If we adopt the priority scheme as described above we can develop a weighting system that reflects it (Table 1).

Table 1: Supply and disposal stream ranking and weighting for land development

Supply streams		Disposal streams	
Ranking	Weighting (%)	Ranking	Weighting (%)
1. Rainwater	80	1. Evapotranspiration	75
2. Groundwater	70	2. Infiltration	55
3. Scheme water	50	3. Stormwater run-off	50
		4. Evaporation	20
		5. Reticulated sewer	10

Assigned values for the weighting of each stream should not only reflect our priority ranking (i.e. decreasing from ranking 1 to ranking 5), but also reflect local conditions. For example, if average local rainfall is relatively abundant and availability of land for rainwater storage tank is not limiting, then the weighting factor for supplying water through rainwater harvesting can be given a higher value, while for scheme water can be given a lower value. The weighting values shown in Table 1 reflect the local conditions in south west of Australia and in particular in the Perth metropolitan region and surrounding areas. The climate of the region is Mediterranean with four distinct but mild seasons. Rainfall is primarily in winter and long-term average rainfall is about 800 mm, although a significant decrease (-20%) has been noted in the trend over the past 20 years. There is a long dry period over summer and storing harvested rainwater for this period is an important consideration. Balancing this disadvantage is the existence of an unconfined aquifer beneath the predominantly sandy soils, acting as storage for infiltrated rainwater in winter that can be drawn in summer.

Determining best practice figures for volumes of water flows into and out of a land development

Best practice volumes are estimated for each of the eight flow streams and they are discussed individually below as they involve quite a number of assumptions. Estimates will improve as we gain experience from application of the LADERS-H2O assessment tool to real cases.

Rainwater

The best practice use of rainwater is determined by calculating the water that could be harvested and used in a home with moderate ease and cost. This usage is determined using standard household usage figures for the density of housing in the development.

Different housing densities will have differing capacities to capture rainwater. For example if the development is high density the volume of water that could be captured per home is reduced as there is less roof catchment area per home than in a lower density development.

Table 2: Calculation of rainwater best practice usage

Zoning R-value*	m²/dwelling unit	% of land under roof	Roof catchment area**, m²	Tank size, kL	Max indoor use***, L/p/day
20	500	60%	150.0	10	36.5
40	250	70%	87.5	5	37.5
80	125	70%	43.8	2	36.2
160	63	80%	25.0	2	32.1

* Zoning R-value of 'n' refers to n dwelling units per hectare
** Roof catchment area for rainwater harvesting = half roof area
*** Takes into account rainfall pattern and size of tank

The household usage is based on a tank size ranging from 2kL to 10kL. The water usage is for laundry, toilet flushing and a garden tap. Household occupancy rate of was based on density from the Perth Domestic Water Use Study (Loh, 2003). Table 2 details this household (or indoor) usage further.

Groundwater

Best practice groundwater usage is determined by the volume of water required to irrigate household and public open space areas using average areas and efficient irrigation systems. Average areas of public open space and of household gardens for Perth developments were used. These averages were determined from a survey of land developments (GHD, 2005) and are dependant on zoning density. The irrigation water required for these areas was calculated assuming efficient irrigation systems (90%), low crop factor plants (0.5) and improved soil. Table 3 outlines this information further. Washing machine used-water is assumed to supplement groundwater for irrigation of private garden.

Table 3: Minimum Irrigation Use

Zoning R-value	m²/ dwelling unit	Area of private garden m²	POS* /dwelling unit m²	Occupancy Rate	Dwelling units full irrigation requirement kL/ha/yr	POS Full irrigation requirement kL/ha/yr	Washing machine water kL/ha/yr	Ground water usage kL/ha/yr
20	500	175	100	3.4	1600	850	700	1750
40	250	50	44	2.6	3200	700	1400	2500
80	125	18.75	22	2.0	4600	700	1890	3410

* POS = public open space

Scheme Water

The best practice scheme water use is determined by subtracting the best practice rainwater use from the Perth average indoor water use (Loh, 2003). Water for indoor use is therefore from rainwater harvesting, and only when this is not sufficient that scheme water is used.

Evapotranspiration

The best practice volume of water that evapotranspires is determined by a percentage of the best practice groundwater use. That percentage is determined by the efficiency of the irrigation system. For an irrigation installed professionally a value of 80% groundwater used can be assumed.

Infiltration

The best practice volume of infiltration is the sum of three infiltration flow paths. They are the infiltration from rainfall, the infiltration from irrigation use and the infiltration from seepage of any open water body. The infiltration from rainwater is the total rainwater falling on the development minus the volume of water harvested in the rainwater tanks and minus the volume of water leaving the site from runoff.

Storm water surface runoff

The volume of surface water runoff is related to the volume of water infiltrated to the ground. Because of the sandy soils and the presence of unconfined aquifer in Perth, maximising infiltration of rainwater in winter and storing it in the unconfined groundwater for withdrawal in summer when there is little rainfall is the preferred option. In this case best practice means zero surface water runoff.

Evaporation

The best practice volume of water evaporated is determined by a percentage of the best practice volume of groundwater use, because groundwater is used for irrigation and excess irrigation should be minimised under best practice. That percentage is determined by the efficiency of the irrigation system. Assuming that the irrigation is installed professionally a value of 7% evaporation is assumed.

Reticulated sewer

This volume of water is calculated from the Perth average in-house water use subtracting the volume of water used by the washing machine (this volume is used for garden irrigation, see above).

Determining actual values of volumes of water flows into and out of a land development and assigning a score compared with best practice.

For all flow streams the score of the development is determined by the difference between the actual quantity of water used by the development and the best practice volume for each flow stream. The higher the difference (deviation) the lower the score and vice versa. Differences can be negative and this results in the maximum score. The deviation calculation is given below for the eight flow streams. The equation is

Deviation = (best practice volume – actual volume)/reasonable maximum difference for Rainwater and Evapotranspiration, and for the other flows

Deviation = (actual volume – best practice volume)/reasonable maximum difference.

Score calculation

To obtain the score for each flow stream the compliment of the deviation percentage for that flow stream is multiplied by the stream weighting. This number is then normalised so that the final score is out of 10.

Flow stream score = (1 - deviation) x weighting x normalising factor

The closer the actual is to the best practice, the lower the deviation resulting in a higher score. If the deviation is negative it is set to zero resulting in the maximum score. A reasonable maximum difference is set that corresponds to a likely worst scenario if no effort is made, e.g. reliance on scheme water only and disposal of wastewater through a centralised sewer. For deviations greater than 1 a score of 0 assigned.

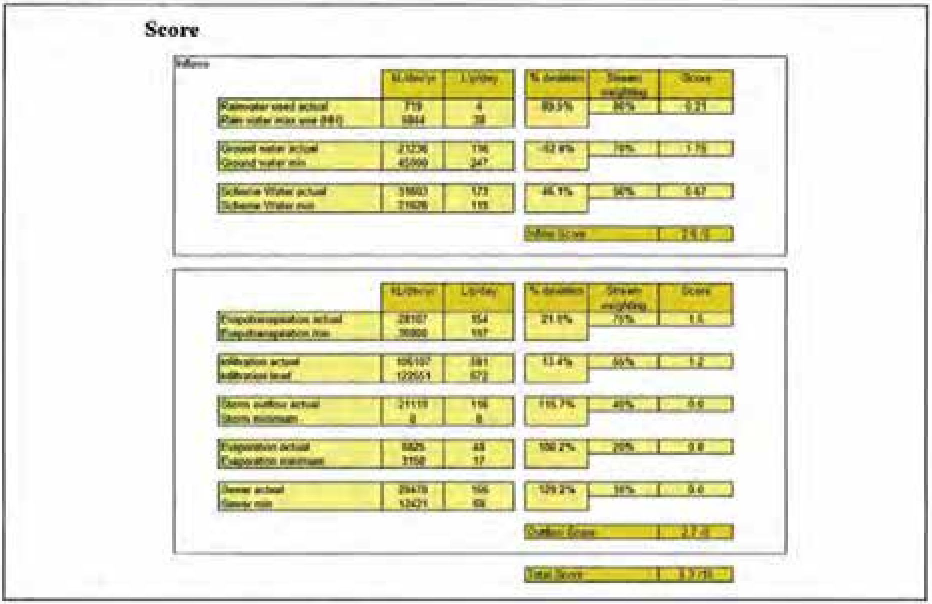

Figure 2: Example Score Calculation

The algorithm for arriving at the final score as described above is set out in an Excel workbook. Inputs as required by the algorithm are requested at appropriate points in the relevant worksheets. An example of a score calculation is shown in Figure 2.The flow stream scores for the three supply flow streams are then added to give a total score for the supply flow streams out of five. The same is done for the five disposal flow streams. These two scores are then added together to give a total score out of ten.

Application to case study land developments

The LADERS-H_2O assessment tool was applied to land developments in south west of Western Australia. Three actual case studies (South Beach, Bridgewater and Timber's Edge) were chosen not only for their innovative water systems, but also because these systems meant there was accompanying documentation. These included water balance audits, nutrient and irrigation management plans and Water Sensitive Urban Design and Integrated Urban Water Management plans. Much of the case study data was obtained from these documents produced by the developer or by consultants on behalf of the developer. A hypothetical case study considered a development in Perth that reflects current practice in the city. Pertinent characteristics of the case studies are shown in Tables 4 and 5.

Table 4: Characteristics of land development case studies

	Perth*	South Beach Fremantle	Bridgewater Mandurah	Timber's Edge Mandurah
Parameters				
Number of houses**	280	300	389	260
Occupancy/ house	3.35	3.3	1.6	2.0
Land Area	20 ha	22.1 ha	13.7 ha	18.0 ha
Land area/ house	600 m²	370 m²	230 m²	540 m²
Roof area/ house	214 m²	180 m²	132 m²	150 m²
Land Use Classification^	Urban – Green Title	Urban - Green Title	Caravan Park & Camping	Urban – Strata Title
Greywater reuse#	0%	0	100%	100%
Rain water reuse	Some rain tanks	none	Unplumbed rain tanks	Some rain tanks

* average or typical values for Pert), ** detached dwellings in all cases, # blackwater to sewer in all cases,
^ Green title = individual title for each land lot, Strata title = common title for land development.

The case studies have differing water regimes. Bridgewater has 100% onsite recycling of greywater for each house as its key feature, Timber's Edge has centralised grey water recycling and South Beach Village has no recycling system. The Perth average case study has no innovative water systems representing current practice in the Perth metropolitan area. The three real case studies have efficient irrigation systems, water-wise landscaping, promote efficient in-house water use and good storm water management.

Results and discussion

Table 5 shows the rating scores for the case study land developments. The table also shows water saving features of the land developments. The rating score correlates well with increased use of water saving or efficient appliances, techniques or design.

Table 5: Rating scores for case study land developments

Land development	Water efficient appliances	Greywater reuse	Drip irrigation	Rainwater tanks	Water efficient landscape	Water balance closure*	Rating score (10)
Perth average	-#	-	-	-	-	2%	2
South Beach	Y#	-	-	-	-	3%	3
Bridgewater	Y	Y	Y	Y	Y	12%	6.5
Timber's Edge	Y	Y	Y	-	-	8%	5
# - = no, Y = yes * Closure = difference between total inflows and total outflows							

Accurate estimates of water inflows and outflows are important in using the assessment tool. An indicator for the accuracy of the estimates is the difference between the total of the inflows and outflows, called the water balance closure. A closure of less than 10% is generally considered good, and this was the case for the estimates for the case studies (Table 5), except for Bridgewater. Further metering of flows can achieve better water balance closure.

Quite a number of assumptions are made in deriving the final rating score for a land development. In particular the derivation of the best practice figures for each flow stream can be refined to reflect improvements or advances in technologies, and will therefore change with time. The rating score values will correspondingly change with time (decrease with advances in technology and practice for the same land development unless a retrofit or better management practice is implemented). Viewed in this way the score should be regarded as an indication of the water use performance efficiency and not an absolute value. Its utility is in comparing between land developments and for a particular land development the relative improvements in overall water efficiency when different techniques, measures or management practices are adopted.

Utility of the rating tool

As indicated above the rating tool will be useful for a land developer to assess the water use performance efficiency of a land development, to compare alternatives for improving the efficiency and assist with choosing alternatives which are more cost-effective.

The rating tool will be useful to regulators who want to promote the efficient use of water. Appliances are now star rated for their water (and energy) use efficiency. The higher the number of stars the higher the efficiency, and the rating will assist consumers in choosing the appropriate appliance taking into account not only price but efficiency, with the former affecting investment cost and the later operating cost. In the same way land developments can be rated. This rating can be employed by land developers to market their land developments to home buyers. They are currently doing this, but their claims are not supported by a rating scheme.

Land developers in Perth are currently required to prepare a water management plan and in some cases a nutrient management plan. The former is largely driven by the decreasing amount of rainfall and hence less scheme water supply and availability of local groundwater, while the latter by the desire to protect surface and groundwater from nutrient pollution. The next logical step is for regulators to establish a land development water use performance efficiency rating that will facilitate both land developers to market their land developments and consumers to choose which land development to live in.

Refinement to the rating tool

The rating tool provides flexibility for assigning ranking for preferred use of sources of water and preferred route of disposal of wastewater. While the ranking as proposed is robust, the assignment of weighting factors relies on local factors. These include whether rainfall is relatively abundant, whether there is groundwater that is naturally recharged by rainfall and ease of withdrawal of the groundwater, the slope of the landscape that will govern how easily stormwater is retained on site, the nature of the soil and underlying materials that may or may not allow rapid infiltration, and thus local climatic, physical and geological features, and of course existing water supply and wastewater sewer infrastructure. Refinement of the rating tool could provide guidance on allocating weighting factors that will remove much of the subjectivity involved.

The rating tool requires that best practice water use and wastewater reuse and disposal be quantitatively determined. As discussed above best practice will continue to improve. What is considered best practice now may not be best practice in the future. Furthermore local best practice may lag behind international best practice. Using local best practice is preferred if the rating tool is to be used to rate local land developments and how future developments can be improved. Using international best practice may not provide a fair comparison because best practice is affected by local factors (climatic, physical and geological factors cited above), so that any comparison should select similar local factors.

Having discussed possible refinements to the rating tool we must not forget that the purpose of the rating tool is to provide a guide for comparing land developments and not absolute score values for the land developments. Precise values are therefore not needed, but only good estimates to allow comparison of land developments to be made by land developers, consumers and regulators.

Measuring progress from centralised to decentralised water systems using the rating tool

The rating tool provides a means of measuring progress from a centralised water system to a decentralised water system. If the best practice conditions for a land development are set with zero flow of water from scheme water and zero flow of wastewater to a centralised sewerage system, then the score will indicate how well the land development is in performing as a decentralised system. The score is a quality measure with the higher score indicating better achievement.

The rating tool highlights the need to consider the broader questions of whether it is realistic to set best practice as equivalent to disconnecting to (or independent of) a centralised water and wastewater systems. In water deficient areas rainfall precipitation on the land development may not be sufficient, and water will have to be imported. Even in areas where rainfall is adequate there is the question of how much water should be retained within the land development area, and whether water is released through run-off to local stream outside the land development or through groundwater flow. In this regard there is an imperative in mimicking nature, i.e how water would have behaved in the natural uncleared area prior to any development.

As the rating tool is applied to more case studies with differing local conditions we will gain greater experience that will provide guidance on how to apply it to general and particular situations.

Conclusions

A rating tool has been developed to assess the water use performance efficiency of land developments. The rating tool provides a structured, systematic and quantitative way all to assess the water flow streams into and out of a land development. It is a quantitative tool that gives a quality rating of not only water use efficiency of a land development, but also progress towards best practice decentralised systems.

The algorithm for the rating tool has been incorporated into an Excel workbook that prompts users to provide input values and relevant local conditions and arrive at the final score. It will be useful for land developers to assess and promote its land development water sustainability, for consumers to choose alternative land developments and for regulators to facilitate more efficient water use at the land development scale.

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Prof. Dr. Goen Ho

Is Decentralisation Low-Tech or High-Tech?

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Abstract: The traditional wastewater collection and treatment system in developed countries, as a result of a historical development, is an end-of-pipe centralized system. However, nowadays it is acknowledged that centralised systems, spending a lot of money just for conveying a large amount of water to a central wastewater treatment, might not be the best solution for sanitation and wastewater treatment. Recently, decentralized systems are discussed for a variety of situations that occur worldwide, such as sparsely populated regions, developing countries as well as single large buildings in megacities. As, however, decentralized systems usually include small treatment units, it is to question whether these are "low-tech" cheap and simple to build and to operate units suspected to show poor treatment efficiency or "high-tech" unites that achieve excellent treatment results, but are suspicious to high investment and operation cost as well as high complexity concerning operation, thus only feasible where skilled personnel is available to operate them. It is shown that today a broad variety of small system units are available and that the main concern is to find the appropriate technology rather than distinguishing between "low-tech" or "high-tech", and that "high-tech" systems must be refined to be simple and cheap in investment and operation efforts.

Keywords: appropriate wastewater treatment technology, decentralized systems, mechanical wastewater treatment, membrane bioreactors, rainwater infiltration.

Introduction

The traditional wastewater collection and treatment system in developed countries is a collect-it-all-and-treat-it-at-the-end-of-the-pipe centralized system. This is the result of a historical development which was felt necessary to improve sanitation in the fast-growing environments of European cities in the mid of the nineteenth century, and it showed great advantages in the struggle against diseases and epidemics. Grown through decades, this system was the „developed countries system", and thus was the pattern for the sanitation scheme in developing countries, too.

In the meantime it was found that this sanitation philosophy might not be the most advantageous one in every situation. Spending a lot of money just for conveying a large amount of water to a central wastewater treatment might not be the best solution for sanitation and wastewater treatment in any situation.

Consequently, a move towards decentralized systems is found today, and some experts even go as far as to condemn what was installed in the developed countries during the last century, which might be in fashion with young wrathful scientists but obviously turns a blind eye to the needs of our ancestors. However, we always must be open to new and deeper insight in what may be the most advantageous sanitation scheme, and no doubt, decentralization is a strategy that offers a lot of advantages. However, concerning the boundary conditions as well as the applicable technologies, "decentralisation" is not just one solution for one case, but can be applied to a variety of preconditions and can utilise a wide range of techniques to solve different tasks in heterogeneous situations. Thus, it is a superordinate concept with a broad range of possible technical solutions.

It is worthwhile to mention at this point that decentralisation of the sanitation system should be regarded as a concept that is broader than just sanitation and wastewater treatment, in that it embraces topics like waste utilization, fertilizer recovery and, of course, water reclamation and water reuse.

Decentralisation – where to be applied?

In developed countries?

Decentralisation is not just an issue with developing countries. According to Dorgeloh and Defrain (2006), in Germany around 2 million small wastewater treatment plants existed in 2004. These plants serve sparsely populated areas, where sewer systems were considered too expensive due to long distance to the next centralised wwtp. Thus, developed countries have a demand for decentralisation.

In addition, in developed countries huge amounts of money must be spent every year to maintain centralised systems operational, and within thus scope it is worthwhile to rethink the centralised sanitation philosophy with the aim of identifying possible advantages when changing from centralised to decentralised systems. However, this approach meets an accepted sanitation scheme existing already, and thus there is a certain resistance against a switchover, which was highlighted by Wegelin and Truffer (2006) for Switzerland as an example for a highly developed country. Figure 1 classifies innovations in the wastewater field concerning their complexity and their degree of need for change and rethinking, denoted as "radicalness".

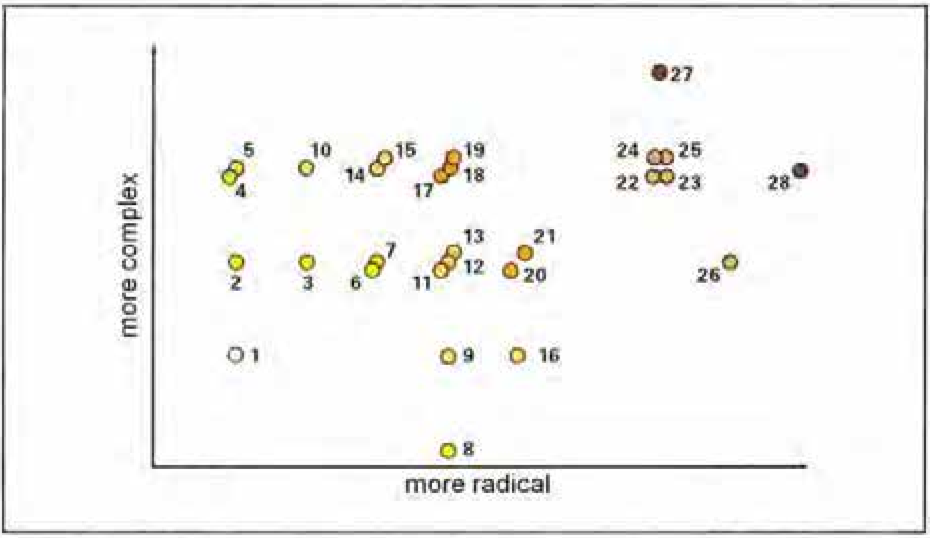

Figure 1: Classification of innovations in the wastewater field concerning their complexity and their degree of need for change and rethinking, denoted as "radicalness", Wegelin and Truffer (2006)

As examples for the scope of the classification, some numbers are explained:

1 – aeration systems, 3 – Compost toilet, 4 – Filtration with Ecolith, 8 – constructed wetlands, 9 – solar sludge drying, 11 – privatizing, 14 – water saving sanitary installations, 15 – decentralised rainwater reuse, 16 – heating & cooling with wastewater, 18 – UV treatment, 21 – waterless urinal, 24 – greywater recycling, 26 SBR on existing wwtp, 27 – decentralised small wwtps, 28 – MBR on existing wwtp

The diagram reveals that in a developed country with a large deal of existing central systems, decentralisation is attributed to be a quite radical approach. Using decentralised small wwtps is attributed to be the most radical approach in a developed country.

Nevertheless, rural or sparsely populated areas even in highly developed countries have a tradition, and here the main questions are:

- How to improve the efficiency of the treatment process itself: small wwtps show a disproportionately high contribution to river pollution. According to Dorgeloh and Defrain (2006), small wwtps discharge 0.5% of the total wastewater/stormwater but are responsible for 3.0% of the total TOC load, giving a factor of 6, which is unacceptable on the long run.

- How to introduce new elements to the existing decentralised systems like rainwater reuse, greywater reuse or even a resource-oriented flow management system, recovering nutrients from the different wastewater flows.

In developing countries?

Decentralisation of course is a much easier task in situations where the sewer network as the backbone of a centralised system does not yet exist, and in such a case – which is widely found in developing countries – the answer should not just be "do it like the developed countries did". Instead, a decision must take into account many aspects, and many of these favour decentralised systems.

There is a very strong linkage between wastewater disposal methods in developing countries and the general health of the population. These problems could be greatly reduced or prevented by the utilization of well known excreta disposal and small wastewater treatment system technologies, but the development of more innovative onsite systems is needed (Randall, 2003).

Especially a holistic approach including water reclamation or even water reuse, irrigation, reclamation of nutrients and strategies for energy recovery from organics including sludge and domestic waste will show the possible benefits that can be achieved using decentralised systems as well as centralised systems.

In megacities?

Trend goes to megacities, as can be observed worldwide. Megacities grow in developing countries, but also, although to a lower extent and with different boundary conditions, in developed countries. Megacities suffer from a large number of problems, of which water supply and sanitation systems as well as waste management are not the most unimportant ones. Environmental pollution problems climax in these settings.

The city of Beijing faces a severe fall of groundwater level, and huge efforts are necessary to provide the city with sufficient drinking water. According to the keynote of the Chinese Vice Minister of Construction, Qiu Baoxing (2006), possibly the project of redirecting huge water flows from Southern China to the Capital region might be unnecessary if all efforts would be taken to minimize water use in Beijing, and this, besides efforts concerning water losses in the water supply systems, explicitly includes in-house water reclamation and water reuse systems, so called "green houses" in Beijing. This means integration of rainwater reclamation as well as greywater reuse after an in-house treatment.

Thus, although operating in adjacent buildings, these systems definitively are decentralised systems, reducing freshwater demand as well as performing stand-alone treatment steps which are defined according to the aims of the respective measure and legislation. It is very likely that approaches like this will be found throughout Asian megacities, especially China and India, very soon.

Decentralisation – which technologies to apply?

Low-tech? High-tech?

It is quite difficult to correctly discriminate what is "low-tech" and what is "high-tech" with respect to wastewater management and treatment. Usually, "low-tech" is associated with properties like

- Simple system
- "No moving parts"
- Low investment cost
- Low energy requirements
- Low O&M necessary
- Can be operated by low-skilled personnel

Consequently, "high-tech" processes, treatment methods or technical units are usually attributed with the antipodal characteristics.

However, in a broader view, the single process itself is not sufficient to define whether a solution is low-tech or high-tech. Instead, the general concept must be taken into consideration when philosophizing on low-tech and high-tech solutions, as was indicated above already.

Also, it is quite difficult to list completely all available technologies that could possibly be included in an integral sanitation concept due to the variety of applications (developed, developing countries, megacities) and to the number of developments suitable for incorporation. Green and Ho (2005) methodically searched for small scale sanitation technologies serving household sized capacities on the internet and in literature. They identified an extensive range of technologies and categorised these according to the major treatment processes for the different types of waste sources. Thus, their paper still may serve as a major source of different systems as well as general approaches. Further searches for technologies could be beneficial due to the large number of internet sources and the ongoing development of new or newly combined treatment systems.

However, some typical examples may be shown here. Regarding different stages of complexity, Morel and Diener (2006) illustrate three applications of greywater management in developing countries, as can be seen in Figure 2. Figure 3 reveals the effect of the greywater system installed in Mali and makes clearly visible that even simple, low-tech systems can contribute remarkably to improvement of public appearance and health. However, even if no skilled personnel is required, it is most important that people who use these systems – and have to do O&M by themselves – must understand the systems in order to keep them running properly.

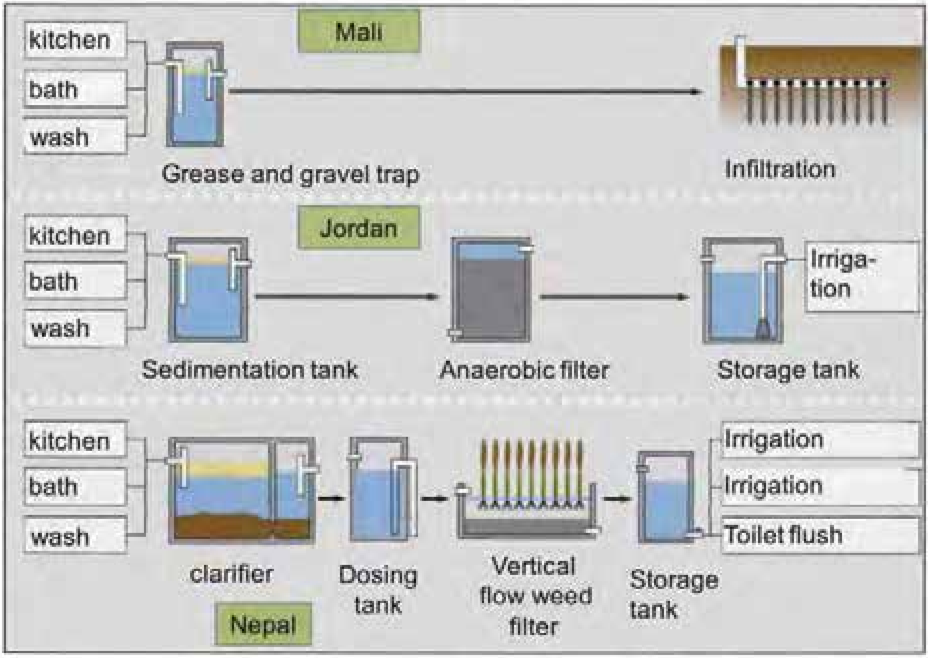

Figure 2: Greywater systems of different complexity in three low and middle income countries, Morel and Diener (2006) ...

Figure 3: ... and the effect of the system installed in Mali: before (left) and after (right) installation of the greywater system, Morel and Diener (2006)

An example from "developed countries" is shown in Figure 4.

Figure 4: Upgrading of a low-tech small wwtp to a high-tech MBR system by introducing a membrane module plus aeration, Dorgeloh and Defrain (2006).

Here an upgrading took place creating a high-tech MBR system out of a low-tech small wwtp

It can be expected that future environmental and public health pressures in developed countries will require increasingly stringent effluent limitations for small and on-site wastewater treatment systems, based primarily on nutrient discharges. As can be seen from this example, technology is there and complexity is acceptable, as well as further developments will lead to even lower degree of O&M requirements as well as to even better and more stable effluent concentrations.

Otterpohl (2006) unveiled a vision that can be seen in Figure 5.

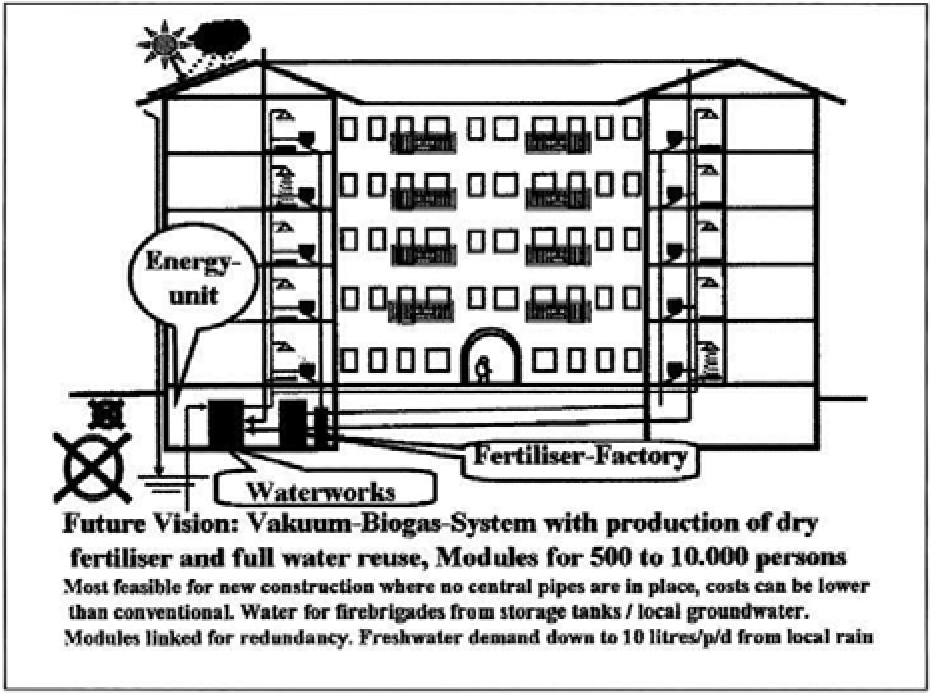

Figure 5: Future vision: system including biogas, fertiliser and water reuse, Otterpohl (2006)

As mentioned before, the holistic approach also includes renewable energy, fertilizer recovery and waste management. Serving as another example, a very innovative "high-tech" system was presented by Kranert et al. (2006) incorporating all theses aspects. The basic flow scheme is depicted in Figure 6.

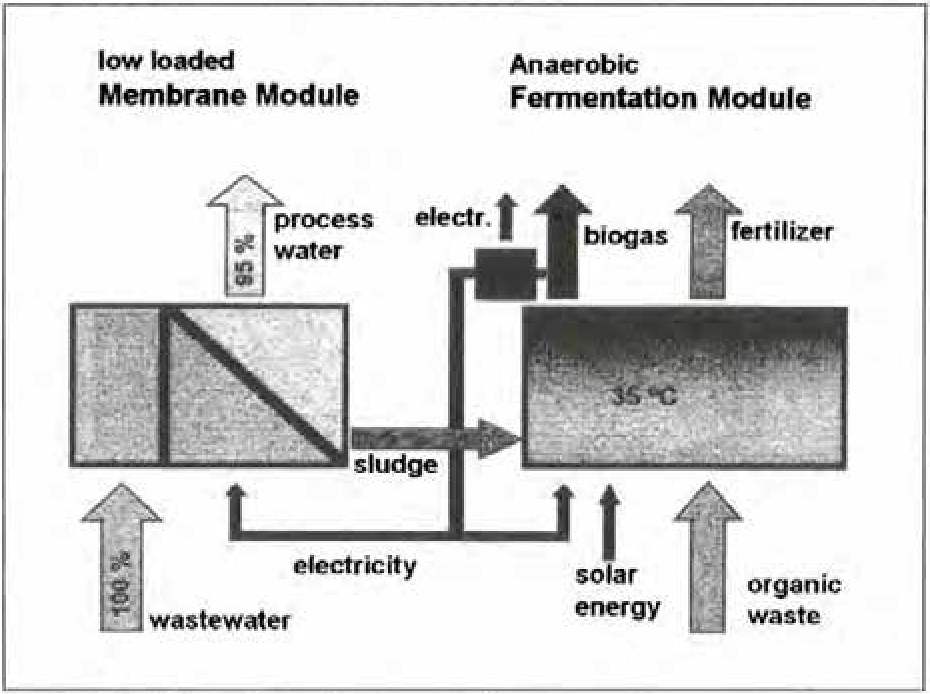

Figure 6: Basic flowscheme of an integrated wastewater/waste management system incorporating renewable energy and fertilizer production, Kranert et al. (2006)

Last and not least, attention should be drawn to wastewater treatment systems that do not include biological degradation, but improved physico-chemical treatment, as outlined by Libhaber (2004). These systems can achieve a high efficiency without a biological process and are able to serve as full treatment systems, meeting the requirements for good practice of wastewater management not only in developing, but also in developed countries, as was shown by Rusten and Ødegaard (2006).

Conclusions

The question asked in the title of this paper must be answered, and the answer is that decentralisation may be low-tech as well as high-tech. The more crucial points are that decentralisation

- Is accepted as a promising strategy to deal with the sanitation problems of the world – first, second and third world,
- Is a very valuable tool necessary to achieve the millennium development goals as set up by the United Nations,
- Must take into account not only stormwater and wastewater issues, but also should include further topics: fertilizer recovery, waste treatment, renewable energy production – sustainable strategies to improve the environment and living conditions on earth
- Needs more research in order to enhance what nowadays is acknowledged as "high-tech" – and identified as highly efficient – in order to overcome the disadvantages of high-tech towards low investment and O&M costs, lower demand on skilled personnel and low energy consumption without losing reliability of the processes involved and the overall efficiency of the total sanitation concept.

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Prof. Dr. Franz-Bernd Frechen

Session V – Discharge to Reuse
Introduction

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Milestones in the Reuse of Municipal Wastewater

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Abstract: Milestones in the reuse of treated municipal wastewater are reviewed with respect to water quality, categories of water reuse, and milestone water reuse studies. An option for indirect potable reuse is discussed in light of various implementation hurdles.

Keywords: Water quality, wastewater, water reclamation and reuse, water reuse studies.

Introduction

Wastewater reclamation and reuse provides a unique and viable option to augment traditional water supplies. As a multiple-disciplined and important element of integrated regional water resources management, water recycling and reuse can help to close the loop between water supply and wastewater disposal as well as integrating water and reclaimed water supply functions. More specifically, water reuse accomplishes two important functions: (1) the treated effluent (reclaimed water) is used as a water resource for beneficial purposes, and (2) the effluent is kept out of streams, lakes, and beaches; thus, reducing pollution of surface water and groundwater.

The foundation of water reuse is built upon three major principles: (1) providing reliable treatment of municipal wastewater to meet strict water quality requirements for the intended reuse application, (2) protecting public health, and (3) gaining public support and acceptance. Whether water reuse is appropriate for a specific locale depends upon careful economic considerations, potential uses for the reclaimed water, and the relative stringency of waste discharge requirements. Public policies can be implemented that promote water conservation and reuse rather than the costly development of additional water resources with considerable environmental expenditures. Through integrated regional water resources planning, the use of reclaimed water provide sufficient flexibility to allow a water agency to respond to short-term needs as well as increase the reliability of long-term water supplies in the region.

In this paper, the milestone events in the reuse of municipal wastewater in the United States are reviewed and the future trends in water reuse are discussed. The paper is organized with the following topics: (1) spectrum of reclaimed water quality, (2) current water reuse from municipal wastewater in the United States, (3) categories of wastewater reuse, (4) three milestones in water reclamation and reuse studies, (5) an option for indirect potable reuse, and (6) observations and future trends in water reuse.

Spectrum of reclaimed water quality

As water is used for various applications, the quality changes due to introduction of various constituents. A conceptual comparison of the extent to which water quality changes through municipal applications is shown in Figure 1. Today, technically proven water reclamation or water purification processes exist to provide water of almost any quality desired.

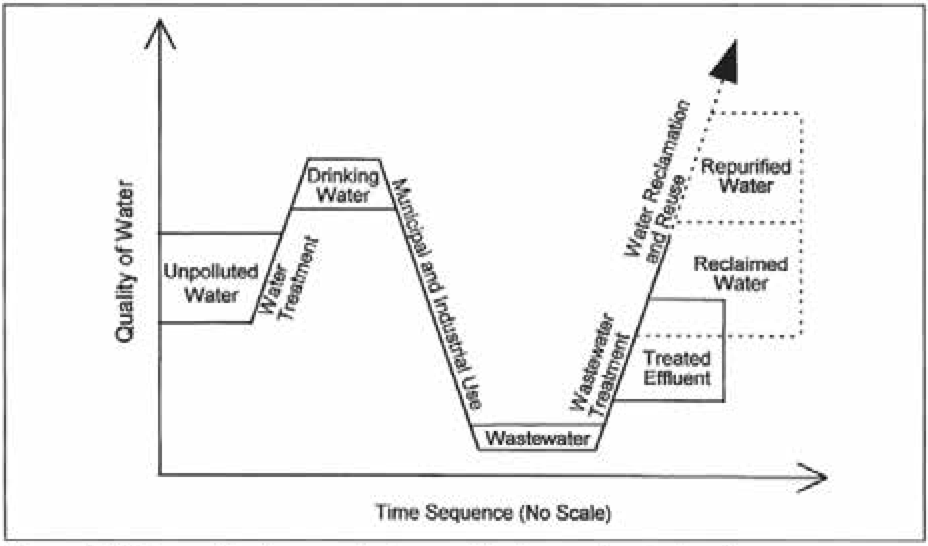

Figure 1: Water quality changes during municipal uses of water in a time sequence

Water reuse from municipal wastewater in the United States

Current national water reuse estimate is approximately 9.8 x 10^6 m^3/d (2.6 x10^3 Mgal/d) or 3.6 x 10^9 m^3/yr and growing about 15 percent annually (WateReuse Assoc., 2005). California reuses approximately 635 x 10^6 m^3/yr in 2002 (about 10 percent of treated municipal wastewater) and in 2030 the amount of water reuse is estimated to be 2500 x 10^6 m^3/yr (about 23 percent of treated municipal wastewater).

Agricultural and landscape irrigation is the largest current use of reclaimed water. Irrigation uses can offer significant opportunity since, in many arid and semi-arid regions of the world; approximately 70 to 80 percent of applied water is used for irrigation. The historical application for agricultural purposes continues to dominate worldwide; for example, in California, water reuse for agricultural irrigation amounted to approximately 70 percent of the total reclaimed water used. At least 20 different food crops were irrigated with reclaimed water, as well as at least 11 other crops and nursery products.

The largest industrial application of reclaimed water in California is for paper manufacturing. Other significant industrial uses were power plant cooling, watering of log decks, and cooling water in a steel manufacturing plant.

Categories of wastewater reuse

In the planning and implementation of wastewater reclamation and reuse, the intended water reuse applications govern the degree of wastewater treatment required and the reliability of wastewater treatment processes and operations. In principle, wastewater or any marginal quality waters can be used for any purpose provided that they are treated to meet the water quality requirements for intended use. Seven categories of water reuse of treated municipal wastewater are identified in Table 1, along with treatment goals and example applications. Large quantities of reclaimed municipal wastewater have been used in four reuse categories: agricultural irrigation, landscape irrigation, industrial recycling and reuse, and groundwater recharge.

Table 1: Applications for using reclaimed water with treatment goals and example applications

Water reuse	Treatment goals	Example applications
Urban use Unrestricted	Secondary, filtration, disinfection BOD_5: ≤ 10 mg/L; Turbidity: ≤ 2 NTU Fecal coliform: ND[b]/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	Landscape irrigation: Parks, playgrounds, school yards; Fire protection; Construction; Ornamental fountains; Recreational Impoundments; In-building uses: toilet flushing, air conditioning
Restricted access irrigation	Secondary and disinfection BOD_5: ≤ 30 mg/L; TSS: ≤ 30 mg/L Fecal coliform: ≤ 200/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	Irrigation of areas where public access is infrequent and controlled Golf courses; Cemeteries; Residential; Greenbelts
Agricultural irrigation Food crops	Secondary, filtration, disinfection BOD_5: ≤ 10 mg/L; Turbidity: ≤ 2 NTU Fecal coliform: ND/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	Crops grown for human consumption and consumed uncooked
Non-food crops and food crops consumed after processing	Secondary, disinfection BOD_5: ≤ 30 mg/L; TSS: ≤ 30 mg/L Fecal coliform: ≤ 200/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	Fodder, fiber, seed crops, pastures, commercial nurseries, sod farms commercial aquaculture

Recreational use Unrestricted	Secondary, filtration, disinfection BOD_5: ≤ 10 mg/L; Turbidity: ≤ 2NTU Fecal coliform: ND/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	No limitations on body-contact: lakes and ponds used for swimming, snowmaking
Restricted	Secondary, disinfection BOD_5: ≤ 30 mg/L TSS: ≤ 30 mg/L Fecal coliform: ≤ 200/100 mL Cl_2 residual: 1 mg/L; pH 6 to 9	Fishing, boating, and other non-contact recreational activities
Environmental enhancement	Similar to unrestricted urban uses Dissolved oxygen; pH Coliform organisms; Nutrients	Use of reclaimed wastewater to create artificial wetlands, enhance natural wetlands and sustain stream flows
Groundwater recharge	Site specific	Groundwater replenishment Salt water intrusion control Subsidence control
Industrial reuse	Secondary and disinfection BOD_5: ≤ 30 mg/L; TSS: ≤ 30 mg/L Fecal coliform: ≤ 200/100 mL	Cooling-system make-up water, process waters, boiler feed water, construction activities and washdown waters
Potable reuse	Meet requirements for safe drinking water; specific regulations do not exist and specific goals remain unresolved at present	Blending with municipal water supply (surface water or groundwater)

[a] Adapted from U.S. Environmental Protection Agency, 1992.
[b] Not detected.

In some situations, however, indirect potable reuse may be the best alternative to make beneficial use of resources. The lack of infrastructure for nonpotable water reuse such as reclaimed water distribution lines and pumping stations may be too expensive to be viable in the implementation in a timely manner. An example of cost estimates for various water reuse applications is shown in Table 2.

Table 2: Comparative cost estimates for various water reuse options[a]

Process	3.8 x 10³ m³/d (1 Mgal/d)	18.9 x 10³ m3/d (5 Mgal/d)	37.8 x 10³ m³/d (10 Mgal/d)	94.6 x 10³ m³/d (25 Mgal/d)
Direct aquifer injection, \$/m³	5.28	2.94	2.93	2.93
Indirect potable reuse[b], \$/m³	4.91	2.99	2.46	2.30
Irrigation[c], \$/m³	3.72	3.88	3.88	3.88
Rapid infiltration basin[d], \$/m³	1.40	1.77	2.22	3.54
Wetlands[e], \$/m³	0.95	0.95	Unknown	Unknown

Adapted from Beverly, et al., 2001.

[a] All costs were based on a 30-year lifespan and 8% interest. Both the indirect potable reuse option and the direct aquifer injection option include costs for treating the water with membranes (a dual train of RO or NF combined with MF or UF as a pretreatment) prior to discharge. The direct injection option includes the cost of injection wells and pumps.
[b] Assumes gravity discharge and no permitting issues.
[c] Source: average cost quotes from municipalities offering public access irrigation (does not include wet weather back-up costs).
[d] Source: PB Water files for areas highly suitable for rapid infiltration basins.
[e] Source: average cost quotes from municipalities, covers wetlands construction and O&M only where available, the highest capacity quoted was 18.9 x 10³ m³/d (5 Mgal/d). Land costs (which could significantly affect this number) were not included, due to widely varying real estate costs).

Three milestones in water reclamation and reuse studies

To highlight significant findings in water reclamation and reuse, the following three milestone projects and studies are briefly summarized (Asano et al., 2007).

Pomona virus study – County sanitation districts of Los Angeles County, Los Angeles, CA (1977)

The Pomona Virus Study was initiated in 1977 to determine the cost effectiveness of alternative treatment systems that were capable of achieving 5 log (~99.999 percent) removal of waterborne enteric viruses, equivalent to the treatment level typically obtained with a full tertiary treatment system consisting of chemical coagulation, sedimentation, and filtration after biological secondary treatment. The alternative systems investigated included direct and contact filtration with low dose (5 mg/L) alum coagulation, followed by disinfection (theoretical chlorine contact time of 2 h with 5 mg/L free and 10 mg/L combined residual Cl_2 and a modal contact time between 90 to 100 min, based on peak dry weather flow).

Conclusions drawn from the frequency distributions of various filter effluent turbidities were that an effluent turbidity of 2 NTU or less was achieved approximately 90 percent of the time for the alternative treatment trains, and greater than 99 percent of the time for the full treatment train. In addition, if the filter influent turbidity could be maintained at 4 NTU or less through proper pretreatment, an effluent turbidity of 2 NTU could be achieved more readily. Based on the comparison of turbidity and virus removals, and an analysis of treatment costs, direct filtration was considered the most cost-effective predisinfection treatment alternative to full treatment for producing an essentially pathogen-free disinfected effluent (Dryden et al., 1979; Chen et al., 1998).

A series of specific design and operational requirements followed from the Pomona Virus Study including "Policy Statement for Wastewater Reclamation Plants with Direct Filtration" (State of California, 1988), which was incorporated into the current water recycling criteria *(Code of Regulations, Title 22, Division 4, Chap. 3, Water Recycling Criteria).*

Monterey water reclamation study for agriculture – Monterey regional water pollution control agency, Monterey, CA (1980–1985)

The Monterey Wastewater Reclamation Study for Agriculture (MWRSA) was a 5-yr field investigation of the safety and feasibility of irrigating artichokes and raw-eaten vegetables such as lettuce, broccoli, celery, and cauliflower with disinfected tertiary reclaimed water. During the early planning stage, Castroville, California was selected as the site for the MWRSA project and an environmental assessment was completed. Next, the existing 1500 m^3/d Castroville treatment plant was upgraded and a field–scale pilot treatment plant for full treatment and direct filtration was designed and constructed, and experimental field plots were established. The 5-yr field study began in 1980 and continued through 1985 (Sheikh et al., 1990).

The tertiary treatment processes were designed based on the conclusions drawn from the Pomona Virus Study. Virus seeding studies were performed, and conclusions drawn from data gathered during these studies were that both full treatment and direct filtration (which included chlorination with 90-min modal contact time) were capable of reducing the numbers of enteric viruses by 5 log or more; a reconfirmation of the Pomona Virus Study. Thus, the acceptance of direct filtration as an equivalent substitute for the full treatment process train specified in the California Title 22 Water Recycling Criteria was a direct result of the MWRSA pilot field testing. Direct filtration has become a widely practiced technique for tertiary-treated reclaimed water.

Conclusions drawn from data gathered during the 5-yr MWRSA were that food crop irrigation was safe and acceptable with respect to pathogens, heavy metals, and crop quality and yield. No drawbacks were observed in terms of soil or groundwater quality degradation. Irrigation with tertiary treated and disinfected (with chlorine) reclaimed water produced excellent yields of high-quality produce. Cauliflower and broccoli yields were significantly improved by irrigation with reclaimed water. The MWRSA successfully proved the acceptability of irrigating food crops with reclaimed water from the standpoints of regulatory agencies, farmers, consumers, and wastewater treatment agencies (Sheikh et al., 1998; 1999).

Water factory 21 and the subsequent groundwater replenishment system at the Orange County water district, CA (1976-2004 and 2005 to date)

Orange County is located on the Southern California coast between Los Angeles County and San Diego County. The Orange County Water District (OCWD) manages the groundwater basin that serves approximately 2.3 million people (OCDW, 2007).

Water Factory 21 was a 56,800 m^3/d (15 Mgd) advanced wastewater treatment plant designed and constructed in 1976 to improve the quality of biologically treated municipal wastewater so that it could be used to provide the injection water for a seawater intrusion barrier system. Processes included were lime treatment, ammonia stripping, breakpoint chlorination, activated carbon adsorption, reverse osmosis, and final chlorination. Because of interest in the use of reclaimed water to augment the domestic water supply, extensive evaluation was made for the effluent quality and efficiency of treatment for inorganic, organic, and biological contaminants.

Built upon the experiences obtained from the Water Factory 21, the current Groundwater Replenishment (GWR) System is a water supply project designed to ultimately reuse approximately 173×10^6 m^3/y (140,000 ac-ft/y) of advanced treated reclaimed water. According to the OCWD, the GWR System has been implemented to:

- Protect the groundwater basin from overdraft and seawater intrusion
- Reduce the amount of treated wastewater discharged to the ocean from OCSD
- Reduce reliance on other water sources (i.e., imported waters from the Colorado and Sacramento Rivers)
- Provide locally controlled water, i.e., the reclaimed water
- Helps meet the state of California's statewide water objectives
- Help reduce the mineral buildup in the Orange County groundwater

Under construction since 2003, the GWR is being built at an estimated total program budget of $487 million (2003 estimate). The phase currently being constructed will supply approximately 88×10^6 m^3/y (72,000 ac-ft/y) and provide the backbone facilities for future expansion. The first phase of the project will be on-line in 2007 (OCWD, 2006). The GWR System consists of three major components: (1) the advanced water treatment facility and pumping stations, (2) a 21-km (13-mi) distribution pipeline connecting the treatment facilities to existing groundwater recharge basins, and (3) the expansion of the existing seawater intrusion barriers with additional injection and monitoring wells (OCWD, 2007).

The treatment process includes microfiltration, cartridge filtration, reverse osmosis, lime addition, and UV photolysis advanced oxidation treatment. The product water will then be introduced into the existing surface spreading basins along with water from other sources. The blended water will be percolated into the groundwater aquifers, where it eventually becomes part of Orange County's drinking water supply. Because of initial concerns for public acceptance and safety, an extensive public outreach program has been conducted to demonstrate the safety of product water and the water quality improvement in groundwater.

An option for indirect potable reuse

When considering potable reuse as an option for public water supplies, critical distinction must be made between indirect and direct potable reuse. Currently in the United States, direct uses of reclaimed water from municipal wastewater for human consumption are not a viable option. However, small but growing numbers of communities are planning and implementing indirect potable reuse through surface water augmentation with the added protection provided by advanced water reclamation technologies and environmental buffer such as blending in a water course and water supply reservoir. The water is then withdrawn downstream after mixing with the ambient water and undergoing water quality modification by natural processes in the environment.

De facto indirect potable reuse

Many communities currently use surface water sources of varying quality for their drinking water supply, including sources that contain significant upstream discharges of wastewater. This situation was referred often to as de facto potable reuse. Thus, planned potable reuse cannot be considered in isolation from more general drinking water issues derived from water sources containing various sources of wastewater and stormwater runoffs. For example, more than two dozen major water utilities in the United States use water from rivers that receive wastewater discharges amounting to more than 50 percent of the stream flow during low flow conditions (NRC, 1998). Although most water systems using such water sources meet current drinking water standards, many of the concerns about planned indirect potable reuse of reclaimed water also apply to these existing drinking water supply systems.

Multiple barrier approach

Fundamental to the practice of planned indirect potable reuse is the reliance of multiple barriers approach in ensuring the safety of drinking water. Every step in the water supply chain needs careful selection, regulation, design, and implementation so that the combination of steps provides the best defense against contaminants in supply, treatment, and distribution if things go wrong. The following five types of barriers are traditionally used in the provision of drinking water.

- **Source protection** Keep the raw water as clean as possible to lower the risk that contaminants will get through or overwhelm the treatment system.
- **Treatment** Treatment trains often uses more than one unit process or operation to removing or inactivating contaminants (e.g., filtration may be followed by disinfection).
- **Distribution system integrity** Securing the distribution system against the intrusion of contaminants and ensuring an appropriate secondary disinfectant (chlorine residual) throughout is highly likely to deliver safe water, even when some earlier part of the system breaks down.
- **Monitoring programs** Monitoring equipment fitted with warning or automatic control devices are critical in detecting contaminants that exist in concentrations beyond acceptable limits and returning systems to normal operation.
- **Responses to adverse conditions** Well-thought out and practiced responses to adverse conditions, including specific responses for emergencies, are required when other processes fail or there are indicators of deteriorating water quality.

Although each barrier offers protection, no single barrier is perfect. Thus, an over-reliance on only one barrier at the expense of another may increase the risk of contamination. Independent failure modes should be established; that is, barriers should be selected so that a failure of one barrier does not result in the failure of all. These barriers include water usage, wastewater treatment, dilution and natural attenuation or cleansing in the water body, storage in reservoirs, effective drinking water treatment, and extensive raw and treated water monitoring to ensure high quality drinking water.

Observations and future trends in water reuse

The social, economic, and environmental impacts of historic water resources development practices and the prospects of water scarcity are driving the shift to a new paradigm in water resources management. The new approach incorporates the principles of sustainability, environmental ethics, and public participation. Sustainable water resources management emphasizes whole-system solutions to meet the water needs of present and future generations reliably and equitably. Achieving sustainable water resources management is dependent upon a clear understanding of the distribution and availability of water resources in the hydrologic cycle and the effect that human activities may have on the environment. Sustainable water resources management seeks to design integrated and adaptable systems, increasing efficiency of water use, and making continuous efforts toward protecting ecosystems (Baron et al., 2002; Wilderer et al., 2004).

Environmental ethics plays a significant role in sustainable water resources management by bringing equity into consideration in the context of societal needs and environmental stewardship. Public participation in planning and project development is essential to identify community priorities and concerns, which include not only equity but also growth impacts, cost, and public safety.

While the World's water problems may loom high, steady progress in water reclamation and reuse has been made since the 1970s. To make full use of the water resource created by reclaimed water, several challenges must be met. These include institutional and social obstacles such as regulatory developments and public acceptance. Technical and economic challenges also must be addressed. Important issues related to the future of water reclamation and reuse are summarized in the following paragraphs (Asano, et al., 2007).

Implementation hurdles

While water reclamation and reuse is a sustainable approach and can be cost-effective in the long run, the additional treatment of wastewater beyond secondary treatment for reuse and the installation of reclaimed water distribution systems can be costly and energy-intensive as compared to such water supply alternatives as imported water (inter-basin transfer of water) or groundwater. Furthermore, institutional barriers, as well as varying agency priorities, can make it difficult to implement water reuse projects in some cases.

Public support

The public's awareness of sustainable water resources management is essential; thus, planning should evolve through a community value-based decision-making process. It is important that water reuse is placed within the broader context of regional water resources management and other options such as desalting to address water supply and water quality problems. Community values and priorities are then identified to guide planning from the beginning in the formulation and selection of alternative solutions.

Acceptance varies depending on necessity and opportunity

To date the major emphasis of water reclamation and reuse has been on nonpotable applications such as agricultural and landscape irrigation, industrial cooling, and in-building applications such as toilet flushing in large commercial buildings. An indirect potable reuse option raises more public concern and uncertainty. In any case, the value of water reuse is weighed within a context of larger public issues. Water reuse implementation continues to be influenced by diverse factors such as opportunity and necessity, drought and reliability of water supply; growth vs. no growth; urban sprawl, traffic noise and air pollution; and the perception of reclaimed water safety, esthetics, political will, and public policy governing sustainable water resources management.

Public water supply from polluted water sources

Due to land use practices and the increasing proportion of treated wastewater discharged into the nation's waters, freshwater sources of drinking water now contain many of the same constituents of public health concern that are found in reclaimed water. Much of the research that addresses indirect potable water reuse is becoming equally relevant to unplanned indirect potable reuse (*de facto* potable reuse) that occurs naturally when polluted water sources are used as a source for drinking water supply. Because of the research interest and public concerns, emerging pathogens and trace organic constituents including disinfection byproducts, pharmaceutically active compounds, and personal care products have been investigated and reported on extensively with regard to public water sources. Concerns for unknown "unknowns" are driving current research; in fact, the ramifications of many of these constituents in trace quantity are not well understood with respect to the significance of long-term health effects.

Advances in water reclamation technologies

Cost-effective and reliable water reclamation technologies are vital to successful implementation of water reuse projects. Comprehensive research on advanced treatment technologies and their combinations including membrane processes, advanced oxidation, and reliable disinfection is essential.

Challenges for water reclamation and reuse

The incentives for a water reclamation and reuse program make perfect sense to technical experts – a new water source, water conservation, economic advantages, environmental benefits, government support, and the fact that the cost of wastewater treatment makes the product too valuable to "throw away" or dispose. So why hasn't the concept been embraced and supported wholeheartedly by the community? (Wegner-Gwidt, 1998). The human side of politics, public policy, and decision-making associated with technological advances are not always in concert with technical experts and technological advances. As technology continues to advance and the reliability and safety of water reuse systems is widely demonstrated and public policy and perception changes to embrace these technological advances, water reclamation and reuse will continue to expand as an essential element in sustainable water resources management.

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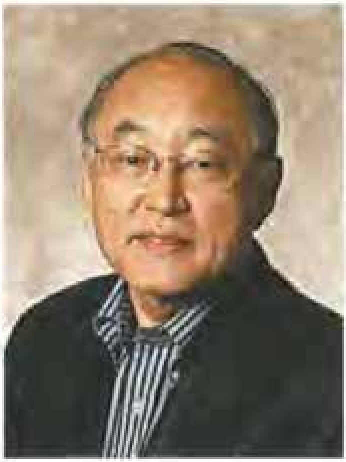

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Water Reuse in Africa: Challenges and Opportunities

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Abstract: Population and urban growth is one of the major challenges facing Africa. Rapid urbanization poses major infrastructure, economic, environmental and social problems. Total water supply and sanitation coverage is extremely low particularly in sub-Saharan Africa and cities are becoming to a large extent informal. Untreated urban wastewater is widely used for irrigation purposes in most of the African cities. Because of yield increase, it has positive income effect but constitutes at the same time a public health and environmental threat. Different population groups are exposed to serious health risks such diarrheal diseases. These can be significantly decreased through water and sanitation investments adequately targeted to achieve impact. Traditionally designed sanitation systems have failed because they were inappropriate, ill-planned, -implemented or -managed and did not take into account the whole urban water system including drinking water supply, wastewater collection, treatment and reuse and impacts on the receiving environment. Designing a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles for the adoption of such an approach remains a challenge. This requires a long-term strategy taking action step-by-step and the creation of new local business models. The involvement of practitioners, researchers, policymakers, and local communities in multi-stakeholder platforms may facilitate dialogue, innovation uptake and social learning and create the effective mechanisms for an integrated water management strategy.

Keywords: Africa, integrated urban water management, urban and peri-urban agriculture, upstream-downstream linkages, sustainable sanitation systems, wastewater reuse.

Introduction

In Africa, urban and rural water supply and sanitation infrastructures are poor. Populations suffer from inadequate access to drinking water and sanitation services. Population growth, improvement of living standards and socio-economic conditions lead to the generation of increased volumes of wastewater. Effluents are discharged untreated into the receiving environment causing major health and pollution threats to downstream waters. Uncontrolled and direct reuse of wastewater is frequently taking place. Often the urban or rural poor rely on this resource for their livelihood and food security needs. This is not without putting at risk their own health, the health of the consumers and that of the environment as a whole.

Water supply and sanitation have been managed separately and planned and designed for different time-scales. The provision of environmentally sound systems that take into account the whole urban water system – water supply, wastewater, solid waste collection, treatment and reuse – requires a holistic approach involving the different stakeholders.

Several key questions need to be first addressed such as can cities in Africa cope with the infrastructure and capacity requirements needed to simultaneously face the (i) water supply and (ii) sanitation needs of growing urban populations, (iii) to reuse the city effluents in a safe and efficient way, and (iv) to protect the public health and the urban and peri-urban environment? How can we make the management of urban wastewater effective, sanitation affordable and reuse safe for urban dwellers in Africa? How can known technologies best be applied to solve development questions? Does linking sanitation to water reuse help meet the MDG water and sanitation target in Africa? Which institutional settings are suitable for sanitation and reuse in these areas? Can sustainable solutions be found through dialogue involving practitioners, researchers, policymakers, and local communities in multi-stakeholder platforms?

This paper gives an overview of the water supply, sanitation and wastewater irrigation situation in Africa, of the development and management issues facing it and attempt to answer some of the questions. Some examples from Ethiopia, Ghana, and Tunisia are used to illustrate different approaches within the continent.

Urbanization and food security

Africa is experiencing fast population and urban growth. Rates of growth of urbanization in Africa are the highest in the world (5.8% in sub-Saharan Africa and up to 10% in some cities) and expected to remain the highest for several decades (UNFPA, 2007). Africa has at the same time, except a few countries, the lowest economic development and growth. Its urbanization is therefore termed demographic urbanization as it has not been accompanied by infrastructural transformations in the agricultural and industrial sectors (Escallier, 1988). According to Songsore (2004), this is one major reason why the economic, social and health benefits of urbanization have so far failed to materialize.

About 38% of the African population is living today in urban areas; this number is foreseen to increase to 53% by 2030. The proportion of urban population is rapidly growing as a consequence of a significant increase in overall population and in rural-urban migration. The projection is that, by 2015, there will be 25 countries in SSA with higher urban than rural populations and 41 countries by 2030 (UN-Habitat, 2001). By 2020, Africa will have 11 mega-cities with 5 million or more inhabitants and almost 720 cities with population of more than 100,000. This translates in the need for investments in basic services, i.e. clean and safe water and sanitation, health care, education, transport, housing, etc.

Population increase is taking place in rapidly growing urban and peri-urban areas. It is putting enormous pressure on land and water resources and has resulted in serious water stresses, poor waste management and severe diffuse pollution. Urban population growth has lead to a significant growth in poorly-planned settlement areas surrounding many major cities in Africa and to a rapid increase in the number of slums, in unemployment and poverty. According to the UN-Habitat, 72% of the urban population in SSA lives under slum conditions. A growing proportion of the urban population is also becoming informal with the proliferation of scattered housing. Construction of spontaneous housing on city outskirts is also leading to annual loss of farm land and causing deterioration in living conditions. The use of inappropriate sites presents major risks, such as development in flood-prone areas and near solid waste landfills. Providing sanitation to the slums and informal settlements requires a different approach given the scale of the problem, the high density of the population, the complexity of the situation, the difficulty to provide adequate services in such conditions (insecure tenure, lack of infrastructure, lack of space, etc.), and the resulting aggravated health, environmental, and other socio-economic problems.

Out of a population of 968 million in Africa, around 50% live on daily incomes equivalent to less than $1 a day and have therefore little resources to meet basic needs. Over 70% work in agriculture, mostly in subsistence agriculture. Agriculture is their major source of food and income. In SSA, 33% of the population is undernourished with a constant low average calorie intake per person ≈ 2000 kcal/p/d. The urban poor depend heavily on rising agricultural productivity to reduce food prices. Ensuring food security for the urban poor is a challenge. Urban and peri-urban agriculture is clearly one of the options for increasing urban food demand and for poverty reduction.

Urban and peri-urban agriculture can serve the inherent function of agriculture, and as a mean of recycling waste products of the urban centres. Reuse of wastewater is a way of solving the urban waste problem, maximising water use efficiency, as well as providing necessary inputs (water and nutrients) to sustain or promote agriculture. The agricultural sector can then provide to the urban sector an "environmental function" as well as an "environmental service". Urban and peri-urban agriculture can, at the same time, provide food to the urban areas and act as an "environmental manager" (Thiébaut, 1995). This leads to reconsidering the relationship between urban, peri-urban and rural areas and requires holistic thinking about urban water management.

Supply of water and sanitation

With only 64% of the population with access to "improved water supply", the African continent has the lowest total water supply coverage (coverage refers to the number of people receiving adequate levels of water supply and sanitation services (WHO *et al.*, 2000)) of any region in the world. The situation is much worse in rural areas, where coverage is 50% compared to 86% in urban areas (Table 1.1). Sanitation (excreta disposal facilities) coverage in Africa is also poor (60%), with 80% and 48% in urban and rural areas respectively. The situation is even worse in some countries with, for example, Chad, Congo, Ghana and Guinea having less than 30% improved sanitation coverage in urban areas and Chad, Ethiopia, Ghana, Guinea, Mauritania, Niger, Somalia, Sudan and Togo with less 15% improved sanitation coverage in rural areas (WHO-UNICEF, 2006). Africa houses 30% of the world's population lacking access to improved water supply (335 million persons), and 19% without access to improved sanitation (498 million persons) (WHO and UNICEF, 2006). These figures are respectively 29.3% (322 million persons, of which 52 million urban and 270 rural) for drinking water and 17.8% (463 million persons) for sanitation for sub-Saharan Africa. Only 16% of the population in SSA has access to drinking water through household connections.

Table 1.1 Drinking water and sanitation coverage in Africa and sub-Saharan Africa in 2004

		Africa		SSA	
		People unserved (Million)	Coverage with improved facilities (%)	People unserved (Million)	Coverage with improved facilities (%)
Drinking water	Total	335	64	322	56
	Urban		86		80
	Rural		50		42
Sanitation	Total	498	60	463	37
	Urban		80		53
	Rural		48		28

Figures in Table 1.1 should be considered with caution as "improved" and "coverage" have not been clearly defined. According to the WHO *et al.*, (2000), "improved drinking water coverage" includes services by either household connections or access within one kilometer to a constructed public water point (standpipe, borehole with handpump, protected wells, protected springs, rainwater collection) where at least 20 liters of safe water per person per day were available. "Improved sanitation coverage" is defined as a household connected to a public sewer or a constructed on-site disposal system (septic tank, pour-flush, ventilated improved pit latrine or pit latrine).

These statistics stress the infrastructure gaps and the dramatic increases in investments needed in Africa in water and wastewater collection, storage, treatment and management to "make" water out of surface water, groundwater, stormwater, sea water or wastewater, maintain the water quality, reuse water, biosolids and solid wastes and reduce the health risks. They underline the need to develop innovative approaches to meet the 2015 MDG water and sanitation target in Africa. They also show that it will be necessary to increase the speed at which people are provided with safe and affordable drinking water and sanitation.

Current practice and problems in wastewater management

The majority of urban dwellers in Africa are served by on-site sanitation systems (over 85% of the population in Ethiopia, Ghana, Mali and Tanzania, for example) and this should grow rapidly. Septic tanks regularly flow into open street gutters in major cities of Ghana, Mali, etc., channel greywater, wastewater and stormwater to larger drains and inner-city streams (Keraita *et al.*, 2003). They are often full with a mix of polluted water and garbage, and often look like large wastewater drains full with solid wastes.

Small proportions of the cities in SSA are sewered and only 1% wastewater is treated (WHO and UNICEF, 2000). This is due to low financial, technical and/or managerial capacity. The rapid and unplanned growth of cities makes the management of wastewater more complex. Existing wastewater treatment plants are often not functioning or overloaded and thus discharge into the environment (rivers, lakes, sea, etc.) effluents not suitable for reuse applications. These effluents may contaminate food and downstream water supplies, creating public health risks, environmental damage, and unpleasant living conditions. The perspectives regarding the increase in wastewater treatment capacity in these cities are gloomy. It is more likely that urban and peri-urban farmers increasingly will use wastewater for irrigation.

Industrial pollution from large industries is still limited and restricted to a few cities in Africa. The bulk of pollution originates from dispersed medium and small-scale industries which are prevalent in Africa's urban centers. Uncontrolled discharges of hazardous contaminants from these industries also results in build-ups of toxic constituents in surface water and contamination of groundwater.

The management of faecal sludge, wastewater collected from on-site sanitation systems (public toilets, septic tanks and pit latrines), is a major issue. Many problems are also associated with the prevailing use of faecal sludge in agriculture and aquaculture.

Problems related to off-site and on-site sanitation systems are frequently reported in SSA. The IWA Task Force on Sanitation (IWA, 2006) analyzed the different reasons leading to the failure of these sanitation systems. It was found that these systems are either inappropriate to the cities they are meant to serve, badly planned, badly implemented, or poorly managed. Other reasons were the gap which exists between the interests of households and the incentives facing utilities/cities, the lack of resources and capacities, lack of focus on long-term operation and maintenance requirements.

There are major differences in the way countries address these issues. Namibia, Tunisia and South Africa stand apart from the rest of the continent in treating sewage sludge through a range of conventional and non-conventional systems and having national guidelines and regulations. Examples from Ethiopia (Box 1), Ghana (Box 2) and Tunisia (Box 3) are given in the following to illustrate the variety of the situations and the approaches adopted in various contexts.

Box 1: Sanitation in Ethiopia

In Ethiopia, 13% of the population has access to improved sanitation (44% in the urban areas and 7% in the rural ones) when 81% of urban population and 11% of rural population has access to safe water supply. The population of Addis Abeba by 2005 was estimated at 3,363,114 and the poverty index at 40-50%. Addis Abeba is facing a high rate of urbanization (4.4%) with huge demands for resources (water, food, energy, land, etc.). The supply of water to Addis is provided through surface and underground water to 58% of the city inhabitants. The city has one wastewater treatment plant, the Kaliti waste stabilization ponds (WSP), which is operational since 1985 and treats about 5% of the city effluent of domestic origin mainly. The WSP receives daily 7500 m^3 through the sewage line plus 1000 m^3 from septic tanks and pit latrines by vacuum trucks which are discharged in lagoons for drying. A certain proportion of the sludge from the on-site systems is co-treated with the wastewater in the WSP. Suction trucks (with a capacity of 3-12 m^3) from the Addis Water Supply Agency (AWSA), from private companies, the Government and from NGOs are used to suck up the content of the pit latrines. AWSA charges the citizens US$7.7 (69 Birr)/truck, others up to US$31.3 (280 Birr). The city is poorly managing the solid waste, industrial and other effluents which pollute the water supply sources and the ecosystem in the tributary rivers, particularly Akaki river and the main Awash itself (Awulachew, 2006).

Box 2: Sanitation in Ghana

In Ghana, urban sanitation infrastructure is poor, less than 5% of the population has sewerage connections and only a small share of the wastewater is treated (Keraita and Drechsel, 2004). 20% of households do not have access to any form of toilet facility; about 31% rely on public toilets, while 22% has access to pit latrines. About 7% of households use KVIPs (Kumasi ventilated improved pit) and 9% has access to water closets. Access to water in rural and urban areas has generally improved gradually resulting in increased generation of faecal sewage and wastewater with increasing waterlogging and stagnant pools of water in many towns and cities because of lack of drains. Inadequate water and sanitation has a significant impact on public health and contributes to 70% of the diseases in Ghana.

In Accra, 46% of the population has access to water. About 10% of the Accra metropolitan (an estimated population of 1.66 million in an area of 200 km^2), mainly the central area, is connected to a piped waterborne sewerage network and receives primary or secondary treatment (Drechsel *et al*., 2002; Scott *et al*., 2004). The remaining areas are served by on-site sanitation systems, in the form of septic tank and pit latrines without adequate drain fields. Very little extension of the sewerage network has taken place since its construction in the early 1970. More than half of all treatment plants in Ghana (42) are in the Greater Accra Region. Waste stabilization ponds are the most common treatment process. Some private enterprises such as large hotels have their own facility (trickling filter, activated sludge plants) that usually has a low capacity (Obuobie *et al*., 2006). Faecal sludge treatment plants fed by trucks receive wastes from public toilets, pit latrines and septic tanks. Due to the limited number of treatment sites and to the poor maintenance of the sanitation and sewerage systems, most of the existing sewage treatment plants in the Accra metropolitan are presently either not operational or discharging effluents not adequately treated. Sewage from the on-site facilities is either disposed of in receiving water bodies or in nearby drains and open spaces resulting in an increase in pollution of surface water bodies in the city, including the marine and coastal ecology (ADB, 2005).

Studies have been carried out to improve sewerage, effluent disposal and sanitation through off-site and on-site sanitation facilities. The Accra Sewerage Improvement Project will provide two new sewage treatment plants, based on waste stabilization ponds, with outfalls discharging into the sea and into watercourses, etc. Transfer of sanitation and sewerage functions from central Government agencies to the Assemblies is considered in the National Environmental Sanitation Policy.

Box 3: Sanitation in Tunisia

In Tunisia, most residents of large urban centers have access to various adequate sanitation systems and wastewater treatment facilities. The sanitation coverage is 85% for all the population versus 96% in the urban areas and 65% in the rural areas. Industries have to comply with the Tunisian standards (INNORPI, 1989) prior to discharge their wastewater into the sewerage system; they are given subsidies to equip their industrial units with pre-treatment processes. Of the 240 Mm^3 of wastewater collected annually, 187 Mm^3 (78%) are treated in 61 treatment plants of which around 41 have a daily capacity less than 3500 m^3 and 10 above 10 000 m^3, the largest with 120 000 m^3/d. Five treatment plants are located in the Tunis area, producing about 62 Mm^3/yr, or 54% of the country's treated effluent. Several treatment plants are located along the shoreline to protect coastal resorts and prevent sea pollution. Most municipal wastewater is from domestic sources (88%) and receives secondary biological treatment, mainly in oxidation ditches, activated sludge processes, and stabilization ponds. Sanitation master plans have been designed for several towns.

Wastewater irrigation

Wastewater irrigation is a common established practice in urban and peri-urban areas in Africa. Practices range from the use of untreated wastewater to the piped distribution of secondary or tertiary treated wastewater to irrigate different kinds of crops and trees. There are a few countries in Africa such as South Africa, Tunisia or Namibia with experience in planned reuse and a record in wastewater treatment plants producing a safe effluent. In most of the other countries, urban wastewater is widely used very partially treated or untreated to irrigate vegetables and fodder for livestock. Farmers grow 70-90% of the vegetables consumed in the majority of Africa's growing cities such as Dakar, Bamako, Ouagadougou, Accra, Addis Abeba or Nairobi. Wastewater is mostly of domestic origin and may be mixed with surface or groundwater.

Wastewater irrigation is both a major health risk and a major economic opportunity for poor people to make a living. There are serious health risks associated to the reuse of polluted and unsafe water for farmers, workers and consumers. Application of raw or partially treated wastewater has generated the existence of endemic and quite epidemic diseases (cholera, typhoid, etc.). Wastewater irrigation raises issues both as potential resources of nutrients and source of pollution. Its content in mineral and organic trace substances and pathogens represent a risk for human health and the environment (potential harmful effects on biota, contamination of the food chains, contamination of groundwater, soils, etc.).

However, wastewater has many advantages for farmers as it contains significant amounts of nutrients for food crop production that reduce the need for chemical fertilizers. Wastewater content in organic matter, nitrogen, phosphorus, and potassium may improve soil fertility, enhance plant development and increase agricultural productivity. It is a reliable water supply, free-of-charge, continuously available nearby. Wastewater reuse supports the livelihood of many farmers and traders and plays a significant role in poverty alleviation. It contributes significantly to urban food supply. It conserves water and contributes to the reduction in wastewater discharge and pollution of the water bodies and the environment in general. Integration of urban and peri-urban agriculture into urban sustainable sanitation planning is therefore critical in the African cities. Salient aspects of wastewater irrigation in three African countries, Ethiopia, Ghana and Tunisia, are highlighted in the following.

Wastewater reuse in Addis Abeba (Box 4) illustrates upstream-downstream linkages and the impacts of upstream producers of wastewater on downstream users.

Box 4: Wastewater reuse in Addis Abeba (Ethiopia)
About 35.5 million m³ of wastewater is annually generated in the city of Addis Abeba. Wastewater is mainly of domestic origin with 13.4% industrial. Most of the wastewater is disposed into the rivers and streams flowing through the city. Akaki river serves thus as a sink to the wastes from the city. Farmers have been producing vegetables using Akaki river for the last 50 years and 1239 ha of land are being irrigated. Rural areas are supplying Addis with almost all crops, livestock, horticulture and fruits, and urban agriculture is providing 61% of the vegetables consumed in Addis (lettuce, Swiss chard, cabbage, spring onion, potato, beat root, etc.) which is mainly irrigated with wastewater. Poor farmers in urban and peri-urban areas get good market both for inputs and outputs, relatively better infrastructure and more access to modern technologies. The main concerns are pollution of the water sources, the health hazard related to the use of untreated water for irrigation, the environmental degradation and allocation of agricultural land to other purposes. A survey carried out by Alebel (unpublished) on a sample of 1258 farmers on the health incidence of wastewater irrigation on the consumers, the producers and the downstream households who are exposed to different health risks compared to the upstream ones showed that (i) prevalence of intestinal illness due to hookworm & ascaris infection and diarrhea is higher in the members of the downstream wastewater irrigators as compared to the upstream ones; (ii) this prevalence of illness increases in parallel with the increase in the pollution level of the river; and (iii) prevalence of illness is higher in those who work in wastewater farms compared to those working in freshwater farms. Awareness and protective dress have significant impact on farmers' illness. The value of the health damage (excluding the impacts on consumers and the environment) due to unsafe use of wastewater irrigation is approximately US$ 1,500,000 per year.

Wastewater reuse in Ghana (Box 5) demonstrates the health risks as well as the socio-economic benefits to the farmers and the overall benefit to the city.

Box 5: Wastewater reuse in Ghana

In Ghana, urban and peri-urban agriculture is developing wherever land is available using any source of water, i.e. raw wastewater, domestic wastewater in drains, partially treated wastewater or polluted water from rivers and streams (Obuobie *et al.*, 2006). Around Kumasi, informal irrigation, which often uses diluted wastewater, is estimated to cover 11,500 ha, which is more than the total area reported under formal irrigation in the whole country (Keraita and Drechsel, 2004). Typical concentration in faecal coliforms of irrigation water ranges from 10^4-10^8/100 mL (Keraita *et al.*, 2003). Watering cans are the most common irrigation method used in the country. Buckets, motorized pumps with hosepipe and surface and sprinkler irrigation are also used to fetch, pump and water crops. In Accra, 800-1000 farmers irrigate more than 15 kinds of vegetables (lettuce, cabbage, spring onions, cauliflower, cucumber, tomatoes, okra, eggplants, and hot pepper) in peri-urban areas within an average radius of 38 km from the city center. Plot sizes vary between 0.1-0.2 ha per farmer and maximum 2.0 ha. All-year-round irrigated vegetable farming can achieve annual income levels of US$400-800/ha. The annual value of the production, a significant part of which is irrigated with wastewater, has been estimated as US$5.7 million (Keraita and Drechsel, 2004).

Irrigated vegetables sold in the markets were found to be contaminated with faecal coliforms and helminth eggs (> 10^3 FC/g fresh weight and up to 3 helminth eggs per gram of vegetables) (Keraita *et al.*, 2003). This results in about 200,000 urban dwellers from all classes of the society daily at risk from consuming vegetables irrigated with polluted water. The urban sanitation challenge is thus affecting municipal food supply and safety significantly. This is a major concern of the authorities who have banned the use of polluted water for irrigation purposes. Alternative interim health risk reduction strategies are needed as proper wastewater collection and treatment infrastructure is not yet available and the existing one not functional.

Tunisia (Box 6) offers an example of water reuse operations integrated in the planning and design of sanitation projects. A phased approach was taken to set up a planned water reuse strategy.

Box 6: Integrated wastewater treatment and reuse in Tunisia

About 30-43% of the treated wastewater is used for agricultural and landscape irrigation in Tunisia. Reusing wastewater for irrigation is viewed as a way to increase water resources, provide supplemental nutrients, and protect coastal areas, water resources, and sensitive receiving bodies. Reclaimed water is used on 8,000 ha to irrigate industrial and fodder crops, cereals, vineyards, citrus and other fruit trees. Regulations allow the use of secondary-treated effluent on all crops except vegetables, whether eaten raw or cooked. Regional agricultural departments supervise the water reuse decree and collect charges (about \$0.01 m^{-3}). Golf courses are also irrigated with treated effluent, while industrial use and groundwater recharge opportunities are being investigated.

Tunisia launched a national water reuse program in the early 1980s to increase available water resources. Most existing reuse programs were implemented and integrated into the scheme of already existing treatment plants. However, for new plants, treatment and reuse needs are combined and considered at the planning stage. Although some pilot projects have been launched or are under study for groundwater recharge, irrigation of forests and highways, and wetlands development, the wastewater reuse policy launched at the beginning of the 1980s favors planned water reuse for agricultural and landscape irrigation (Bahri, 2000). About 35 Mm^3 of reclaimed water annually is allocated for irrigation. In some areas, irrigation with reclaimed water is well established and most of the volume allocated is being used, while in new areas, where irrigation is just beginning, the reuse rate is slowly increasing. The annual volume of reclaimed water is expected to reach 290 Mm^3 in the year 2020. At that point, the reclaimed water could be used to replace groundwater (18%) that is currently being used for irrigation in areas where excessive groundwater mining is causing seawater intrusion in coastal aquifers.

The area currently irrigated with reclaimed water is about 8,000 ha, 80% of which is located around Tunis and a few other locations near Hammamet, Sousse, Monastir, Sfax, and Kairouan. The Medjerda catchment area sanitation program has equipped the 11 largest towns of that area with sewerage networks, treatment plants, and reclaimed water irrigation schemes in order to protect natural resources, and particularly the Sidi Salem dam (550 Mm^3), from contamination by raw wastewater. One new large water reuse project is planned for Tunis West area. The new wastewater treatment plant for the City of Tunis West will have a design capacity of 224,700 m^3/d (82 Mm^3/yr) by the year 2016, which will enable the irrigation of about 6,000 ha. By 2020, the area irrigated with reclaimed water is planned to expand up to 20,000-30,000 ha, i.e. 7-10% of the overall irrigated area, from which 14,500 ha will be located around the Great Tunis. Reclaimed water is used mainly during spring and summer, either exclusively or as a complement to groundwater. The most common irrigation methods are sprinklers (57% of the equipped area) and surface irrigation (43%). Another common water reuse practice is golf course irrigation. In fact, eight existing golf courses are irrigated with treated effluent.

Water reuse in agriculture is regulated by the 1975 Water Law and by the JORT Decree No. 89-1047 (1989). The Water Law prohibits use of raw wastewater in agriculture and irrigation with reclaimed water of any vegetable to be eaten raw. The 1989 decree specifically regulates reuse of wastewater in agriculture. As an enforcement of these regulations, using secondary treated effluents is allowed for growing all types of crops except vegetables, whether eaten raw or cooked. The main crops irrigated with treated wastewater are fruit trees (citrus, grapes, olives, peaches, pears, apples, and grenades), fodder (alfalfa, sorghum, and berseem), sugarbeet, and cereals. Specifications regarding the terms and general conditions of reclaimed water reuse (and the precautions that must be taken in order to prevent any contamination to workers, residential areas, and consumers) have also been established.

The National Sewerage and Sanitation Agency is responsible for the construction and operation of all sewerage and treatment infrastructure in the larger cities of Tunisia. When effluent is to be used for agricultural irrigation, the Ministry of Agriculture, Water Resources and Fisheries is responsible for execution of the projects, which include the construction and operation of all facilities for pumping, storing and distributing the reclaimed water. Regional Commissariats for Agricultural Developments (CRDAs) are in charge of the enforcement of the regulations related to agricultural reuse and collection of charges, about \$0.01/m^3. Water users' associations are in charge of the management of the water distribution system, fees collection and enforcement of the regulations related to agricultural reuse for small perimeters. A water reuse strategy aimed at developing water reuse and considering reclaimed water as a water resource has been drafted. Forthcoming projects aimed at meeting a real water demand -in quantity and quality- should allow a higher utilization of reclaimed water. Water reuse primarily for agricultural purposes and secondarily in other sectors, will continue to develop in Tunisia. By upgrading the water quality and with more widespread information, reclaimed water reuse should gain wider acceptance in the future.

Inter-departmental coordination and follow-up commissions with representatives from the different ministries and their respective departments or agencies, the municipalities and representatives of the users (Water users' associations) have been set up at national and regional levels so as to bridge the gaps between the needs of different parties, ensure the achievement of development objects, and preserve the human and natural environment. Within the Regional Commissariats for Agricultural Development, a multi-disciplinary unit is in charge of planning, design, implementation, follow-up and assessment of schemes irrigated with reclaimed water.

The impacts of inadequate supply of water and sanitation and of wastewater irrigation

Lack of clean, adequate, safe and affordable water supply and sanitation facilities affects people's life, health, growth and development. It affects more particularly women and children in charge of water collection and raises issues of personal safety and dignity (Norström, 2007). It jeopardizes children's education and gender equity (WHO and UNICEF, 2006). It has a huge impact on human suffering and productivity. It is a barrier to economic development through (1) the labor hours lost due to disease and time spent fetching water (overall average for Africa is about half an hour) and (2) the human capital lost when sick children miss school. It may deepen the inequities between the urban rich and the urban poor who pay more for water provision, and are usually the last to be extended water and sanitation.

Lack of water access and sanitation and reuse of polluted water increases the emergence of diseases and illnesses. At any given time, one-half of the African population is suffering from one or more diseases associated with inadequate provision of water and sanitation services and wastewater irrigation (diarrhea, intestinal worms, schistosomiasis, cholera and trachoma). Africa has the worst statistics for cholera and child diarrhea (Warner, 2000). "In Africa, 155 children die every hour of everyday from sanitation, hygiene and water related diseases. The number of cholera cases reported from Africa is increasing every year. A total of 187,545 cholera cases and 8,051 deaths were officially reported in 1999 in the African Region" (WHO, 2000). Recently, several cholera outbreaks were reported in different African countries: Zimbabwe, Tanzania, Rwanda, Kenya, Angola, Republic of Congo due to contaminated drinking water or poor sanitation. In SSA, the annual global burden of water-related diseases is estimated at 82 million Disability Adjusted Life Years (DALYs). Diarrheal diseases form the bulk of the health risk and kill more Africans every year than HIV/AIDS. There are an estimated 1.2 billion cases of diarrhea in sub-Saharan Africa every year (25 million DALYs) that lead to the deaths of 770,000 children under 5. This places an average health burden on every African of 21.7 years of ill health (In Rijsberman, 2006).

The impact of providing clean water and sanitation and the use of safe water for irrigation is huge as it can increase economic well being at the household level, mainly through saving large amounts of people's time and energy. SSA overall economic cost of reduced access to water and sanitation is estimated to be $23.5 billion, or 5% of GDP. But, the health benefits are significant and the largest share of the economic benefits from meeting the water and sanitation MDG target arises in SSA (Evans, 2005). According to Fewtrell *et al.*, (2005), diarrheal morbidity can be greatly reduced through water and sanitation investments: up to 45% reduction from improved hygiene, up to 39% reduction from household water treatment, up to 32% reduction from improved sanitation, and between 6 and 25% reduction from improved drinking water.

Reaching the MDG goals to halve hunger, poverty, and people with no access to safe water and basic sanitation by 2015 is therefore especially a challenge in Africa.

Sustainable approach to water supply, sanitation and reuse

Water and nutrient recycling has so far not been considered as an objective sufficiently important to modify the general approach to sanitation. When conventional technology is adopted for treating wastewater, treatment plants are designed with no concern for reuse and independently of the type of reuse. A key element of sustainable sanitation in Africa is the incorporation of the agricultural system into the sanitation system with nutrient and water recycling. It will result in improved food security and quality of life. Safe reuse in agriculture and other sectors has such a high value that it is the only way to make sanitation affordable for African slum dwellers. Providing affordable solutions that can be linked with sustainable agriculture while generating sustainable livelihoods for urban and peri-urban farmers is the opportunity and challenge. According to Rijsberman (2006), the reuse potential of different waste products as a function of crops, soil and climate conditions, including health, socio-cultural, economic, and reuse policy aspects have to form an integral part of future sustainable sanitation strategies.

For social equity and environmental concerns, there is a need to consider the full range of sanitation, treatment and reuse systems from pit latrines to water borne sewered system - from the safe collection, storage, and disposal/re-use of human excreta to the treatment and disposal/re-use/recycling of sewage effluents and hazardous waste. A combination of different technology solutions, depending on local conditions, the site, etc., may help solving the problem in a sustainable and environmentally sound manner. In order to overcome the financial constraints faced in providing wastewater services, these services may be developed in a phased manner moving gradually along the "sanitation ladder" (4WWF, 2006).

Adopting a closed-loop systems approach, which focuses on sustainable management of domestic residue flows (urine, faeces, greywater, organic and non-organic solid waste), would radically reduce water consumption, while safely recycling valuable nutrients into the soil (Niemczynowicz, 1994; Rose, 1999). The economics of collection systems required for such methods of segregating sanitary streams are, however, still major constraints (Braden and Ierland, 1999).

Some appropriate technologies remain untested or not enough researched such as the faecal sludge systems for example (Ingallinella *et al.*, 2000). The development and implementation of strategies and options to cope with faecal sludges adapted to the conditions prevailing in Africa has been neglected. There are different initiatives towards improvements through the R&D efforts of organizations such as CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût based in Ouagadougou (Burkina Faso)), EAWAG-SANDEC (Swiss Federal Institute of Aquatic Science and Technology – Water and Sanitation in Developing Countries), the Water Research Commission in South Africa and other agencies on sustainable sanitation. Recent initiatives in the management of sludge from on-site systems are reported in several countries (Benin, Bostwana, Ethiopia, Ghana, Mali, Senegal, South Africa and Tanzania).

Development of treatment systems that make the wastewater biologically and chemically safe, but keep the nutrients that replace fertilizer for farmers, is also still the challenge. It is urgently needed to design a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles that constrain making a full complement of sanitation alternatives available to communities. A well articulated portfolio of sanitation alternatives would help both communities and planners choose and access to viable sanitation options (IWA, 2006).

Low implementation costs, proven technology, ease of operation and flexibility of upgrade in subsequent stages are all desired features of appropriate wastewater treatment technology to address the sanitation challenges. Where land is available, natural systems such as waste stabilisation ponds or constructed wetlands may be used. Land treatment techniques could also be implemented, such as rapid infiltration, overland flow, slow rate or subsurface infiltration. Chemically enhanced primary treatment and upflow anaerobic sludge blanket reactors are other examples of applicable and affordable technology. These processes can meet both the objectives of treatment and reuse. Adaptation and standardisation of some unconventional processes still needs to be done.

There are opportunities for the design of sanitation systems using local materials, technology, and know-how. Systems based on conventional practices or combining natural and conventional systems may be used when land is not available or in the case of topographical or others constraints. Financial savings both in terms of investment and O&M costs may be achieved in addition to ecological advantages and landscape fit-in. Land application of sludge may also be practised after proper treatment (composting, digestion, etc.).

For optimized water collection, distribution, sewerage and reuse systems, the challenge consists in the development of a decentralized approach to infrastructure planning and design to address the needs of urban and rural settings. Decentralized systems such as water harvesting for domestic and agricultural purposes or satellite wastewater treatment plants may better protect watersheds and water resources and avoid transfers over long distances. Senegal which is increasing its urban sanitation coverage with on-site sanitation systems as its main focus is treating (ONAS in collaboration with Sandec) the increasing volumes of faecal sludge in decentralized treatment plants. The design of simple and multiple facilities with locally-capable O&M instead of sophisticated and large facilities would leave a needed resource close at hand and facilitate reuse at local scale (Kreissl, 1997). Local recycling and reuse may reduce the total water withdrawal. Smaller amounts of wastewater flows will be generated and more easily controlled; less energy might be consumed and less sludge produced (Harremöes, 1997).

Promising areas of innovation in sanitation are also in new business models to create local products and markets. Local knowledge can inform design for appropriate technology, provide credibility in management and reality into the process.

Risk management and interim solutions (non-treatment) are needed in the near term to prevent adverse impacts from wastewater irrigation. A multiple barrier approach combining source control, and farm-level and post-harvest measures can be used to minimize risks and protect agricultural workers and consumers (Lazarova and Bahri, 2005; WHO, 2006; Qadir *et al.*, 2007). Risk reducing alternatives e.g. at farm, market and consumer level are being tested in order to explore possibilities of combining non-treatment and treatment options (Drechsel, *et al.*, 2007).

These technical and institutional solutions can make services more affordable to different users, the low-income users in particular. They are however unlikely to solve the problem of access to water (access encompassing the entire continuum from drinking water and sanitation to water for agriculture) without involving all stakeholders in the planning, implementation and operation stages of water supply, sanitation and reuse operations.

The traditional communication systems do not enable users to "add" their knowledge to the array of knowledge systems. There is a need for platforms through which appropriate blending of knowledge systems can occur. The use of participatory techniques will facilitate greater consensus between key municipal, state, and national stakeholders and allow community participation, personal involvement in decision-making processes, appropriation of sustainable sanitation and adequate operation and maintenance. This will also ensure technical innovations to gain acceptance.

In order to enable the community of stakeholders to participate to the decision-making process, optimize the management process and the output, two approaches are being investigated: The "Household Centred Environmental Sanitation" (HCES) approach (SANDEC/WSSCC, 1999) and the learning alliance stakeholder approach (LA). The HCES put people and their quality of life at the centre of any environmental sanitation system (rather than trying to change people's behavior to accommodate technology). The learning alliance stakeholder approach seeks to facilitate dialogue and breaks down barriers to information sharing at multiple levels. It is designed to speed up identification, development and uptake of innovation and the scaling up of research outputs through their alliances of practitioners, researchers, policymakers, activists and local communities. The SWITCH (http://www.switchurbanwater.eu) and Cities Farming for the Future are two examples of projects implementing the LA approach.

The SWITCH project's key proposition is that sustainable urban water management is only possible if the entire urban water cycle is managed in a holistic manner in the context of the entire catchment. IWMI is responsible for the pilot project in Accra on productive use of water (including wastewater, storm water and freshwater) and should come up with recommendations on technology options and guidelines for the use or reuse of these water sources for agriculture and other livelihood opportunities to be integrated into the policy, planning and decision-making frameworks of Accra municipality using the LA platform.

Cities Farming for the Future aims at integrating agriculture in cities in the eastern and southern Africa region. The main objective of this programme is to contribute to urban food security, urban poverty reduction, environmental management, empowerment of urban farmers and participatory city governance through capacity of stakeholders in urban agriculture and participatory multi-stakeholder policy formulation and action planning.

Conclusion

With a few major exceptions, most countries in Africa are characterized by inadequate water supply, poor environmental sanitation services and food insecurity. The approaches followed over the past 40 years have not succeeded in achieving sustainable water supply and sanitation services. New concepts and directions that fit African traditions and needs are required (Warner, 2000).

The growing water demand and the discharge of wastewater pose a special challenge of managing the water resources in an integrated manner. Reuse of wastewater is widely practiced in the urban, peri-urban and rural areas of Africa and this is set up to grow. Wastewater reuse is an important component of many local economies in Africa with many large socio-economic benefits from the irrigated areas. However, wastewater-induced pollution limits access to safe water and reuse of polluted water threatens public health and endangers ecosystems. The challenge is to make a productive asset out of municipal wastewater through viable interventions along the contamination pathway which reduce health risks for farmers and consumers (Rijsberman, 2006). Incorporation of the agricultural system to the sanitation system with water and nutrient recycling is one of the major ways of closing the loops in the urban, peri-urban and rural areas. It may help meeting the MDG target on water supply, sanitation and hunger.

Alternative wastewater treatment methods based on the principles of closing cycles exist and several unconventional and low-cost wastewater technologies can be implemented for individual and collective sanitation systems. Designing a range of cost-effective solutions that addresses the technical, institutional, social, behavioural and cultural obstacles for the adoption of such an approach remains a challenge. A long-term strategy taking action step-by-step and the creation of new local business models is needed.

One of the major challenges for the continent will be our capacity to design a more sustainable urban and rural development that will limit rural-urban migration and put an end to informal settlement. Lessons can be drawn from experiences within the continent that can lead to more effective programs at the national and community levels. A key need is to ensure that proposals for technological solutions are based on holistic scientific, economic and social overviews of the entire urban water system including potable resource supply, treatment and reuse and impacts on receiving waters involving practitioners, researchers, policymakers, and local communities in multi-stakeholder platforms.

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Water and Wastewater Treatment Alternatives and Quality Standards Towards a Comprehensive Reuse Policy

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Abstract: Israel is a water-scarce country situated in a sensitive hydrological area. This has mandated a careful water resources management that integrates water resource augmentation and pollution control. Desalination of seawater and brackish groundwater, together with reclamation and reuse of municipal wastewater, has become a vital component of this concept. It is planned that by 2020, practically all municipal wastewater will be reused, mainly for agricultural irrigation. Recent legislation requires stringent quality standards for treated wastewater destined for agricultural irrigation or for disposal in rivers. These include the need to upgrade secondary processes for nitrogen and phosphorus removal and to add tertiary filtration to enable more effective disinfection. Other water quality problems related to the presence of emerging trace substances, such as endocrine disrupting compounds (EDCs), may require a quaternary treatment stage that combines activated carbon adsorption, advanced oxidation, and desalination. The need for effluent desalination may also be required, due to salination of soil and groundwater caused by long-term irrigation with reclaimed wastewater. Since by 2020, almost 30% of Israel's fresh water supplies will consist of desalinated water, it will change considerably the composition of the water in use in general and consequently, that of the resulting wastewater. Effluent salinity will indeed be reduced, but other problems, related to the decrease of essential nutrients (required for human health, water conditioning, wastewater treatment, and irrigated plants), may arise.

Keywords: Desalination, irrigation, quaternary treatment, reclamation, reuse.

Introduction

Growing problems of water scarcity and environmental pollution have motivated Israel to develop a careful water resources management system based on effective integration of natural water sources, new water supplies, and reclaimed wastewater. The national policy has promoted and enforced water conservation in the domestic, industrial, and agricultural sectors. However, there is a growing need for production of new water sources by desalination of seawater and brackish groundwater, as well as by reclamation and reuse of a greater proportion of municipal wastewater.

On the one hand, wastewater reclamation can contribute to substitution of higher quality water supplies for various applications, while preventing water pollution and health hazards on the other. Although pollution prevention and protection of human health are global necessities in any sustainable development, the use of reclaimed wastewater for the augmentation of natural water supplies is a management issue peculiar to arid and semi-arid countries, due to increasing water shortages. If treated properly, municipal wastewater can provide valuable products, instead of being a problematic waste to be disposed and that can potentially jeopardize sensitive environments. There are many potential uses for reclaimed wastewater, some of which require high quality effluents; these include agricultural crop irrigation, recreational use, aquaculture, and groundwater recharge. In order to enable flexibility in reuse applications and to prevent pollution of surface- and ground- water, at times when there is no need for the reclaimed water, sophisticated water management should be implemented.

The core of most municipal wastewater treatment plants is the biological process, also known as the secondary treatment stage. The specific processes selected are dictated by the characteristics of the raw sewage (especially the organic and nutrient content) and the permitted destinations for the effluents (either reuse or disposal). In this respect, the activated sludge system is considered a reliable and an efficient biological treatment process, capable of producing low biochemical oxygen demand (BOD) and total suspended solids (TSS) effluents. The activated sludge process is most prevalent in developed countries, where stringent standards for effluent quality exist. It is also considered a versatile process that can easily be modified to meet nitrogen and phosphorus limitations when effluents are destined for aquifer recharge, or disposal into receiving water bodies. This process is also most suitable for further application of a tertiary treatment stage, or can incorporate internal membrane separation in place of sedimentation (membrane bioreactor - MBR) when more stringent reuse limitations are required.

In this regard, granular filtration and membrane separation processes (such as microfiltration or ultrafiltration) have been proven to be effective means of removing residual dispersed particles very efficiently (Messalem *et al.*, 2000). These methods considerably improve effluent disinfection, due to direct removal of problematic microorganisms, such as *Giardia and Cryptosporidium* in the filtration stage, and more effective destructive action by the disinfection process in the filtrate, which contains lower values of pathogens and disturbing colloids. The resulting tertiary effluents thus become suitable for unrestricted non-potable reuse applications.

Future water management in Israel might become more complex, due to mutual effects caused by mixing of multiple-quality water sources. While agricultural irrigation is the main target of reclaimed water, salt accumulation in soils and groundwater cannot be eliminated by gradual increase of desalinated water supplies. In addition, the comprehensive reuse of treated wastewater may ultimately cause a long-term buildup of toxic chemicals in the closed cycle of water supply and wastewater treatment and reuse (Kolpin et al., 2002; Kim et al., 2007). The problems of emerging pathogens and trace organic constituents, such as pharmaceuticals and personal care products (PPCPs), some of which are considered endocrine disrupting compounds (EDCs), may require the use of a quaternary treatment stage as an integral part of reclamation schemes.

Water balance in Israel

Basic data regarding water consumption in 2004 and water demand forecast for 2020 in Israel are given in Tables 1 and 2. Two aquifers in Israel are the main sources of fresh water, the coastal and the mountain aquifers. Their annual production potential is approximately 300 and 350 Mm^3/Y, respectively. Other small local aquifers can add another 300 Mm^3/Y. The Sea of Galilee is a surface water source that can supply approximately 450 Mm^3/Y. Several runoff catchments and direct utilization of water from the main rivers feeding the Sea of Galilee, together add approximately 250 Mm^3/Y. There are also various local small aquifers of brackish water, especially in the southern part of Israel (The Negev Desert). This water is partly used in agriculture and industry (see Table 1). The maximum production potential of brackish water is approximately 300 Mm^3/Y. As can be seen in Table 1, most of the water is consumed by the agricultural sector, which is gradually converting to the use of marginal water, especially treated effluents. The specific municipal water consumption in 2004 was approximately 100 m^3-capita/Y (population of 6.9 M). The 2020 forecast of the specific municipal water consumption is 130 m^3-capita/Y, based on a population forecast of 8.5 M.

Population growth, frequent drought incidents, and environmental pollution have put increasing pressure on available natural resources and mandated the development of a sustainable water resource management concept. It has become a national policy to gradually substitute higher quality water supplies by reclaimed wastewater for direct non-potable applications.

Table 1: Water consumption in Israel (2004 balance in Mm^3/Y)

	Fresh	Effluents	Brackish & Runoff	Total	% of total	% of fresh*
Agriculture	565	327	236	1128	58	42
Domestic	705	/	/	705	36	52
Industry	82	/	30	112	6	6
Total	1352	327	266	1945	100	100

* % fresh water of total fresh water consumption

Table 2: Year 2020 water demand forecast (Mm^3/Y)

	Fresh	Effluents	Brackish & Runoff	Desalinated	Total
Agriculture	550	550	100	/	1200
Domestic	700	/	/	400	1100
Industry	150	50	50	/	250
Total	1400	600	150	400	2550

Integrated management of water and wastewater

In order to fulfil the existing and projected water shortages, several seawater desalination plants have been designed and are gradually being erected along the Mediterranean Sea shore (see Table 3). Thus, by the year 2020, according to the figures presented in tables 2 and 3 (and taking into account additional local desalination plants for brackish water), approximately 30% of the fresh water supplies will consist of desalinated water. This change of raw water supplies will also affect the composition of the reclaimed wastewater and may require careful future management.

Table 3: Planned desalination plants in Israel

Plant	Year	Capacity (Mm^3/Y)
Ashkelon	2006	100
Palmachim	2007	30
Shomrat	2009	30
Hadera	2010	100
Ashdod	2010	45

According to the Israeli strategy, by the year 2020 (and even before), approximately 50% of agricultural water demand will be provided by reclaimed wastewater, assuming that agriculture maintains its present size (see Table 2). This means that all municipal wastewater should be treated and reused, mainly in agriculture, but also for recreational purposes and river restoration. Since 60-70% of the municipal water consumption results in sewage that can be collected, treated and reused, this is a very reliable water source, since domestic water supply will always be of high priority. According to a recent survey conducted by the Israel Water Commission (2004), the total amount of wastewater in Israel for that year was 469.3 Mm^3/y, 85% of which was municipal wastewater. Further details on treatment technologies applied and reuse applications are given in Tables 4 and 5, respectively.

Table 4: Wastewater treatment in Israel (year 2004)

	Quantity [Mm^3/y]	% of total*
Connected to sewer systems	451.1	96.1
Mechanical & stabilization systems	427.7	91.1
Primary treatment	22.6	4.8
Raw sewage to sea	5.5	1.2
Raw sewage to rivers	13.4	2.9
*Total = 469.3 Mm^3/y		

Table 5: Wastewater reuse in Israel (year 2004)

	Quantity [Mm^3/y]	% of total*
Tel-Aviv SAT** system	112	23.9
Effluent irrigation	200	42.6
Net amount of reused effluents	312	66.5
Other sources diluted with effluents	83	17.7
Total reuse of effluents & marginal water	395	84.2
Effluent disposal when there is no use	116	24.7
*Total = 469.3 Mm^3/y; **Soil aquifer treatment		

Up to the 1980s, waste stabilization ponds were the most common method of wastewater treatment. Due to water shortage, Israeli farmers were willing to accept the nutrient-rich effluents and actually managed many of the treatment systems. However, reuse limitations on industrial crops, sanitary problems and pollution of surface- and ground- water have changed the approach from agricultural wastewater management to environmental management. This transition has resulted in new standards issued by the Ministry of Health, to gradually convert most of the extensive treatment systems to intensive process systems. The standards require that each municipality larger than 10,000 people must treat its wastewater to the level of 20 mg/L BOD and 30 mg/L TSS. This calls for an activated sludge system, a proven technology applied successfully in Western Europe and the US for many years. This trend is illustrated nicely in Figure 1 that shows a significant increase in treatment and reuse since the eighties.

Two pioneering wastewater reclamation plants for agricultural reuse were actually established during the 'eighties and have proved successful over the last twenty years. The Dan Region Wastewater Treatment Plant treats that of the Greater Tel-Aviv area, having a present capacity of 130 Mm^3/Y. The core of this treatment plant is a biological nutrient removal (BNR) activated sludge system, capable of nitrogen and phosphorus removal. The final effluents are recharged into a local section of the coastal aquifer that serves as an in-situ soil aquifer treatment (SAT) system. High quality effluents are pumped after a lengthy storage-and-polishing and conveyed by a special pipeline to the Negev Desert area, to be utilized for agricultural irrigation (Icekson-Tal *et al.,* 2004). The second large reclamation plant is the Kishon Project Complex, based on a series of long-term stabilization reservoirs that receive secondary effluents from the treatment plants of the cities of Haifa and Afula, and local runoff water. This system is currently designed to enable reuse of 25 Mm^3/Y high quality effluents for unrestricted agricultural irrigation in the Yizrael Valley area.

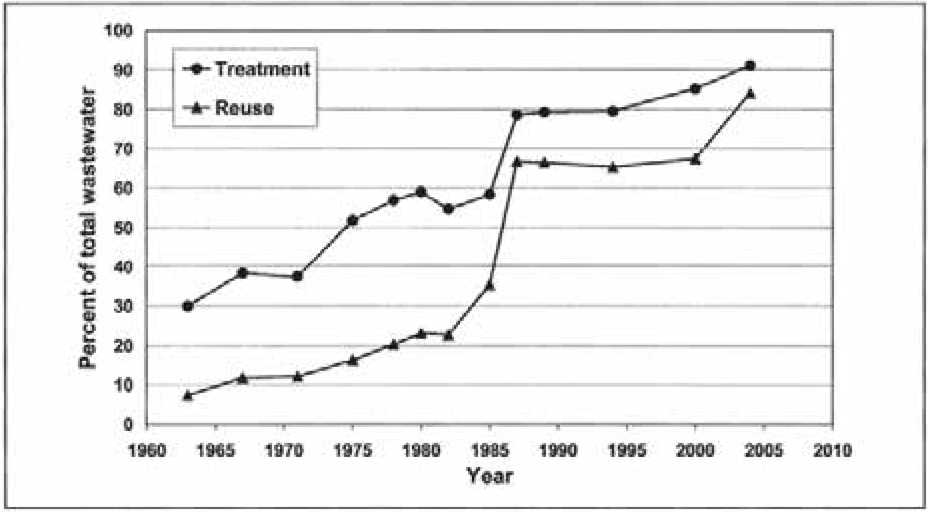

Figure 1: Development of wastewater treatment and reuse in Israel

For several reasons, future management is not as simple as may be reflected in Table 2. In Israel, as in many dry regions, most of the precipitation occurs during a short season of 4-5 months. Furthermore, there is a steep precipitation gradient from north (600-800 mm annual rainfall) to south (less than 100 mm annual rainfall) along a distance of approximately 500 km. This situation requires careful design of water conduits (from north to south) and storage reservoirs (from winter to summer). There is also uneven distribution of population (consuming water and consequently producing wastewater). The coastal plain is densely populated while the southern Negev Desert is much less so, but has the highest reserves of land for agriculture. Therefore, wastewater conveyance systems (from center to south) are required. Storage systems are also necessary for reclaimed wastewater, because it is continuously produced during the entire year, while agricultural demand is mainly during the summer. Storage can be provided in open reservoirs (the most common practice in Israel) or by aquifer recharge. Both strategies affect water quality, because of chemical and biological processes occurring during long storage periods.

Another major issue that has to be considered in extensive reuse of reclaimed wastewater for agricultural irrigation is the salination of soil and groundwater, and the buildup of toxic chemicals in the closed cycle of water supply, wastewater treatment and reuse. The dilution of natural water supplies by a high fraction of desalinated water will reduce salt concentration, but will not reduce salt quantity accumulated in irrigated soils. Under effluent irrigated agriculture, a certain amount of excess water is required to percolate through the root zone, to remove the salts that have accumulated as a result of evapotranspiration. This requires excess water for irrigation. However, this might transfer the problem of salts accumulation to groundwater down below. Thus, desalination of effluent may become necessary in order to prevent soil and groundwater salination, and to conserve excess irrigation water needed to leach salts out of the root zone. Effluent desalination should thus be combined in a quaternary treatment stage that also includes carbon adsorption and/or advanced oxidation, in order to effectively remove emerging trace substances, since desalination by nanofiltration or reverse osmosis is not capable of absolute removal of a variety of trace compounds (Snyder *et al.*, 2007).

Future management of multi-quality water resources (including natural water supplies, desalinated water and reclaimed wastewater) also requires some modification to the traditional upstream treatment strategies commonly applied for drinking water supplies. For example, in desalinated water, the levels of alkalinity and essential minerals, such as calcium and magnesium, are very low. Therefore, desalinated water may be associated with inferior taste and corrosion problems that result in the release of metal colloids into water distribution pipes. In addition, the water-intake of these essential nutrients will be reduced dramatically in some populations. Water treatment processes can affect mineral concentrations and contribute to the total intake of calcium and magnesium for some individuals. Therefore, the Israeli Ministry of Health has proposed new quality standards for desalinated water, requiring the application of post-treatment for the conditioning of desalinated water, mainly through dissolution of calcium carbonate. This process can supply the proposed quality, including: alkalinity > 80 mg/L as $CaCO_3$; 80<Ca^{2+} < 120 mg/L as $CaCO_3$; calcium carbonate precipitation potential (CCPP) > 3 mg/L as $CaCO_3$; pH < 8.5. These quality standards actually cover the need to account for nutritional supply of calcium (> 50 mg/L as $CaCO_3$). The proposed water quality standards do not include a requirement for magnesium addition, on the assumption that this mineral's intake-requirements can be obtained from food products more easily than calcium. However, there have been complaints by farmers who use effluents originating from desalinated water that lack of magnesium affects plant yield and quality.

Addition of alkalinity to drinking water may also be crucial for wastewater treatment schemes employing alkalinity-consumption processes, such as nitrification. The current proposed standard for alkalinity of desalinated water (based on human health considerations, related to corrosion of metal pipes) may not be sufficient to support wastewater nitrification, since typical municipal wastewater in Israel has a relatively high concentration (BOD = 400 mg/L, TKN = 70 mg/L). Alkalinity is usually increased during municipal water use; however further measures may be required to remedy the lack.

There is another problem related to the quality of desalinated water, based on its conversion after primary use to municipal wastewater destined for reclamation and reuse. Boron toxicity to plants may limit the application of reclaimed wastewater originating from seawater, because of the high content of boron (approximately 5 mg/L) and its limited rejection in conventional reverse osmosis processes (Hyung, and Kim, 2006). The new desalination plants planned in Israel are therefore required by the Israel Water Commission to upgrade their processes to reduce boron levels to 0.3 mg/L. In addition, source control measures have been applied by the Israeli Ministry of Environmental Protection, enforcing a gradual reduction of boron content of detergents for washing machines that constitute a major source of boron in municipal wastewater. Another source control policy enforced in Israel (by legislation) to reduce the increase in salinity of municipal wastewater (a more than two fold increase has been recorded in several municipal wastewater systems) is to forbid the disposal of industrial brines and ion exchange regeneration liquids into municipal sewers (Weber and Juanico, 2004). This has partially prevented point-source intrusions of salts into municipal wastewater and, consequently, has reduced the total salinity of many waste streams. In addition, the legislation has led many plants to convert to reverse osmosis in place of ion exchange, to reduce the quantities of salts requiring disposal. These measures, together with more stringent source control of heavy metals, have improved the overall quality of both effluent and sludge, but cannot be considered a solution of the problem sufficient to replace advanced wastewater treatment.

Conclusions

Future management of water resources in Israel is indeed a complex issue, incorporating several measures such as modification of traditional water treatment schemes and quality standards, upgrading of wastewater treatment processes, and source control, as illustrated in Figure 2. New water sources based on desalinated water and reclaimed wastewater should be integrated with natural water supplies, in order to enable sustainable water management. This concept is crucial in water-scarce countries, where reclaimed wastewater should be regarded as a resource and not as a waste product requiring disposal. Management of complex water systems composed of multi-quality sources requires a revolution in the traditional treatment concepts applied so far.

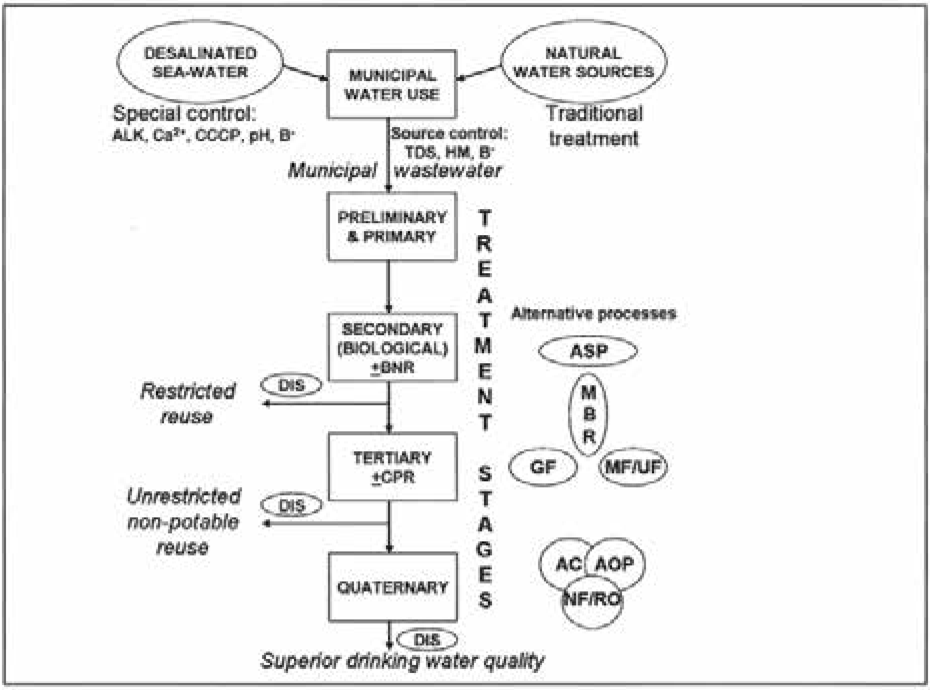

Figure 2: Integrated management of multiple-quality water sources, incorporating multiple-barrier wastewater reclamation train. (ALK-alkalinity; CCPP-calcium carbonate precipitation potential; HM-heavy metals; TDS-total dissolved solids; ASP-activated sludge processes; BNR-biological nutrient removal; MBR-membrane bioreactor; CPR-chemical phosphorus removal; DIS-disinfection; AC-activated carbon; AOP-advanced oxidation processes; GF-granular filtration; MF-microfiltration; UF-ultrafiltration; NF-nanofiltration; RO-reverse osmosis)

In Israel, it is planned that by 2020, practically all municipal wastewater will be reused, mainly for agricultural irrigation. In addition, 30% of Israel's fresh water supplies will consist of desalinated water. This will change considerably the composition of water in general and consequently, that of the resulting wastewater. Measures to reduce the salts, sodium, and boron content of effluents destined for agricultural irrigation should be applied in the management of both water production, and treatment. On the other hand, lack of essential minerals in desalinated water, which are essential for human health, or are required to enable efficient wastewater treatment and fulfil agronomical needs, should also be resolved in a sustainable manner. Thus, with a massive national program of seawater desalination and wastewater reuse, it is now clear that wastewater treatment processes and reuse considerations may affect raw water treatment strategies, which have been traditionally related to human health considerations only.

The tertiary wastewater treatment stage, based on granular or membrane separation processes (MF, UF) followed by effective disinfection technologies, have significantly improved human health problems related to pathogenic microorganisms. However, the era of effluent BOD, as a control parameter for effluent organic content, has actually ended. Emerging organic trace compounds recycled in the closed loop of water use and reuse, require application of a quaternary treatment stage as an integral part of wastewater reclamation schemes to ensure superior water quality effluents even for non-potable reuse applications. The quaternary stage may integrate a combination of processes such as activated carbon adsorption, advanced oxidation, and tighter membrane separation processes (NF, RO). The technological formula that ensures absolute protection from these problematic compounds has not yet been defined, and therefore should be further investigated.

Acknowledgements

This article is based on data obtained from the Israel Water Commission and on experimental knowledge gained by the author through research projects that were financially supported by the Israel Water Commission and by the Israeli water company *Mekorot*. However, it reflects the independent opinion of the author.

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Session VI – Medium-Sized Enterprises (MSE) Introduction

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Sustainability and Innovation – Challenges and Opportunities for Medium-Sized Enterprises

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Introduction

Many may have heard of the project „Great Man-Made River" (GMR) in Libya. This project gives an ideal opportunity to discuss not only the necessity of water for mankind's existence in general, but also the sensibility of technical solutions in view of the concept of sustainability, whereby the genial art of such engineering remains beyond question. After fossil water reservoirs have been detected during oil drilling work in a depth between 300 and 2,000 m beneath the Sahara desert, the ambitious GMR project was conceived and pursued during the mid 80s. The project's goal is to supply water from the desert to the coastal population centres. This water was collected in huge underground caverns at the end of the last ice age, between 10,000 and 30,000 years ago, when the glaciers melted.

A gigantic water pipeline that was built as part of this project runs parallel to major portions of the Libyan coast and conveys over 6 million m^3 of drinking water, daily. The costs of the entire project are estimated to be 25 billion dollars.

- 960 wells with a depth of 450 to 650 m had to be drilled within an area covering 8,000 km^2.
- Every pipe segment is wrapped with 18 km of carbonated metal wire. This means that only for the first project phase a length of wire was used that would be sufficient to surround the globe 230 times.
- The water reserves in the Kufra basin have a volume as big as the flow of the river Nile over a 220 year time period.
- If and when the project will be finished, a volume of water will be removed and conveyed that equates to half of the global oil production.
- Experts estimate that the Libyan population, consuming 6 million m^3 of water per day, can be supplied with water over a 50 year period.

In addition to supplying potable water to the population, another aim of the project is to develop Libya into an exporter of agricultural products. A feared and, to a certain extend, already happening consequence is that the groundwater table is lowered.

This example clearly demonstrates the value of water resources and our dependency thereon, but many people living in developed countries do not seem to be aware of it. We in Germany even believe that we generally have an abundance of water; as often and for how long we open the water faucets, water is flowing and does not cost a fortune, as it does in Libya. And yet, the importance of water has not become a jota less, in spite of the fact that it is shrouded from our conception by our changing way of life, our modern technology and our relatively sustainable water management. However, what does sustainability mean under such circumstances? The fact alone that we in Germany reduced our water consumption by about 40% over the last 20 years is by many experts not regarded as sufficient to achieve sustainable water management - and they are correct. Much has been already said and written about the term "sustainability". Most define this term as a just balance between social, economical and ecological needs and respect the specific demand to prevent over-utilization of our natural resources beyond their natural regeneration rate. Therewith, another aspect is introduced into our discussions: time! And time is a most important factor of water and wastewater management because our investment into the necessary infrastructure for water distribution and wastewater collection is a long-term decision that can usually not be reversed.

The time horizon considered by mankind, and in particular by the political class, is often too short and the question whether our decisions are really long-term sustainable is often neglected. And this is blatantly evident from the example of the Libyan water project; it is certainly laudable to supply people with potable water and to use an existing resource, but few seem to have considered so far what will happen after 50 years. One could not read a word in the planning concepts about wastewater reuse for irrigation to permit agricultural development for export. And the aspect of time becomes visible a second time when we try to answer the following question: What do innovative technical solutions for wastewater treatment look like that really meet the challenges of preventing water shortage, safeguard water supply and protect water reservoirs? We must always keep in mind that good wastewater treatment is precondition for sustainable and affordable potable water supply. This is why planning and design of water supply systems must be done simultaneously with that of wastewater treatment and reuse systems.

Sustainable wastewater management

Sustainable management is characterized by its time dimension and directed towards the future. It is thus understood that sustainable wastewater management has to achieve its goals in the far future, respects the needs of nature and mankind in equal measure, and – of course – also permits the industry to provide affordable and operable concepts and technologies in the near future. It must be adaptable to given and changing circumstances and should keep a sense of proportion in respect to treatment efficiency requirements. It should also permit value generation in the countries where it is implemented and, if this is the case, it is usually superior to projects funded by development aid agencies that either do not provide advanced technical solutions or, in the other extreme, are too complex and inoperable "presents" by industrialized countries.

In view of these aspects, we see many new challenges and opportunities for research institutes and the industry, in particular for medium-sized enterprises that are generally quicker to develop innovative concepts and then realize solutions and products. Medium-sized enterprises are not only nimbler, but they also have opportunities that large companies are usually lacking because the business interests of the latter force them to remain focused on large projects and centralized utilities.

To recognize the challenges and potentials, we should first look at current practice and technology in view of sustainability and consumption of other resources, such as energy and nutrients. Optimized and innovative solutions can be developed on this basis. Let us not forget that forward looking wastewater management must be adaptable to changing circumstances; climatic change, growth of population or its shrinkage require flexible solutions. Specific requirements exist for different countries or regions. Adapted concepts and solutions must be discussed, developed and implemented in view of climatic, social, economical and ecological conditions – an enormous challenge, but also an enormous opportunity, for medium-sized enterprises to improve centralized solutions by use of new products, or to implement de-centralized solutions by development of new concepts and products.

A view into the past

Particularly in Germany we have a situation that is assumed to be an ideal example for most other countries. We have safe and secure water supply and highly-efficient wastewater treatment in large centralized plants or in small de-centralized household units guaranteeing bathing water quality in most of our lakes and many rivers. If we look closer, however, we also see a few drawbacks that some times inhibit or even prevent the transfer of our technology to other countries and cultures. The following points shall be given as examples:

- The greater part of wastewater management costs of centralized systems is determined by construction of often poorly inspected sewer systems that sometimes need a long time to build, whose useful life is often over-estimated, that are difficult to adapt to hydraulic changes, and that are very problematic in earthquake-prone regions.
- For the transport of faecal matter and urine about 20 times their volume of drinking water is consumed. All this potable water becomes contaminated with germs and organic micro-pollutants.
- Organic carbon and nutrients (the latter mainly introduced with the urine) are degraded in expensive processes and under consumption of energy instead of being reused.

- Sludge generated by wastewater treatment in large quantities is often difficult and expensive to dispose of.
- Micro-pollutants from human excretion generate a potential risk for drinking water supplies.
- Requirements concerning effluent quality depend on the size of the treatment plant. These are valid for each treatment plant of that size, in general.

A view into the future

Our view into the future - and it shall also be somewhat visionary within the framework of this symposium – shows various potentials for innovation that can be associated with different aspects. Separation of wastewater flows might have the best chances in many cases, comparable to the introduction of solid waste separation in Germany many years ago, but at the same time it meets the hardest resistance because it means a paradigm shift away from present wastewater management methods. Flow separation, however, does not necessarily need to be an element of all innovations by medium-sized enterprises that meet our requirement of sustainability.

Demographic change

Decreasing population in Germany is a challenge in two respects: reduced freights arriving at the wastewater treatment plant and impaired transportation of solids through the sewers – increased by water saving behaviour of the population – will generate a need for new concepts. It is for example conceivable that more concentrated wastewater, after removal of coarse solids, will be fed directly into an anaerobic reactor with high biological efficiency and the benefits of low sludge production and biogas generation. Existing tanks could be retrofitted for this purpose. Subsequent nitrification could also be performed in existing tanks; controlled nutrient recovery from the effluent of the anaerobic reactor after fine-screening could also be considered. Sewers will need to be retrofitted with intelligent, remotely controlled equipment for flushing to guarantee reliable transport of the solids to the treatment plant and to prevent deposits in the sewers.

Renovation of buildings

Renovation of existing houses and improvement of their sanitary appliances in combination with the need for improved thermal insulation and heat recovery from grey water could become an interesting field for innovations. After installation of separate pipe systems, reuse of separately collected and treated grey water for irrigation, toilet flushing or as cooling medium for air conditioning, with simultaneous recovery of heat from the grey water, requires compact treatment units with integrated heat exchangers and controlled heat recovery for installation in buildings. Biological processes, combined with disinfection, but also use of ceramic filters or nano-filtration could provide new opportunities for the development of technical solutions and products. Development of low-maintenance, easy to clean heat exchangers to prevent scaling and fouling is a challenge for universities and companies.

Achievement of the millennium development goals (MDGS)

Shortage of potable water, lacking sewers and wastewater treatment plants, enormous water consumption and rising demand for nutrients for agricultural food production, severe environmental pollution and damages at many places, unchecked population growth in many regions worldwide, and the intention to achieve the MDGS within the timeframe set by the United Nations, make the search for other, better and probably entirely new methods for water and wastewater management an imperative necessity. Reuse of wastewater must be a particular and central portion of all concepts. If we remember the challenges existing in Germany for sustainable wastewater management, we can distinguish some focal points in other regions that promise great potential for innovations, especially where the needed infrastructure has not yet been built:

- Separation of rainwater and grey water from the remaining wastewater, their de-centralized treatment in suitable processes and their reuse could make it necessary to provide surplus rainwater or grey water storage tanks for controlled sewer flushing. Treatment of the remaining concentrated wastewater, together with organic household waste – reduced to small pieces-, in high-efficiency anaerobic reactors, and recovery of nutrients from their effluents with suitable process technology and with the aim of controlled reuse of the nutrients in agriculture, offer great opportunities for new developments.
- Urine separation also offers a series of interesting aspects with the need for new technical solutions. The following principal advantages can be stated: most of the nutrients and micro-pollutants are retained, comparatively simple and inexpensive wastewater treatment without the need for nitrification and de-nitrification is sufficient, the sludge has a better quality and can be used for soil improvement in agriculture. Where urine is separated, even simple mechanical treatment by fine- or micro-screening is very effective for fast and inexpensive reduction of environmental pollution, and it is far more effective than current treatment of sea and river outfalls. Selective destruction of relatively high-concentrated organic micro-pollutants in separated urine and recovery of nutrients from urine require development of new process technology if direct agricultural land application of the urine will not be possible. Urine management, i.e. separate collection, conveyance to outdoor storage tanks, odourless storage and selection of suitable materials to prevent or reduce precipitation and scaling, also requires innovative products.
- Extensive introduction of highly efficient de-centralized treatment units from larger buildings down to single households does not necessarily needs to use aerobic

processes, but could be envisioned to be done in full-automated anaerobic units that treat domestic wastewater (with grey water separated) together with organic solid waste. Use of the generated biogas could be done such that the biogas from individual small units is collected through gas pipelines and used in a central plant. Instead of "unproductive" and large diameter sewers, small diameter pipes would be installed to convey an energy source.

Superior aspects

Use of modern communication technology and respective strategies are opening further innovation potentials, extend the present concept of sustainability into the area of products' life cycles, and may become relevant for future wastewater management. It is for example conceivable that

- wastewater treatment plants on a common receiving water body communicate with each other such that information about their effluent quality is transmitted to a central control unit. This unit then controls the operation of all plants and reduces their energy consumption in view of actual quality parameters of the receiving water body. Suitable sensors monitoring the effluent and water quality and an expert system would be a field for new development.
- equipment and entire processes become self-monitoring and schedule their service and maintenance themselves, depending on their loads, hours of operation and condition. Selection of suitable parameters and monitoring sensors as well as sophisticated computer software for their analysis would be the objective of development. Some companies have already started such activities.

Summary

Discussion of the aims of sustainability and of their application for wastewater management show many challenges and also many opportunities for innovation; only some of them could be indicated here. There are interesting potentials especially for small and medium-sized enterprises because they do not need to think in all-embracing and overarching dimensions, but can focus on their search for and occupation of specific niches suitable to their company's profile. For German enterprises it will be very important, however, that they are provided with opportunities to introduce and test their innovations in their home market and permitting them to prove and demonstrate their innovations' applicability and efficiency for foreign markets.

Prof. Dr. Franz Bischof

HUBER Solutions for Global Water Challenges

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Abstract: It is inconceivable that the UN Millennium Development Goals could be achieved with conventional technologies that have been developed in and for water-rich industrialized countries. They are not suitable for arid or semi-arid developing and emerging countries. There are more cost-effective innovative solutions for central treatment plants. Anyway, decentralized wastewater treatment and reuse is the key to sustainable water and nutrient resource management. Membrane bio-rector (MBR) technology is now also available for decentralized wastewater treatment. MBR systems produce effluents of bathing water quality that can be reused without restrictions for irrigation or as service water. Their effluents can even be discharged into very sensitive surface waters or ground infiltrated for groundwater replenishing. Decentralized wastewater treatment is cost-competitive where the housing density is low. Where fresh water is scarce and expensive, large buildings, such as hotels, condominiums, apartment and office complexes should be provided with decentralized MBR systems for the treatment and reuse of combined wastewater or separated grey water.

Keywords: Cost-Effective Wastewater Treatment, Decentralized Sanitation, Effluent Reuse, Grey Water Treatment, Membrane Bioreactors.

Global water challenges

About 1.1 billion people have no access to potable water, and even 2.6 billion people are without sanitation. The UN Millennium Development Goals state that these numbers should be reduced by half until the year 2015. To meet these goals, access to potable water for over 150,000 people and new sanitation for about 400,000 people must be provided every calendar day. It is hard to conceive how planning, design, construction, installation and financing could be achieved at such a pace, unless innovative solutions become available.

Lack of clean water and sanitation is the number one cause for epidemic diseases and deaths in developing countries. Over 5,000 people, most of them children, are killed every day by water pollution.

As the world's population is growing and climatic conditions are worsening, water scarcity is rising.

Over 70 % of human water consumption serves for irrigation. This percentage is bound to rise even further to provide food for growing populations in arid and semi-arid regions.

Competition for water is becoming fiercer and a fundamental reason for violence, population displacement and war.

Not only our fossil energy resources, but also our water and phosphorus resources are gradually depleting. Energy, water and nutrients will certainly become ever more expensive and less affordable for the poor.

In many regions soil fertility is decreasing due to erosion. Soils loose organic carbon and thus their water and nutrient absorbing capacity. They become less fertile and need even more irrigation and fertilizer.

Sustainable and adapted solutions

The only sustainable solution for global water challenges is closing loops by reuse of water, nutrients and organic carbon, and by recovery of energy. In addition, we must reduce water consumption.

We have to understand that in many countries wastewater is our most dependable water resource. As we use water, we produce wastewater. As we eat, we excrete nutrients and energy-rich organic carbon. As we have learned to separate and recycle solid waste, we now must learn to separate and recycle wastewater and its ingredients. Sustainable solutions create value from waste.

Only adapted solutions can be successful. They must be adapted to regional and local conditions: climatic, environmental, social, cultural, technical and economical conditions.

Solutions must be efficient, affordable and easily operated. Sanitation technology developed long ago in water-rich industrialized and wealthy countries is not suitable for arid and poor developing and emerging countries. It is a terrible mistake that "conventional" sanitation technology, which is wasting freshwater as transport medium, is employed where it should have no place.

Different solutions are required for cities with sewers, cities without sewers, small towns, suburbs, rural villages, resorts and isolated dwellings.

HUBER SafeDrink® solution (potable water from surface water)

Simple and affordable production of potable water from moderately polluted surface water is needed in developing and emerging countries.

Screening, sedimentation, flocculation, sand filtration and disinfection are the basic and simple steps of our SafeDrink Solution (see Fig. 1). Operation and maintenance are easy. SafeDrink plants have a capacity of 10 m³/h or larger.

Two identical HUBER SafeDrink plants are operating in Dongola City and Eldebba, Sudan (See Fig.2). Each plant has a 150 m³/h capacity of and provides potable water for 70,000 people.

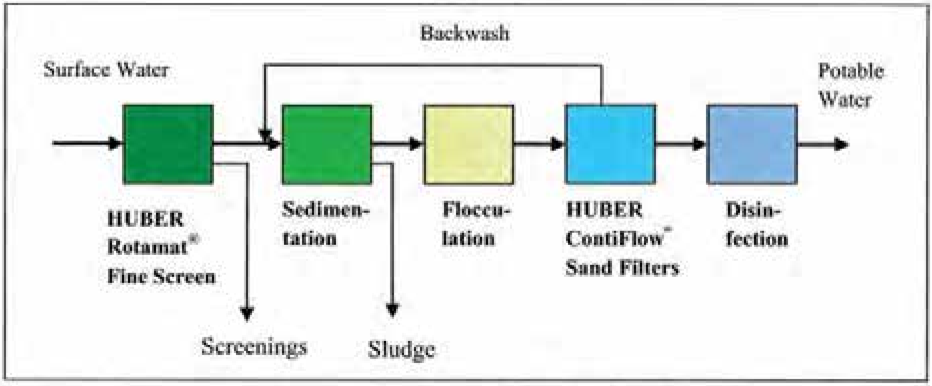

Figure 1: Basic and simple steps of the affordable HUBER SafeDrink® Solution

Figure 2: ContiFlow® sand filter in Sudan

Figure 3: ROTAMAT® fine screens at lagoons in the Middle East

HUBER PondPlus® solution (upgrading of wastewater lagoons)

Wastewater lagoons or ponds are widespread as simple technology for wastewater treatment where sufficient area is available. Their large surface area has the disadvantage that a great portion of the water evaporates in hot and humid climate. Treatment efficiency is limited and sludge removal is difficult.

Our PondPlus Solution improves lagoon treatment effectiveness and facilitates effluent reuse for irrigation, particularly for water saving drip irrigation.

The first improvement step is addition of fine screens or micro-screens for wastewater pre-treatment (See Fig. 3) They prevent scum formation on lagoons and clogging of drip-irrigation lines.

The next improvement step is filtration of the overflow from aerated lagoons through our rotating VRM membrane filters. The membranes retain all solids and bacteria, but nutrients remain in the effluent. The retained active biomass is returned to the aerated lagoons (See Fig. 4) whose biomass concentration, treatment efficiency and capacity are thus greatly increased. Of course, their aeration capacity has to be increased in order to provide sufficient oxygen for COD removal and nitrification, and to keep the biomass in suspension.

Anaerobic, non-aerated, settlement and polishing lagoons are no longer needed and can be upgraded into additional aerated lagoons, further increasing treatment capacity and effectiveness. Methane emission and breeding of disease carrying mosquitoes are prevented.

Our PondPlus Solution upgrades aerated lagoons into compact and efficient membrane bio-reactors. We increase efficiency and capacity, reduce foot print, surface area and evaporation losses.

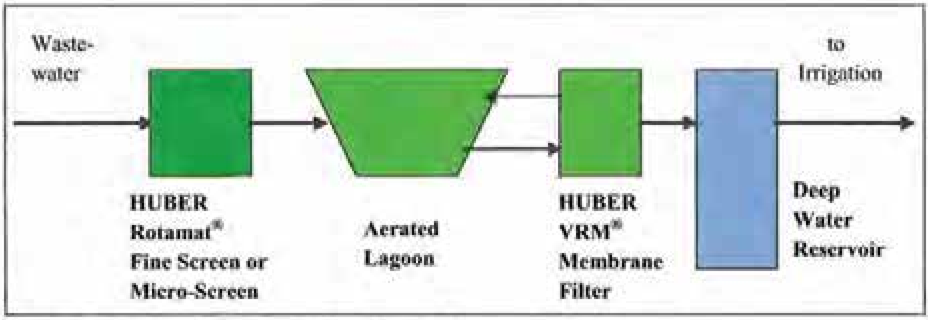

Figure 4: HUBER PondPlus® Solution for lagoon improvement

HUBER MeChem® solution (cost-effective Mechanical/Chemical wastewater treatment)

Budgets for environmental protection projects are notoriously tight, particularly in developing and emerging countries. It is imperative to achieve the greatest possible improvement with a limited amount of investment.

Since costs rise exponentially with treatment efficiency, basic treatment of all wastewater flows must come first.

Our MeChem Solution provides a modular step-by-step wastewater treatment system (See Fig. 5). The first mechanical step of fine screening is least expensive and most cost-effective. The following mechanical (See Fig. 6 and 7) and chemical steps further improve effluent quality, but become gradually more expensive.

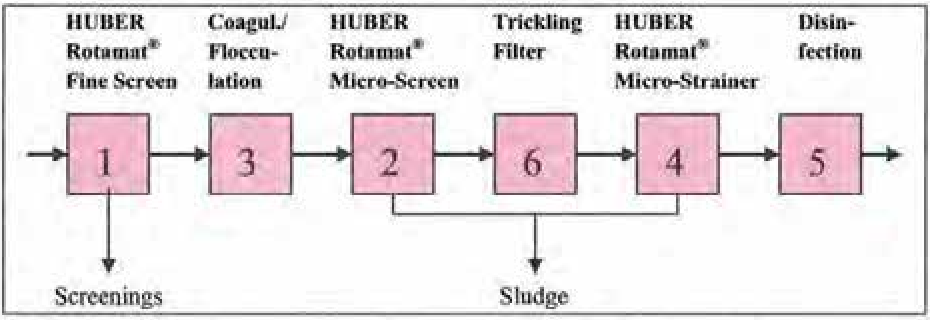

Figure 5: Step-by-step implementation of modular HUBER MeChem® Solutions

The steps taken depend not only on the available budget, but also on the effluent requirements and type of effluent reuse. For outfalls into the sea and large rivers, basic mechanical treatment may be sufficient (steps 1 to 2), for outfalls into more sensitive small rivers, streams or lakes mechanical treatment should be combined with chemical treatment by P-precipitation / coagulation / flocculation (steps 3 to 4).

Urine separation at the source would be desirable to prevent eutrophication and excessive growth of oxygen consuming algae and plants in lakes or bays. Urine contains most of the N- and P-nutrients. However, where the effluent is used for irrigation, high nutrient concentrations add value.

Whether disinfection (step 5) is needed depends on the type of crops that are irrigated and on the irrigation technique. Disinfection is usually required where receiving surface waters are used for bathing or as a freshwater recourse.

Biological treatment (step 6) is the last and most expensive step. Chemical treatment is no longer needed, unless P-removal should be required.

Maximizing investment results

We assume that your budget permits an investment of 1 million Euros. Table 1 compares how much COD can be removed with progressive MeChem steps. It also shows the specific investment per COD removal capacity.

Mechanical treatment has the additional advantage of very low operation costs in comparison with chemical and biological treatment. Chemical treatment has low investment, but high operation costs. For this reason the overall costs of step 3 and 4 are significantly higher than those of step 2, but still much lower than those of step 5 and 6.

The costs of screenings and sludge disposal are not included in table 1. It should also be noted that specific costs depend on individual and local circumstances.

If you want to spend your money wisely, you should invest in basic wastewater treatment first. This is not only more economical, but has the additional benefits that basic technologies are much quicker to design and implement, and easier to operate and maintain.

Table 1: COD freight removal with an investment of 1 million €

MeChem Solution (Steps)	**Unit**	**1**	**1 + 2**	**1 - 3**	**1 - 4**	**1 - 5**	**1 - 6**
Investment per inhabitant	€/I	3	13	18	25	29	125
Population served	I	333,000	77,000	55,500	40,000	34,500	8,000
COD freight in	kg/d	40,000	9,230	6,667	4,800	4,140	960
COD removal efficiency	%	7.5	25	35	50	50	95
COD freight removed	kg/d	3,000	2,300	2,333	2,400	2070	912
Investment per COD removal capacity	€/(kg/d)	335	435	430	420	485	1,100
Operation costs	-	very low	low	high	high	high	medium
Ease of operation	-	easy	easy	medium	medium	difficult	difficult
Reliability of operation	-	very high	very high	high	high	medium	medium

Figure 6: RoMem® micro-screen

Figure 7: RoDisc® micro-strainer

HUBER SeptageTreat® solution (septic sludge treatment for reuse)

Sludge from septic tanks is odorous, offensive and corrosive. It often contains grit, gravel and stones, as well as all kinds of objects that can pass through toilets.

Where possible, septic sludge is hauled to a large central wastewater treatment plant where it is screened and blended into raw wastewater or sewage sludge. Because sufficiently large central treatment plants are usually not available in developing and emerging countries, septic sludge is hauled to remote wastelands. Long-distance transport of thin septic sludge is expensive and fuel consuming. During anaerobic digestion methane is released; methane is about 23 times worse than carbon-dioxide in its effect as greenhouse gas.

Our SeptageTreat Solution serves for treatment and reuse of collected septic sludge. The sludge is screened, de-gritted and dewatered. To prevent odour nuisance and corrosion, we provide enclosed stainless steel equipment. The removed screenings are washed, dewatered, compacted and bagged; they are disposed of as domestic solid waste. The removed grit can be washed and reused as a construction material, e.g. for road or pipe bedding.

Filtrate from sludge dewatering is treated in one of our compact membrane bio-reactor systems. Its effluent is reused as wash water or for irrigation. It contains valuable nutrients.

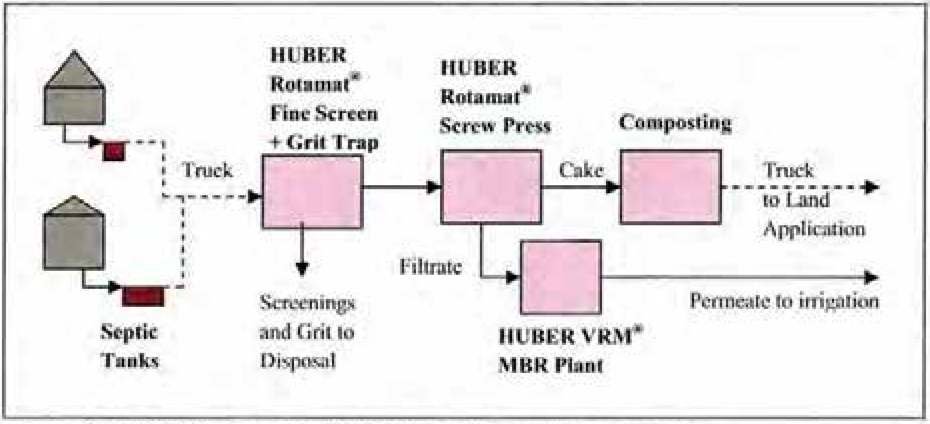

Figure 8: HUBER SeptageTreat® Solution with aerobic composting

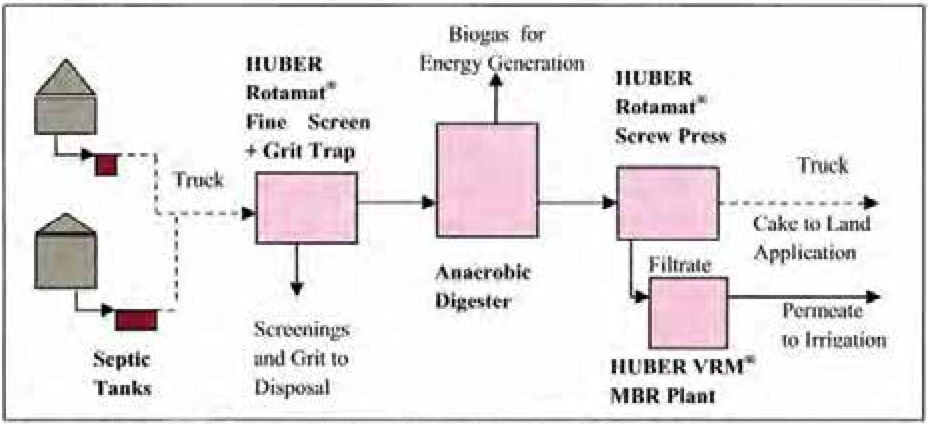

Figure 9: HUBER SeptageTreat® Solution with anaerobic digestion

There are two options: Either the dewatered sludge cake is aerobically composted in simple windrows (See Fig. 8), or the septic sludge is anaerobically digested and stabilized before being dewatered (See Fig. 9). Windrow composting is cheaper, but labour-intensive and odorous. Anaerobic digestion is done in closed reactors; it generates energy-rich biogas and a better product.

In both cases, the produced bio-solids can be reused for land application and soil improvement. They contain humus forming organic carbon and nutrients.

About thirty HUBER SeptageTreat plants are in successful operation in East and South-East Asia. (See examples in Fig. 10 and 11)

Figure 10: ROTAMAT® Ro 3.3 pre-treatment unit in Malaysia

Figure 11: ROTAMAT® RoS 3 screw presses in China

HUBER DeSa/R® solutions (Decentralized Sanitation and Reuse)

The idea driving our DeSa/R developments is that wastewater is a most dependable source of water, nutrients, organic carbon and energy. We produce wastewater every day.

Sanitation is best done where the wastewater is produced and where it can be reused, where we live and work. Decentralized wastewater treatment produces reusable water where it is needed.

Treated effluents can be reused for irrigation of yards, gardens, parks, sport facilities (such as golf courses and stadiums) or fields in the vicinity of dwellings, offices, hotels or resorts.

In addition or alternatively, well-treated effluents can be reused as service water for cooling, flushing or washing purposes. Freshwater consumption is thus reduced.

Rain water and well-treated effluents can be used for ground infiltration and groundwater replenishing and, after soil filtration, be recovered as freshwater.

At first glance, decentralized treatment appears to be more expensive, but enormous costs for construction and maintenance of long sewer networks are saved. In addition decentralized sanitation and reuse reduces freshwater consumption as well as water treatment and distribution costs.

More and more international experts propagate decentralized wastewater treatment and effluent reuse, e.g Beck et al. (1994), Lange and Otterpohl (1997), Henze (1997), Harremoes (1997), Longdong (2000), Dockhorn (2006).

HUBER SeptiMem® solution (upgrading of septic tanks to membrane bio-reactors)

Septic tanks are used all over the world for basic decentralized sanitation, but their effluents are still highly polluted. Treatment remains insufficient even where the effluent is percolated through drain fields. Effluents from tanks pollute groundwater resources.

Fig 13 shows a septic tank that is upgraded to a membrane bio-reactor (MBR). The last chamber of the tanks is retrofitted with a HUBER Membrane Clearbox® (MCB) that includes ultra-filtration membranes and a fine-bubble air diffuser (See Fig 12). A permeate pump, a scouring and an aeration air blower as well as a control panel are installed above ground. A level sensor in the tank controls pumping, air scouring and aeration periods and intervals. Nitrification occurs during aerated periods and denitrification during non-aerated intervals. Phosphorus removal can be achieved through an electrically charged anode releasing iron ions into the water. The ions precipitate phosphate.

All solids and bacteria are retained by the membranes. High biomass concentrations can thus be maintained in the MBR chamber. As a result, efficient biological treatment happens in a small volume.

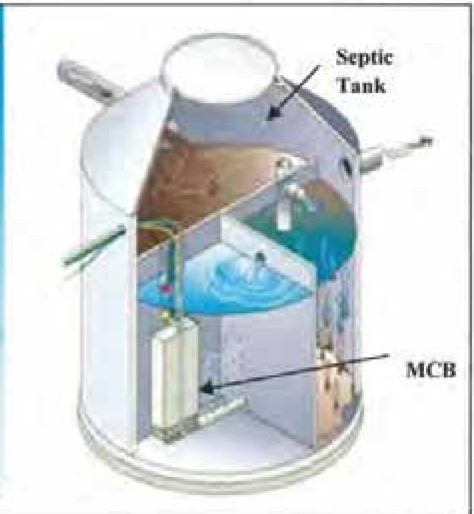

Figure 12: HUBER Membrane ClearBox® **Figure 13:** MBR Septic Tank

The disinfected effluents comply with the European Directive for bathing water quality and can be reused for irrigation or as service water, e.g. for toilet flushing and laundry washing. Table 2 compares the results from certification testing with European and German requirements for service and irrigation water. Effluents can also be discharged into sensitive surface waters, or they can be used for ground infiltration and ground water replenishing.

Surplus sludge is pumped from the last MBR chamber into the first sedimentation chamber about once per year. Every few years, septic sludge is removed from the first chamber.

We or our local partners offer full-service and maintenance contracts. Cleaning and even exchange of the membranes is included.

Over three hundred HUBER MCB units are in operation in septic tanks today.

Table 2: Requirements for effluent reuse and results from certification testing

Parameter	Unit	Discharge as Disinfected Effluent (DIBt:Class D+H)	Reuse as Flush and Wash Water (fbr Guideline H 201)	Reuse for Irrigation Classes 2 to 4 (EU Directive 76/160/EEC for Bathing Water and DIN 19650)	MCB Effluent (Permeate)
BOD_5	mg/l	< 15	< 5	-	2.0
COD	mg/l	< 75	-	-	23.7
NH_4-N	mg/l	< 10	-	-	5.4
N_{inorg}	mg/l	< 25	-	-	24.2
Faecal Coliforms	1/ml	< 1	< 10	< 2	< 1

Cost-comparison with central treatment

Investment for a new septic tank including an MCB unit is about € 8,000 per single-family home. Where MCB units are installed into existing cesspools or septic tanks, the investment is lower.

Pecher (1994) investigated German statistical data of investment and operation costs of sewers and central wastewater treatment plants. Table 3 includes the costs of sewers, pumping stations and treatment plants; and have been updated by the authors to present costs.

Table 3: Investment and operation costs of sewers and central treatment plants according to Pecher (1994) and updated by authors to present prices

Total Population	P	≤ 10,000	10,000 – 50,000	50,000 – 100,000
Investment	€/P	6,750	5,050	4,220
Sewer length	m/P	8.7	6.4	4.9
Investment	€/m	775	790	860
Operation	€/(m*a)	6.9	11.3	16.7
Operation	€/(P*a)	60	72.5	82

Investment per connection of average 3 person single-family homes to a central treatment plant serving a total population of up to 10,000 persons is about € 20,000. The smaller the town or village, and the longer the specific sewer length, the higher is the investment. Assuming an average life of decentralized systems of 35 years, and of centralized systems of 65 years, and a real interest rate of 3 % per year, the annuity is about € 370 for the decentralized solution and about € 700 for the centralized solution.

Operating costs of an MBR septic tank including power consumption, sludge removal and a full-service contract (even including membrane exchange or replacement) are about € 700 per year in central European prices. Savings of fresh water costs – assuming that only 25 % of the effluent is reused – are about € 100 per year. Operating costs of the centralized solution are € 180 per year according to Table 4. Assuming 1.75 % and 1.4 % of the investment for yearly repair and maintenance for the decentralized and centralized alternatives respectively, the R+M costs are € 140 for the decentralized and € 280 for the centralized solution.

Table 4: Cost-comparison between centralized and decentralized solutions

Costs	Centralized Solution	Decentralized Solution
Annuity	700 €	370 €
Operation	180 €	700 €
Water Savings	-	- 100 €
Repair and Maintenance	280 €	140 €
Sum	**1,160 €**	**1,110 €**

Decentralized MBR systems are not generally more economical than conventional centralized treatment plants, but they can be less expensive than centralized solutions for villages, small towns, suburbs and housing developments. If we also consider their better effluent quality and positive effects on the environment, and also the benefits of effluent reuse to water resource management, decentralized MBR system look indeed very attractive.

HUBER ClearOnSite® and ClearNear® solutions (decentralized or semi-centralized wastewater treatment and reuse)

MBR systems are either installed in locally provided concrete tanks, or they are supplied as complete turn-key package plants and installed above or below ground. Their application ranges from condominiums to large hotels and housing developments, from decentralized commercial to industrial wastewater treatment. They are installed in environmentally sensitive areas, or where the effluent is reused.

Huber installations to date include a hotel, an office building, a system for the treatment of landfill leachate and eighty-some container plants for oil exploration camps in Canada.

At small plants a settling tank is provided for wastewater pre-treatment. Figure 14 shows an example of a small MBR system that is designed for 8 m^3/d wastewater flow and installed at the clubhouse of a golf course. Three 12 m^3 concrete tanks are buried. The first tank (on the right hand side) serves for sludge and scum separation. The second tank is used for buffering and equalization of the widely varying flow. Since the liquid level in the second tank varies, the wastewater is pumped to the third tank (on the left hand side) which serves as MBR. 12 MCB units and 6 fine-bubble tube diffusers for aeration are installed in the third tank. The permeate pump, blowers supplying aeration and scouring air and a control panel are installed above ground (not shown).

The effluent is stored in a pond, and water from the pond is reused for irrigation of the golf course. Table 5 shows average results of this MBR system. Since the effluent is reused for irrigation, nutrient removal is not intended.

Larger plants are provided with a 3 mm perforated screen for wastewater pre-treatment (See Figure 15 to 18). The retained debris is washed, dewatered, compacted, bagged and then discharged as domestic solids waste. Since the sludge age within the MBR exceeds 20 days, the bio-solids are aerobically stabilized and can be used as fertilizer and for soil improvement. No septic sludge is produced in this case.

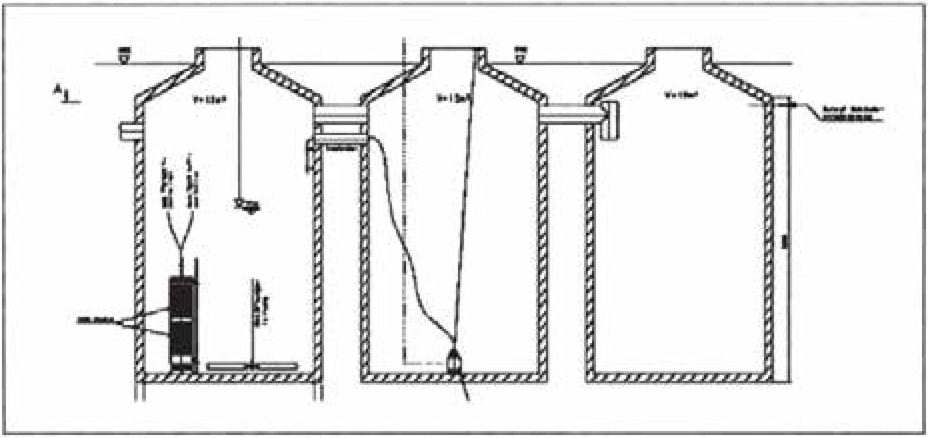

Figure 14: Small underground MBR system at a golf course

Table 5: Results from the MBR system at the golf course

Parameter	Unit	Wastewater Inflow	Permeate Effluent	Reduction
COD	mg/l	573	23.7	95.9 %
NH_4-N	mg/l	84.3	15.7	81.4 %
N_{tot}	mg/l	85.4	34.5	59.6 %
PO_4-P	mg/l	12.1	6.9	43.0 %

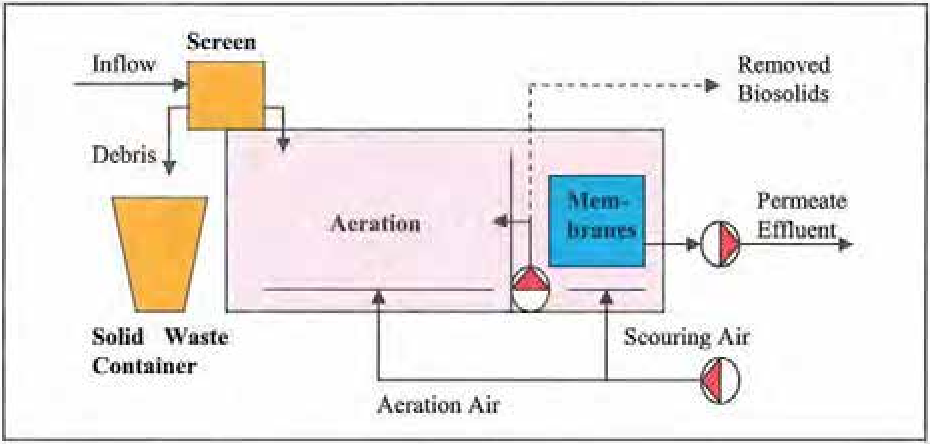

Figure 15: Schematic diagram of an MBR package plant

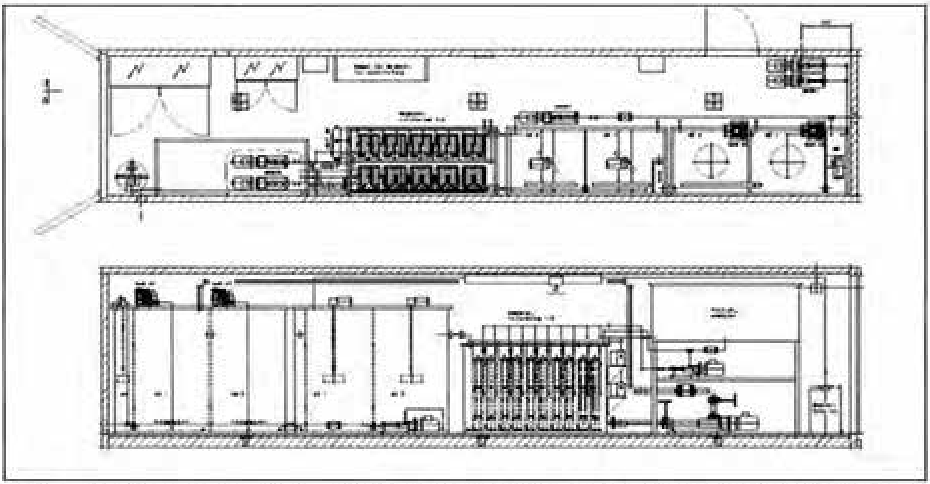

Figure 16: Drawing of a turn-key MBR system with a capacity of 15 m³/d supplied in a 40 foot container; the fine screen for pre-treatment is not shown

Figure 17: Clear Effluent from highly polluted wastewater

Figure 18: VRM Membrane Filters

HUBER GreyUse® solution (grey water treatment and reuse)

Grey water from bathrooms, kitchens and laundry machines contains few solids, COD and BOD, nutrients and pathogens, but most of the detergents. It is easier to treat than combined domestic wastewater. MBR plants for grey water are similar to those for combined wastewater, but they are smaller and produce less sludge (bio-solids).

Separate grey water collection, treatment and reuse are done at large buildings where water is scarce, e.g. in hotels and apartment or office complexes.

Results from an MBR system for treatment of grey water from our office building are shown in Table 6. The effluent has bathing water quality and is reused for irrigation or as service water for toilet flushing without any restrictions.

Table 6: Results from an MBR system for grey water and requirements for effluent reuse

Parameter	Unit	Grey Water Inflow	fbr Guideline (H 201) for Flush and Wash Water	Reuse for Irrigation Classes 2 to 4 (EU Directive 76/160/EEC for Bathing Water and DIN 19650)	Grey Water Effluent
COD	mg/l	514	-	-	23
BOD_7	mg/l	257	< 5	-	< 2.4
P_{tot}	mg/l	7.3	-	-	4.5
Anionic Tensides	mg/l	64.6	-	-	0.5
Total Coliforms	1/ml	3.3 * 105	< 100	-	< 1
Faecal Coliforms	1/ml	1.3 * 104	< 10	< 2	< 1

Conclusions

It is inconceivable that the UN Millennium Development Goals could be achieved with conventional technologies that have been developed in and for water-rich industrialized countries. They are not suitable for arid or semi-arid developing and emerging countries.

Sustainable, adapted, efficient and affordable solutions for the global water challenges are needed. There are cost-effective innovative solutions for central treatment plants, as our examples show. However, decentralized wastewater treatment and reuse is the key to sustainable water and nutrient resource management

MBR technology is now also available for decentralized wastewater treatment. MBR systems have the advantages that they are very compact and produce effluents of bathing water quality that can be reused without restrictions for irrigation or as service water, e.g. for toilet flushing or laundry washing. Their effluents can be discharged into even very sensitive surface waters or ground infiltrated for groundwater replenishing.

Decentralized wastewater treatment is cost-competitive where the housing density is low, particularly in rural areas, villages, suburbs and housing developments. Where fresh water is scarce and expensive, large buildings, e.g. hotels, condominiums and apartment and office complexes should be provided with decentralized MBR systems for the treatment and reuse of combined wastewater or separated grey water.

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Dr. Johann Grienberger

A Contribution to Sustainable Growth by Research and Development

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Abstract: Developed in industrializing countries 100 to 150 years ago and improved ever since, centralized systems for water supply and wastewater management have become the norm. We call this an "end of pipe" solution for wastewater management. It is a matter of fact that sewage collection and central treatment have been a success in view of its original objectives to reduce the spreading of wastewater born diseases and to solve the water pollution problems. Centralized sanitation is highly recognized all over the world and is viewed, particularly in developing countries, as a status symbol for wealth and lifestyle.
In respect to sustainability, however, our centralized system for wastewater management is no longer adequate. Longevity of its infrastructure, long lockup of capital, waste of drinking water for flushing and conveying of faecal matter, energy consuming nutrient removal and, last but not least, pollution of surface waters with micro-pollutants are only some reasons why conventional sanitary systems are increasingly criticized. In addition, because of its high consumption of construction materials, energy and freshwater, our flush canalization can hardly be a model for arid or semi-arid regions.
To permit sustainable development, innovative sanitary systems are needed; systems that simultaneously achieve the economical, ecological and social objectives of sustainable water management. Recycling and integrated resource management take thereby centre stage. Adapted concepts and solutions, adapted to local conditions and constraints as well as to the needs of the local population, which guarantee orderly wastewater treatment, must be developed, tested and implemented. Ideal solutions would include energy recovery and reuse of solid waste as an integral part.
This paper introduces research projects of the Hans Huber AG that have been carried out with the objective to develop and test, under practical conditions, innovative wastewater systems that generate service water of various quality and recover nutrients as well as energy from wastewater. We focus particularly on our experience with innovative technologies for the treatment of separated wastewater flows that we have operated and investigated within the framework of our demonstration project "ReUse Concept" at our headquarters in Berching. Finally we discuss holistic and integrated approaches called "**s**hort **W**ater, **M**aterial & **E**nergy **c**ycles" (sWMEc).

Keywords: Adapted solutions, **D**ecentralised **Sa**nitation and **R**euse (DeSa/R®), production of service water, recovery of nutrients, energy production, yellow water, brown water, grey water, **s**hort **W**ater, **M**aterial & **E**nergy **c**ycles (sWMEc).

Introduction

For decades, in industrialized countries, the infrastructural "status quo" has been continuously upgraded and extended. Under the assumption that centralization permits better monitoring and control, existing water supply and sewage collection networks are simply extended. Almost ubiquitous networks guarantee water supply. Various kinds of wastewater are collected through extensive sewer networks, treated in central plants and then discharged into surface water. In this way, wastewater management achieves its original objectives of safeguarding public health and controlling water pollution.

Traditional water infrastructures in industrialized countries have become, for historic reasons, "end of pipe" systems. Such systems have admittedly the benefit to provide safe and secure water supply and wastewater collection, but on the other hand, they have a large number of characteristics preventing sustainable development. The constraints of such systems can be listed as follows (Dalkmann et al., 2004; Steinmetz, 2007):

- Centralized water and wastewater systems require long-term planning, design and construction
- Over many decades investment must be done into an infrastructure having a long technical and economical life. In addition repair and maintenance of centralized sewer systems is expensive.
- Central wastewater treatment plants for nutrient removal are also costly to operate.
- Centralized systems have low flexibility. They are extremely difficult and expensive to adapt to changing conditions and requirements (e.g. to decreasing population as in eastern Germany).
- Flush canalization systems require large volumes of freshwater for flushing and transportation of faecal matter. Water conservation can even compromise their proper function due to sewer deposits.
- Wastewater flows of different quality are blended, e.g. domestic, commercial and industrial wastewater, storm water and infiltrating groundwater. Dilution results in higher treatment costs.
- Valuable nutrients are removed during wastewater treatment under consumption of much energy. Industrial production of ammonium for fertilisers is energy-intensive and global resources of sufficiently pure phosphorus minerals are limited and depleting.
- Effluent reuse is impractical with centralized systems due to the disposal in receiving waters.
- Effluents of wastewater treatment plants contain micro-pollutants, such as persistent chemicals, pharmaceutical and endocrines, and thus contaminate surface waters.

For above reasons, experts are increasingly doubtful whether it would be reasonable to implement the conventional sanitary systems around the globe. Flush canalization, due to its massive resource consumption, is absolutely unsuitable for regions with freshwater scarcity. Such regions often suffer freshwater as well as fertilizer shortages, and especially, they don't have the necessary finances to build and operate an expensive infrastructure. In theory, our traditional infrastructure would be beneficial for densely populated cities in developing and emerging countries, but fast growth, particularly of their slums and suburbs, resulting from rapid urbanization, usually constrains or even prevents construction and extension of water and sewer networks. Governments and administrations of fast growing mega-cities can not cope with their hygienic, social and ecological challenges. In most cases, a contra-productive "policy of no action" prevails, and in the end no viable concept of wastewater management is pursued.

Innovative sanitary concepts – DeSa/R®

According to a 2006 report of the United Nations, 1.1 billion people worldwide (one fifth of world population) have no access to clean potable water and around 40 % of the global population have to live without proper sanitation and wastewater treatment. Most of these people live in developing or emerging countries. In order to achieve the **M**illennium **D**evelopment **G**oals (MDG) to half the numbers of people without access to clean drinking water and without proper sanitation by the year 2015, it is imperative to develop adapted concepts and customized solutions, achievable with available resources and adapted to the needs of the people.

In view of different climatic, geographic, ecologic, social and political conditions in every country it is demanding to develop sanitary concepts that guarantee proper wastewater treatment and, at the same time, avoid intensive consumption of scarce resources and extreme inflexibilities of traditional systems. Sanitary concepts for mega-cities must differ from such for rural areas. Generally, decentralized and resource-saving solutions must be preferred; solutions permitting sustainable development by consequent recycling and integrated management of resources.

Innovative sanitary concepts are often called **De**centralised **Sa**nitation and **R**euse (DeSa/R®) concepts. It is a concept for "Proximal Ecology" (Larsen et al., 2005) and based on integration of water supply and wastewater treatment. Besides the traditional objectives of public health and water pollution control, two further objectives come to the fore: resource conservation and recycling.

Reuse of wastewater for irrigation is supported by the World Health Organization (WHO). Their guidelines state: "The use of wastewater (i.e. excreta and grey water) in agriculture can help communities to grow more food and make use of precious water and nutrient resources. However it should be done safely to maximize public health gains and environmental benefits." In this context, wastewater becomes a "secondary raw material", raw material for the production of service water of various quality, for production of phosphorus and nitrogen and, last but not least, for power and/or heat generation. A fundamental paradigm shift, turning our traditional way of thinking on its head, is happening: The era of wastewater discharge is ending - a new era of wastewater reuse has dawned.

Research at Hans Huber AG

Implementation of alternative and innovative sanitary concepts in developing and emerging countries is often impeded or even inhibited by the fact that traditional wastewater management of industrialized countries is still conceived as state-of-the art. Successful export of DeSa/R® solutions is only feasible if we have reference installations at home and gain experience with their operation. This is the reason why Hans Huber AG invests in several research and demonstration projects that we conduct either in cooperation with universities or alone. It is our objective to promote public acceptance of innovative system solutions and, finally, to improve our chances to export our own technologies, by transfer of know-how and participative processes (Paris et al., 2007).

Our approach is multifaceted (Table 1). For arid or semi-arid regions, such as Algeria, it is obvious to reuse partially treated wastewater for park irrigation. Suitable treatment systems are compact, easy-to-operate and cost-effective combinations of solid/liquid separation and subsequent disinfection (BMBF Algeria). Freshwater consumption in households can be reduced by use of high-quality service water for toilet flushing, laundry washing and irrigation. Big and rapidly growing cities, like Beijing and Shanghai, need wastewater or grey water recycling (BMBF China). An immense challenge is water supply and sanitation for mega-cities like Lima. A promising approach is the common digestion of wastewater compounds and kitchen waste for biogas generation (BMBF Peru).

Table 1: R&D projects of Hans Huber AG concerning DeSa/R® Solutions

Project	Objective			Resource	Machine of Hans Huber AG	Location
	Service Water Production	N and P Recovery	Energy Production			
BMBF Algeria[1] – Decentralized reuse of raw sewage for park irrigation				Municipal wastewater	Ultra-fine screens	Algeria (Emirates)
BMBF Jordan[1] – Development of innovative wastewater treatment with membrane bio-reactors and requirements for ground infiltration and groundwater replenishing in Jordan River valley				Municipal wastewater	Ultra-fine screens and MBR	Jordan
BMBF SMART[1] – Pre-project: Lower Jordan Valley "SMART": Design, installation and start-up of a research and demonstration system for wastewater treatment and farmland irrigation				Municipal wastewater and sludge	Ultra-fine screens and anaerobic reactor	Fu Heis (JOR)
BMBF Peru[1] – Water and wastewater management in mega-cities: Conceptual study for metropolitan Lima				Municipal wastewater and sludge	Anaerobic reactor	Lima (PER)
DBU Storm Water[2] – Development and optimization of a multi-stage system treating runoffs from streets and parking lots for flood control				Storm water runoff from traffic areas	Adsorptive filter	Munich (D)
BMBF China[1] – Semi-central water supply and wastewater treatment systems for urban areas in China				Grey water	Micro-strainer, sand filter and MBR	Darmstadt (D); later China
"ReUse Concept"[3]; **BMBF Vietnam**[1] – SANSED II: Closing nutrient loops via hygienically harmless substrates from decentralized water management systems in the Mekong delta				Yellow, brown and grey water	MAP-precipitation reactor, stripping and absorption column, anaerobic reactor and MBR	Berching (D); Can Tho (VIE)

Legend:
[1] Project with 50 % funding by BMBF (German Federal Ministry for Education and Research)
[2] Self-financed with support by DBU (German Federal Environment Foundation)
[3] Self-financed

Ecological benefits of ReUse concepts

Early in 2006 we implemented our basic ecological recycling concept, the "ReUse Concept", at our headquarters in Berching. Our integrated water and wastewater concept for our new office building is based on separate collection and specific treatment of different wastewater flows. It is our objective to recover a maximum amount of nutrients and service water from the wastewater generated by our employees. We use innovative technologies in our "Recovery Plant". With our "ReUse Park" we demonstrate various possibilities for reuse of treated wastewater and its components, such as irrigation and fertilization of fruit and vegetable plants, and feeding a fish pond with treated effluent (Fig. 1).

Furnishing our office building with no-mix-toilets, waterless urinals and three parallel drain pipelines allowed us to separately collect urine, brown and grey water from their source. We use specific processes for the treatment of these separate flows:

- Precipitation, stripping und absorption for the urine
- Digestion for brown water together with bio-waste
- Membrane bio-reactor (MBR) treatment for grey water

We report about our results and experiences with these innovative processes in the following chapters.

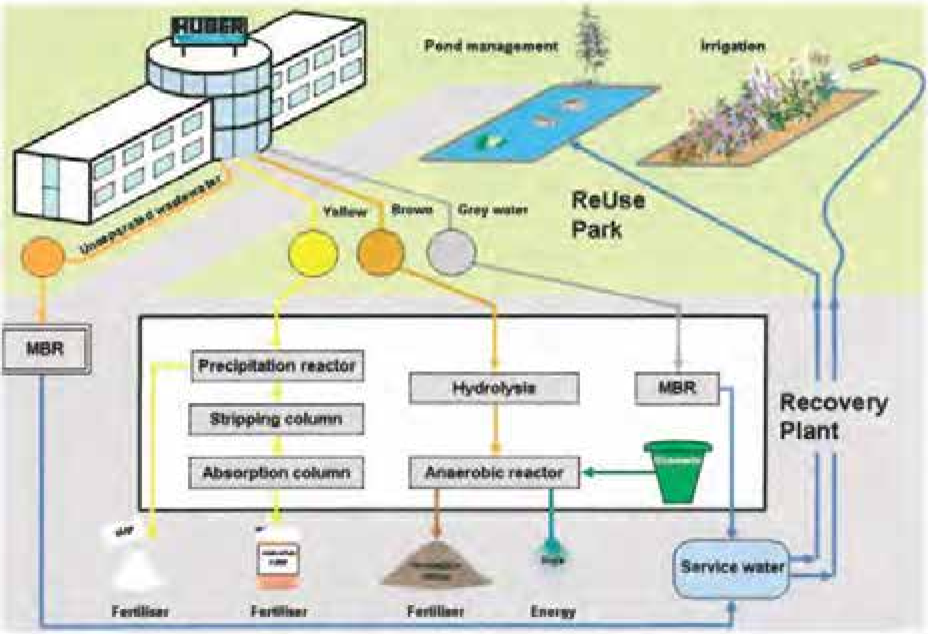


Figure 1: ReUse Concept of Hans Huber AG as implemented in Berching

Urine treatment for recovery of valuable nutrients

Most of the nutrients in wastewater are introduced with urine: Around 87 % of the nitrogen and 50 % of the phosphorus are dissolved in only 1 to 1.5 l/(P*d) of urine. They are dissolved in the form of ions and can easily be resorbed by plants. In addition, urine contains a lot of pharmaceutical residues that are excreted un-metabolized by the human body. It is suggestive to collect undiluted urine, recover its valuable nutrients and eliminate micro-pollutants. We developed a process for nutrient recovery from undiluted urine. Our **Nu**trient **Rec**overy (NuRec) process is comprised of two chemical-physical stages: The first stage is a **m**agnesium **a**mmonium **p**hosphate (MAP) precipitation; the second is a combination of stripping with air and absorption in sulphuric acid. We operate and continuously optimize this process for treatment of urine from our office building.

Characteristics of urine

In fresh urine nitrogen is dissolved in form of urea (Table 2) which is after only a few hours of storage completely transformed by the enzyme urease into hydro-carbonate and ammonium ions. During this enzymatic process the pH-value rises from initially 6 to approx. 9.3. Now the urine contains about 4.7-9.4 g/l NH_4-N and 200-800 mg/l PO_4-P (Hanaeus et al., 1994; see also our averages in Table 2). MAP precipitation and stripping / absorption are suitable processes for such concentrations.

Table 2: Composition of fresh (Udert et al., 2003) and stored urine (own results)

Parameter	Unit	Fresh urine (Udert et al. 2003)	Stored urine of Hans Huber AG
NH_4-N	mg/l	254	3,870
Urea	mg/l	5,810	-
N_{tot}	mg/l		4,570
PO_4-P	mg/l	367	204
Ca	mg/l	129	-
Mg	mg/l	77	-
Na	mg/l	2,670	-
K	mg/l	2,170	-
SO_4	mg/l	748	-
Cl	mg/l	3,830	-
COD	mg/l	8,150	2,870
pH-value	-	7.2	8.9

NuRec process

With the two-stage NuRec process nutrients are recovered in a MAP precipitation reactor and a series of stripping / absorption columns with closed air recirculation (Fig. 2 and 3).

MAP precipitation reactor

Stored urine, having a favourable pH-value, is fed in batch into the reactor. When magnesium oxide powder is added above its saturation concentration, orthorhombic MAP crystals precipitate (their molar $Mg:NH_4:PO_4$ is 1:1:1) and are then separated in a filter bag. With a β-ratio > 1.5 we achieved P elimination of over 96 %.

The dried precipitate is a white powder and has nutrient composition that is comparable to that of a valuable multi-component fertilizer. Investigations by Ronteltalp et al. (2007) proved that MAP from urine is virtually free of pharmaceutical residues and hormones, and that heavy metals are below their detection limit. Our composite sample from 21 cycles had a copper (Cu) concentration above the limits set by the German Fertilizer Regulation (DüMV, 2003; See Table 3). This high concentration can be explained by our use of brass components for our system and can be avoided by use of other materials.

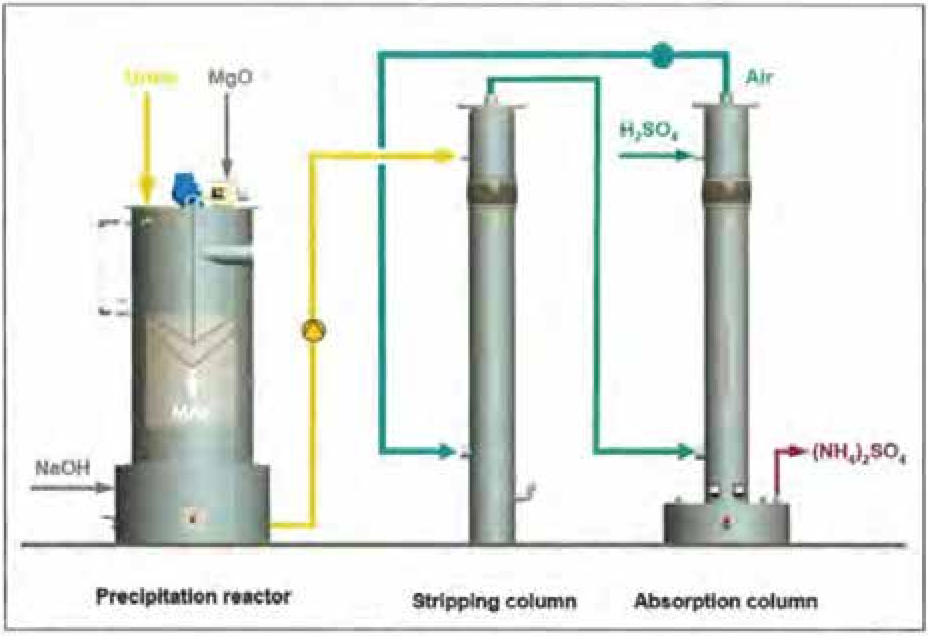


Figure 2: Process flow diagram of our NuRec process with MAP precipitation reactor, stripping and absorption columns

Operational data:

- Batch volume: ca. 48 l
- Cycle duration: ca. 4 h
- MgO cons.* : 1.29 mg MgO per kg PO_4-P
- H_2SO_4 cons.*: 3.5 kg H_2SO_4 per kg NH_4-N

* stoichiometric calculation

Figure 3: Photo and operational data of our NuRec system with MAP precipitation reactor, stripping and absorption columns

Stripping column

After MAP precipitation, the liquid phase still has a high ammonium concentration that is in a thermodynamic equilibrium with its ammonia concentration. By raising its temperature and pH-value (so called conditioning) we move the dissociation equilibrium towards ammonia. By air stripping alone we transfer NH_3 into the gaseous phase. We could transfer approx. 95 % of the nitrogen from conditioned urine with a temperature of 40°C and a pH-value of 10.5 when we operated the stripping column near its flooding limit and re-circulated the media for 2 hours.

Table 3: Heavy metal concentrations in our MAP precipitate and ammonium sulphate solution in comparison with the limits set by the German Fertilizer Regulation (DüMV 2003)

Heavy Metal	Limits of the German Fertilizer Regulation (DüMV, 2003) [mg/kgDS]	MAP of Hans Huber AG [mg/kgDS]	Ammonium sulphate of Hans Huber AG [mg/kgDS]
As	40	< 2.8	< 0.3
Pb	150	< 2.8	< 0.3
Cd	1.5	< 0.3	< 0.03
Cr	-	9.2	2.0
Cu	70	**521**	0.7
Ni	80	2.8	1.9
Hg	1.0	0.1	< 0.003
Zn	1,000	183	24.0
Ti	1.0	< 0.4	0.3

Absorption column

We operated the absorption column that is filled with a packed medium with a 10 % sulphuric acid. By chemisorption gaseous ammonia in the air is absorbed in sulphuric acid and instantly reacts to ammonium sulphate which is a fertilizing chemical. This reaction is exothermic and raises the pH-value to a saturation value of 4.4. Our results showed almost complete absorption occurring even at higher pH-values as a result of physical absorption.

Heavy metal analysis of the ammonium sulphate showed good quality. Their concentrations were far below the limits set by the German Fertilizer Regulation (DüMV, 2003) as Table 3 shows. However, we can get certification as a commercial nitrogen fertilizer only when we increase its nitrogen and sulphur content to above 8 and 9 % respectively. For this reason it is convenient to operate the process with higher concentrated sulphuric acid (> 30 %).

Future Activities

Further experiments have the objectives to produce fertilizers that comply with the German Fertilizer Regulation DüMV (2003) while also further optimizing our process. We applied for funding of a further research project with the objective to analyze our products for pharmaceutical residues.

Anaerobic treatment of brown water for the production of biogas and of bio-solids for soil improvement

Brown water is wastewater consisting of faecal matter, toilet paper and flush water. An average volume of 18.8 l/(P*d) is generated by use of water saving no-mix toilets (Starkl et al., 2005). Brown water, of course, is very odorous and contains many germs and organic solids. Nutrients are organically bound and only slowly resorbed by plants. Precondition for reuse is stabilization and disinfection which is achievable by thermophilic digestion, or mesophilic digestion in combination with thermal pre- or post-treatment. Anaerobic treatment generates biogas that can be used for power and heat production. Disinfected bio-solid product contains much organic carbon and is useful for soil improvement. In Berching we operate mesophilic digestion for stabilization.

Characteristics of Brown Water

Brown water from our office building is in accordance with data published in literature (Tab. 4). As a result of beginning hydrolysis in our storage tank, our brown water has higher concentrations of organic acids and thus a slightly lower pH-value; and it has somewhat higher concentrations of N and P indicating that some urine is blended with the brown water in our no-mix toilets.

Table 4: Composition of brown water (averages at Hans Huber AG and data from literature)

Parameter	Unit	Average at Hans Huber AG	Data from Literature	
DS	%	0.74	0.5 – 1.9	Heerenklage et al., 2003
VolatileDS	%	82.5	80.5	Peter-Fröhlich et al., 2006
COD_{hom}	mg/l	8,741	7,627	Peter-Fröhlich et al., 2007
COD_{fil}	mg/l	1,986	-	
N_{tot}	mg/l	282	156	Peter-Fröhlich et al., 2007
NH_4-N	mg/l	125	44 - 92	Heerenklage et al., 2003
P_{tot}	mg/l	77	40	Peter-Fröhlich et al., 2007
PO_4-P	mg/l	58	10 - 27	Heerenklage et al., 2003
Organic Acids	mg/l	786	462	Peter-Fröhlich et al., 2007
pH-Value	-	6.4	6.7 – 7.6	Heerenklage et al., 2003

Anaerobic plant

Our system for brown water treatment combines hydrolysis and mesophilic digestion (Fig. 4). We also use the hydrolysis stage for thickening. In order to achieve quasi-continuous supply of substrate, we feed the anaerobic reactor four times per day. Operational data are also included in Figure 4.

Continuous operation with a 14 d hydraulic retention time and a volumetric organic solids loading of 0.54 kg VS/(m³*d) produced 110 l/d biogas. Slumps of biogas generation were the result of interrupted feeding for one or two days, but biogas production recovered quickly after feeding was restarted. It even rose to a short peak before it decreased back to its average level (Fig. 6). The average specific biogas yield was 645 l per kg of fed volatile solids. Compared with specific values of 350-500 l for sewage sludge (Lenz, without date), brown water contains more energy.

The parameters pH-value, and the concentration of ammonium and organic acids, that are relevant for process monitoring and control, remained almost constant during our operation and indicated good process stability (Fig. 4). Volatile solids were degraded by an average of 64.4 %.

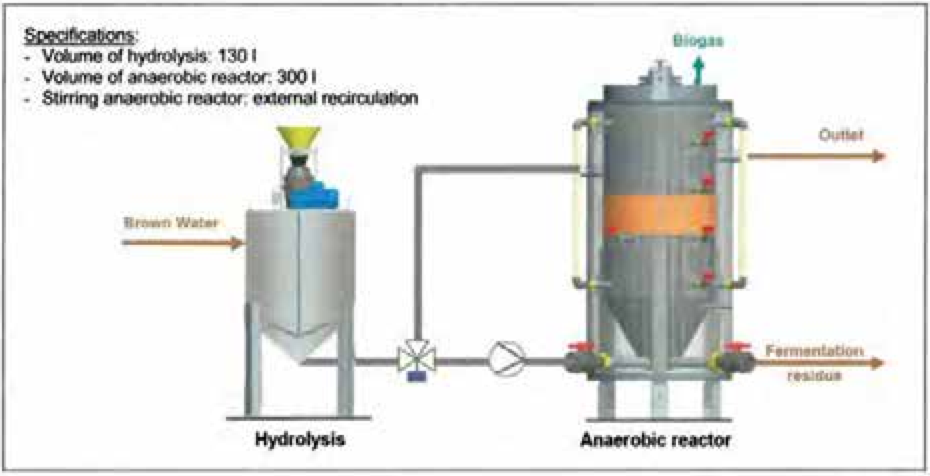


Figure 4: Process flow diagram and data of the anaerobic plant at Hans Huber AG

Hydrolysis	
HRT	ca. 5 d
Temperature	ambient temperature
DS	0.7 - 1.1 %
VS	81 - 88 %
Organic acids	1,100 - 1,900 mg/l
pH-value	5.0 - 5.8

Anaerobic reactor	
HRT	14 d
Temperature	40 °C
DS	2.5 - 3 %
NH_4-N	220 - 390 mg/l
Organic acids	190 - 240 mg/l
pH-value	6.9 - 7.2

Figure 5: Photo and operational data of the anaerobic plant at Hans Huber AG

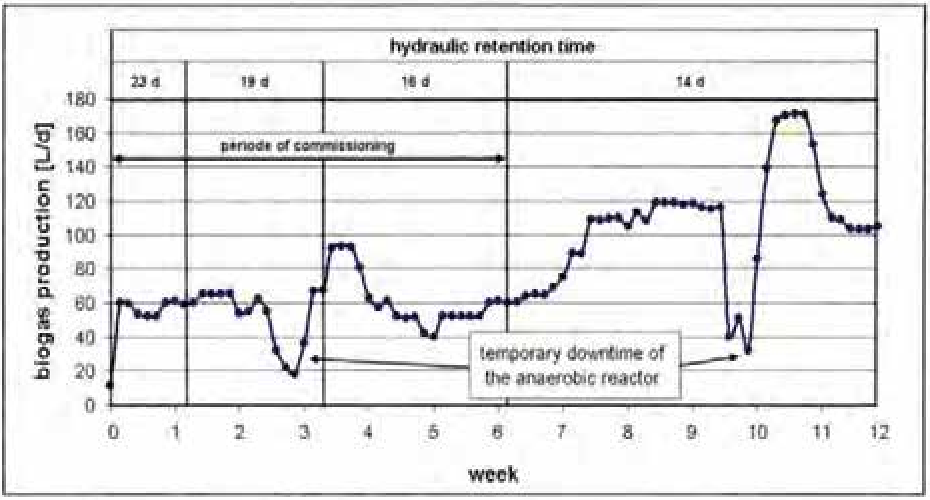


Figure 6: Daily biogas generation in the anaerobic reactor

Future Activities

We plan further investigation of disinfection efficiency by mesophilic digestion of brown water. On the basis of these results we want to select a suitable method for disinfection. We also plan to add bio-waste to increase biogas production.

HUBER GreyUse® – grey water recycling and MBR

Grey water is the effluent from bath tubs, showers, washbasins, dishwashers and laundry machines. In German households that are equipped with modern appliances an average of 70 l of grey water are generated per person and day, which is over 50 % of the entire domestic wastewater (Mehlhart, 2001). In comparison with blended domestic wastewater grey water contains only little organic pollution, has a low nutrient concentration, but high concentration of detergents. Effluents from bath tubs, showers and wash basins contain by one or two orders of magnitude lower concentrations of total and faecal coliform bacteria (Nolde, 1995; Bullermann et al., 2001). It is suggestive to collect grey water separately, to treat it with comparatively little effort and to produce service water that can be used for toilet flushing, laundry washing or irrigation, depending on its quality. For grey water treatment and service water production we have developed a compact and efficient unit that includes a membrane bio-reactor (MBR). We use such a GreyUse® unit to treat the grey water from our office building.

Characteristics of grey water

In our office building we collect grey water from washbasins, kitchen sinks and dishwashers. Its concentrations of organic substance, nutrients and coliform bacteria are within the typical range for grey water from bathrooms, kitchens and laundry rooms (fbr-Guideline H201, 2005). Its COD/BOD ratio is about 2 and indicates normal biological degradability (Table 5).

Table 5: Characteristics of grey water of different origin (extract from fbr-Guideline H201 and averages at Hans Huber AG)

Parameter	**Unit**	**From bathrooms, kitchens and laundry rooms (fbr-Guidlines H201, 2005)**	**From wash basins kitchen sinks and dishwashers in the offices of Hans Huber AG**
COD	mg/l	400 – 700 (Ø 535)	514
BOD_5	mg/l	250 – 550 (Ø 360)	257
SS	mg/l	n.n.	11.0
P_{tot}	mg/l	3 – 8 (Ø 5,4)	7.3
N_{tot}	mg/l	10 – 17 (Ø 13)	15.5
pH-value	[-]	6.9 – 8	6.9
Total coliforms	1/ml	$10^2 – 10^6$	$3.3 \cdot 10^5$
Faecal coliforms	1/ml	$10^2 – 10^6$	$1.3 \cdot 10^4$

HUBER GreyUse®

Our GreyUse® unit (Fig. 7) consists of three main components:

- Screen and grey water collection tank
- Membrane bio-reactor (MBR)
- Service water storage tank

The membrane bio-reactor includes a submersed ultra-filtration membrane module. Some technical data can be found in Fig. 8.

Our investigations showed that, with our grey water's nutrient concentrations, a good biocoenosis grew in the MBR. The system operated stable throughout our test period. COD reduction was in average 94.8 %. Changes of the feed concentration in the range of 351-860 mg/l did not cause any problems. The COD concentration in the effluent was always below 40.2 mg/l (Fig. 9).

Because of its low BOD concentration (< 2.4 mg/l) the permeate could be well stored without odour generation. The permeate was also free of solids and virtually free of germs. Its quality easily complied with the requirements of fbr-Guideline H201 (2005) for toilet flushing, laundry washing and irrigation (Tab. 6).

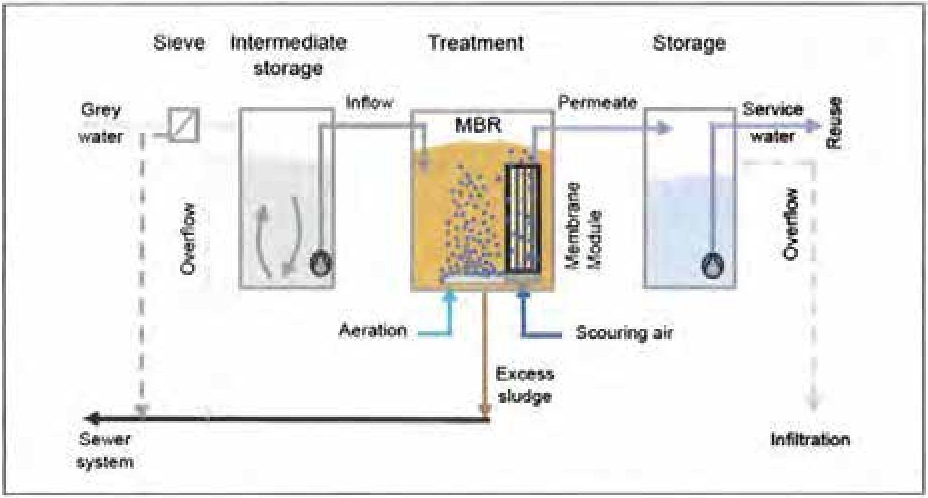


Figure 7: Process flow diagram of the HUBER GreyUse®-unit

Technical Data:
- MBR volume: 0.7 m³
- Membrane surface: 4 m²
- Membrane material: PES
- Average pore size: 38 nm

Operational Data:
- Capacity: 60 l/h (450-800 l/d)
- Suspended solids: 5-7 g/l
- Sludge load: $\leq$ 0.1 kg COD/(kg SS • d)
- Power cons.: 2.2 kWh/m³ (for MBR)

Figure 8: Photo and technical data of the HUBER GreyUse® unit

Table 6: Requirements on service water for toilet flushing, laundry washing and irrigation (fbr-Guideline H201) and effluent quality at Hans Huber AG (Paris and Schlapp, 2007)

Parameter	**Guide values of fbr-H201 (Limits of Directive 76/160/EEC)**	**Service water at Hans Huber AG**
BOD_7	< 5 mg/l (-)	< 2.4 mg/l
Oxygen saturation	> 50% (80-120%)	> 50%
Total coliforms	< 100/ml (100)	< 1/ml
Faecal coliforms	< 10/ml (20)	< 1/ml
Pseudomonas aeruginosa	< 1/ml (-)	-

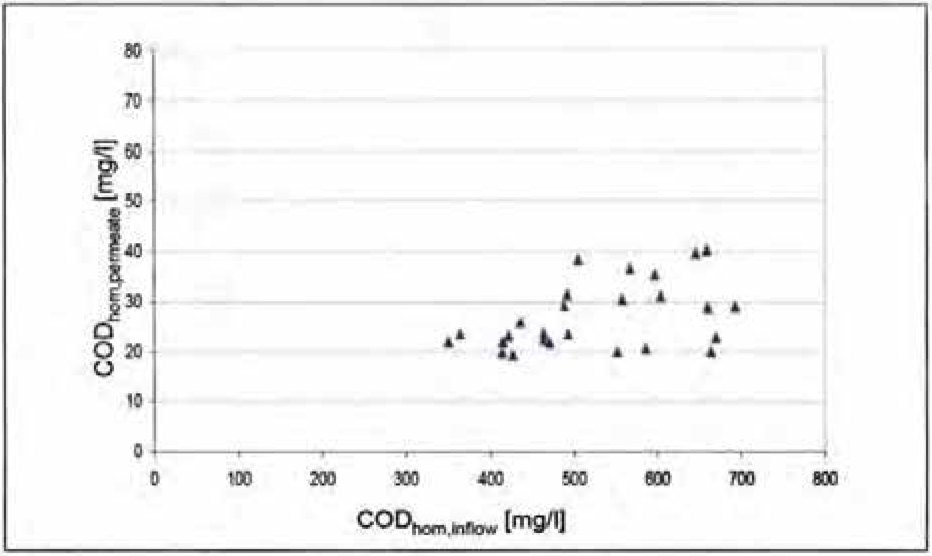


Figure 9: COD concentration of the permeate depending on COD feed concentration

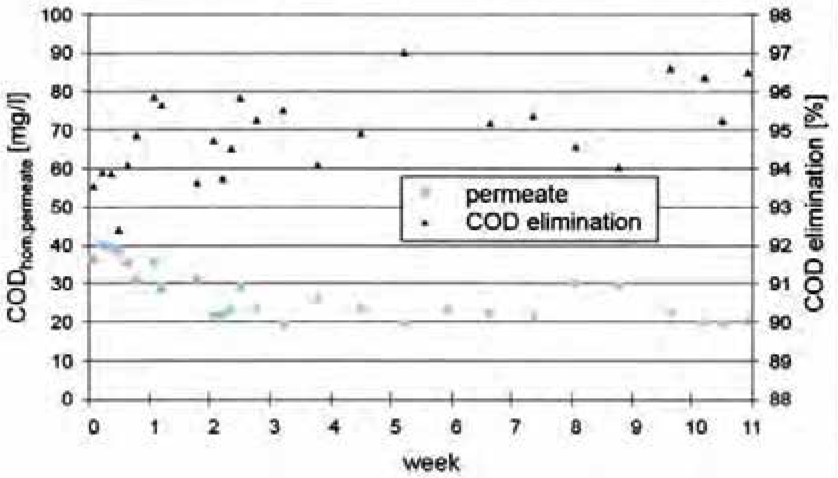


Figure 10: COD concentration of the permeate and COD removal ratio

Future Activities

So far we used the treated grey water from our office building for irrigation of our company garden, our so-called ReUse Park. In future, it shall also be used, together with collected rain water, for toilet flushing in our office building extension that we plan to inaugurate on 28th of September 2007.

Economic considerations – example of grey water recycling

It is generally difficult to determine representative investment and operation costs of new technologies since available data are only available from manufacturing, installation and operation of not yet optimized pilot systems. For "on source" innovations, such as the treatment of separated material flows for reuse, it is even harder because the introduction and implementation of such new technologies in industrialized countries require modification of the existing infrastructure, which again requires a certain investment. In order to carry out a realistic cost analysis for such cases, the costs of this changed or new infrastructure and also the savings by substitution of freshwater and industrially produced fertilizer must be taken into account in addition to the investment and operation costs of the new technology itself. Furthermore all consequences for the general public and the environment, resulting from the introduction of alternative systems, must be evaluated and taken into account.

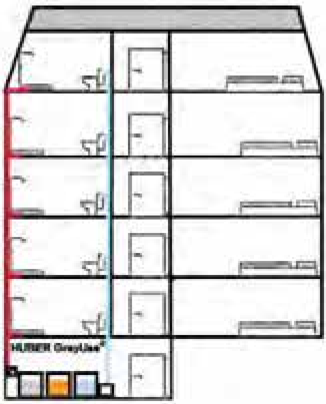
However, for a scenario of decentralized grey water recycling and treatment of black water in existing wastewater plants, its economics can be calculated relatively easily because the existing infrastructure remains in use for some time. The monetary advantage by freshwater substitution can be calculated from the savings of drinking water and wastewater costs. As an example we here present a payback calculation for a HUBER GreyUse® solution for a new-built business hotel in Berlin.

The 4-star hotel with a capacity of 410 beds shall be built with separate grey water collection and flush water distribution pipelines. The average flush water consumption in hotels is 31.5 l/(P*d) (Nolde, 2000) and therewith higher than in normal households. If we assume that 400 beds are occupied in average, the drinking water consumption for toilet flushing is reduced by 12.6 m^3/d.

A compact HUBER GreyUse® unit shall be installed in the basement. Thanks to modular design of the building, the additional pipelines can be installed in a relatively easy way (Fig. 11).

Table 7 shows the investment and operation costs of the HUBER GreyUse® unit. To guarantee its reliable operation we assume yearly maintenance, replacement of spare parts and exchange of the membrane module. The total cost savings are calculated from the sum of water and wastewater costs that are 4.73 €/m^3 (net) in Berlin.

Drinking water and wastewater costs have remained stable in Germany for the last 10 years (wvgw, 2005), i.e. they rose only by about 2 % per year, in parallel to the general costs of living. We assume that this trend will continue. For power, however, we assume yearly cost increases of 5 %. Under such assumptions the payback period is a little below 4.5 years of operation. Savings after 10 years of operation are approx. 87,800 € (Fig. 12). If water and wastewater costs should rise faster, the payback period would be shorter and the savings are significantly higher.



Technical data ot the HUBER GreyUse® unit:

Space required: L = 5,800 mm
W = 2,900 mm
H = 2,100 mm

Max. capacity: 14.6 m^3/d

Power cons. incl. pumping: 3.8 kW/m^3

Figure 11: Schematic diagram of the 4-star hotel in Berlin with 410 beds and technical data of its Huber GreyUse® unit

This calculation shows that both economical and ecological benefits can be achieved by grey water recycling. If service water is used for toilet flushing, laundry washing and house cleaning, German households can reduce their tap water consumption by more than 41 %. Economical water savings can be particularly achieved by businesses, such as hotels, camping places or sport facilities, because of their high water consumptions. Grey water recycling is also a suitable method to save valuable and scarce freshwater in densely populated cities.

Table 7: Net costs of the HUBER GreyUse® unit of Figure 11

Costs	**Amount**
HUBER GreyUse® unit (investment)	47,553 €
Pipelines	20,000 €
Total investment (Interest rate 4 %/a)	**67,553 €**
Maintenance and spare parts (Cost increase 2 %/a)	2,301 €/a
Power costs (14.5 ct/kWh) (Cost increase 5 %/a)	2,560 €/a
Total annual costs	**4,861 €/a**
Annual water and wastewater savings* (Cost increase 2 %/a)	**21,753 €/a**
* cost savings are calculated from the reduced freshwater consumption and the lower wastewater treatment costs	

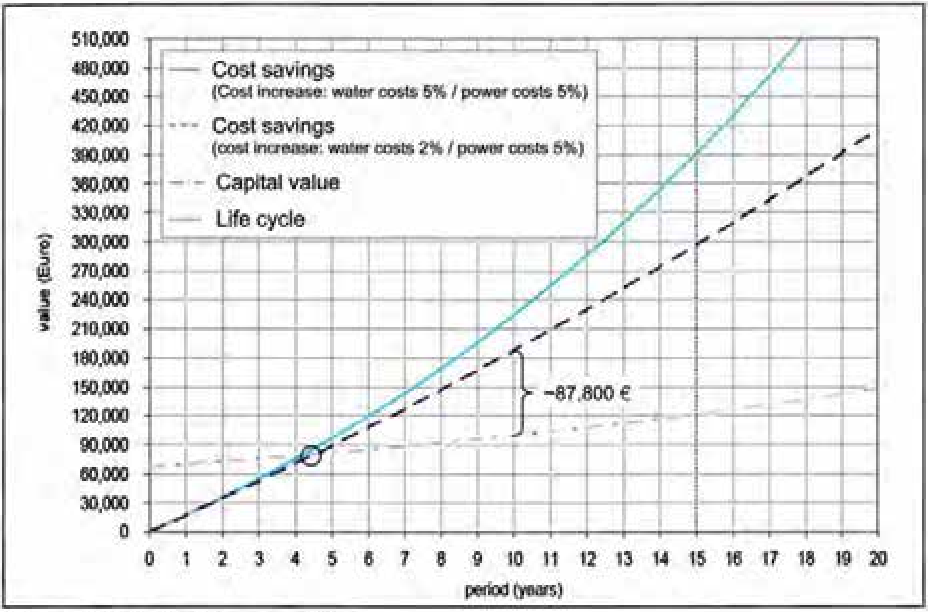


Figure 12: Cost savings over time

Heat recovery from grey water

Grey water is also interesting in respect of its heat content. Most of the energy households consume is for room heating, but second is warm water heating. German household consume in average 35 l/d of warm water per head. About 25 % thereof are used in kitchens, the remainder is used for personal hygiene and cleaning (www.stmwivt.bayern.de). To heat 35 l water from a temperature of 12°C to 40°C heat of 4,100 kJ (1.14 kWh) is necessary. This is about the same amount of heat that is lost when warm grey water is discharged into the sewer.

If grey water is collected separately it is possible to recover at least some of the input energy by use of a heat pump and a heat exchanger. An advantage of decentralized systems is that grey water is warm where it is collected. If 55 % of the grey water heat is recovered, CO_2 emission is reduced by about 71 kg per person and year.

Significant synergy effects can be utilized where decentralized solutions are combined with water and energy recovery. Not only water, but also energy that is contained in this water can be recovered. The required technology can be installed in a basement since it is quiet and almost odourless. Intelligent systems will be controlled by their heat demand, i.e. they are automatically switched on and off depending whether warm water is needed.

Forecast – short water, material and energy loops

Systematic cooperation is necessary for implementation of complex and holistic solutions that are based on integrated water, energy and, last but not least, solid waste management. The ambitious objective of achieving integrated resource management on a small and local scale requires cooperation by experts in various fields, cooperation by consulting engineers, architects, urban planners, waste management experts, energy engineers, economists, politicians and others. Most important hereby is that we close and consequently integrate "**s**hort **W**ater, **M**aterial and **E**nergy **c**ycles" (sWMEc) under consideration of preventive health and environment protection. We are convinced that decentralized concepts with adapted technologies will be preferred in future, such as technologies permitting economical reuse of human excreta and bio-waste in biogas generating plants, collection of undiluted urine and reuse of its nutrients as fertilizer on farmland, or generation of service water and heat recovery from grey water. First pilot systems and experiences with such technologies are already available (e.g. Hans Huber AG, Berlin Water Works, GTZ).

In respect to planning, "**s**hort **W**ater, **M**aterial and **E**nergy **c**ycles" (sWMEc) have to be integrated into urban development concepts, whereby all local components are to be considered that are relevant for sustainable development of the infrastructure. As planned in a demonstration project for Amman (Huber und Arnold, 2007), the urban master plan shall take account not only of the spatial, but also of the social constitution of the urban development area. By flexible and modular design of individual quarters, a fair and just ground utilization is achieved that can be adapted to changing specific needs. It would be ideal if all water, material and energy systems could be integrated within the development area, even located in its centre.

Due to the wide range of sWMEc solutions, interesting markets open up for manufacturers, suppliers and consulting engineers. Great demand for holistic, innovative and decentralized solutions is expected particularly in emerging and developing countries where no widespread infrastructure has been built. But only those exporters will be successful who had the opportunity to test and demonstrate these technologies in their home countries. To safeguard her competitiveness in international markets, Germany must provide more experimental opportunities, must generate a favourable framework for innovative concepts and must strengthen policies supporting alternative projects. This would support our own efforts to develop and test new technologies and to conquer new markets for Hans Huber AG.

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Conclusion

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Technologies
for water

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2.0 / 1 – 9.2007 – 9.2007