Session I

Urban case studies

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Darren Saywell (WSSCC, Switzerland)

Uwe Stoll (KfW, Germany)

Ron Sawyer (Sarar Transformación SC, Mexico)

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Claudia Wendland (Technical University Hamburg-Harburg, Germany), *Martin Oldenburg*

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This paper has been peer reviewed by the symposium scientific committee

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S. Vishwanath (Rainwater Club, India)

Operation experiences with a source-separating project*

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Keywords

Anaerobic digestion, biogas, blackwater, source separation, vacuum toilet, water consumption

Abstract

In Lübeck-Flintenbreite, a source separation is realized in a housing estate firstly in Germany. The project demonstrates the feasibility of the source control system combined with water saving technology as well as fertiliser and energy production.

The water consumption decreases significantly due to the installation of vacuum toilets. The source separation is very effective by a strict separation of black-, grey- and stormwater: The blackwater with a very low volume is containing the main load of nutrients which can be recycled very efficiently. Anaerobic treatment together with organic waste leads to a production of biogas which is used for energy and heat production. The treatment of storm- and greywater is very easy because of the lack of nutrients and takes place in swales respectively in constructed wetlands.

Despite of the high technical approach the operation costs can be much lower than for conventional sanitation systems.

Description of the project Lübeck-Flintenbreite

The described sanitation system is installed in a housing estate for 350 inhabitants named Lübeck-Flintenbreite and is an example for a densely populated rural area. This semicentral system is capable to realise resources and energy recovery in more densely populated housing areas up to 5000 people. The area of the housing estate is not connected to the central sewerage system. All components of the sanitation concept are in use in different fields of application since many years and therefore well developed (Otterpohl et al 1999).

The sanitation system consists mainly of the following components (Figure 1):

- vacuum toilets with vacuum-sewer system and anaerobic digestion with co-treatment of organic waste in a semi-centralised biogas-plant, recycling of digested anaerobic sludge to agriculture with further storage for growth periods. Utilisation of biogas in combined power and heat generator (heating for houses/digester and production of electricity) in addition to natural gas.
- decentralised treatment of grey water in vertical flown constructed wetlands (reed-bed filters) with in interval feeding.
- storm water retention and infiltration in a swale system.

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On the 3.5 ha area there are situated terraced, twin houses and flats. The houses are realised

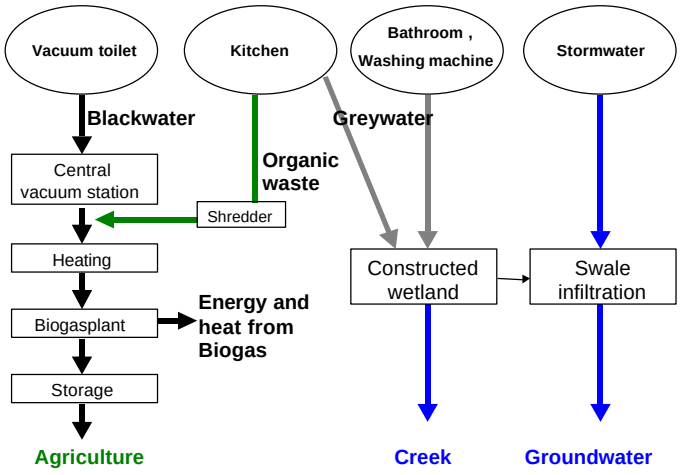

Figure 1: Scheme of sanitation system in Lübeck-Flintenbreite

as low energy houses to reduce the consumption of heating and energy. The construction of the technical equipment and the houses began in February 1999. Until now 28 houses are realised with 95 inhabitants. The central technical equipment is installed in a central community building which is regarded as the heart of the housing estate. First it contains the units for the production of heating and electricity, the vacuum station, the anaerobic digester and all distribution facilities. Secondly the residents can use the central convention room for meetings, parties and other events.

Operation experiences with the vacuum toilet system

The vacuum toilet system has been running for two years without any technical problems. The flushing system which has been optimised during operation needs only about 0.7 l per flush.

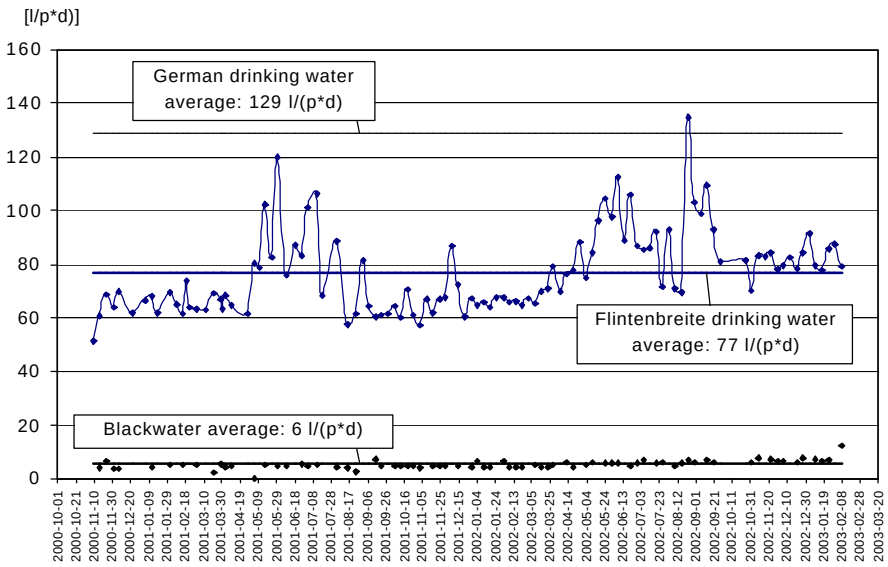

Figure 2: Drinking water consumption in Germany and in Lübeck-Flintenbreite and blackwater amount

Therefore the drinking water consumption is significantly low compared to the German average. (fig 2). The long time drinking water consumption in Lübeck-Flintenbreite is carried out to be

only 77 l/(p*d). The peaks in spring and summer time are caused by garden irrigation.

The average amount of blackwater is found to be approximately 6 l/(p*d). The average amount of greywater is about ten times higher.

Regarding the nutrients in these two water flows, the source separation is very effective. Almost 90% of the nitrogen load is found in the blackwater (Oldenburg et al 2002). The blackwater composition shows the high concentration of organic substances and nutrients compared to conventional domestic wastewater (Table 1).

Parameter	Unit	Minimum	Average	Maximum
Total solids	g/l	7	12	23
Volatile solids	%	65	73	83
TOC	mg/l	3340	5511	10650
Total N	mg/l	1050	1364	1910
Total P	mg/l		131*	

* only one sample

Table 1: Characterization of blackwater

To find out the acceptance of the vacuum system by the users, a questionnaire for the inhabitants was carried out. The evaluation showed that the vacuum toilets are as accepted as the conventional system. Some residents even said that they are more hygienic. Noise might be a concern with vacuum toilets but the modern units which are installed in Flintenbreite give a shorter and a different but not a louder noise than conventional toilets. As an overall result of the questionnaire it can be emphasized that the residents are very satisfied with the vacuum toilet system.

Lab-scale studies with the anaerobic digestion of blackwater

In Lübeck-Flintenbreite, the anaerobic digestion of the blackwater is assigned with further agriculture usage of the digested liquid product. To kill the pathogens, the blackwater which is mixed with shreddered organic kitchen waste is heated previously to 55 C for 10 hours. But since there is only the fourth part of the calculated inhabitant number living there until now the installed digestion plant has not run yet.

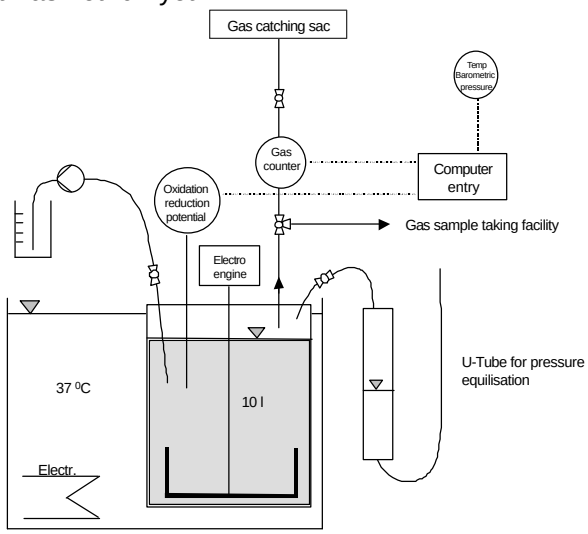

Figure 3: Scheme of the Lab scale digestion plant for blackwater and organic waste

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For the determination of optimal process conditions for anaerobic digestion in Lübeck-Flintenbreite preliminary experiments in laboratory scale have been started in December 2002.

The lab-scale pilot plant consists of three parallel reactors (10 l each), which are made of PVC and arranged in a heated water tub to keep constant reactor temperatures. Three times a week the reactor is fed with new pre-heated substrate. Until now no kitchen waste is added to the reactor? The retention time is chosen to be 20 days. Weekly samples are taken from the feed and the reactor, which are analysed regarding the parameters pH, TS, VS, TOC, TC, TN and TP. The produced quantity of biogas is registered and standardised in Norm-l online. The process is controlled by oxidation reduction potential, which is also measured online. Gas samples are taken and analysed regularly.

The first results show that the digestion process and the biogas production are very stable. However the starting phase is very sensitive (Wolff 2000). The produced biogas amount is about 500 Norm-l/kg VS_{feed}, thus comparable to production rates of organic waste (Gosch 1997) or sewage sludge digestion (ATV 1996). Even with pure blackwater no process inhibition takes place due to the high concentration of ammonia. Further studies with different kinds of organic waste are going to carried out. Different combinations of blackwater and organic waste, retention times e.g. will then be investigated in order to optimise the digestion.

Results

The results of the first three years of operation with the source separation can be named as:

- A low water consumption is achieved due to the installation of water saving technologies.
- A very effective source separation is realised. Nearly 90 % of nitrogen is found in the blackwater.
- The rate of operational problems/disturbances caused by misuse of the system is very low. Problems and their reasons can be identified very easily.
- The vacuum toilet technology is accepted by the inhabitants. After a time of accustomi ng the vacuum toilets are accepted and are seen more hygienic than conventional flushing toilets.
- The first results from the anaerobic digestion of blackwater in laboratory scale are confirming common design parameters like the gas production.

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Urine harvesting through institutional participation: a Nigerian experiment

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Keywords

Urine harvesting, institutional participation, stakeholders, fertilizer, vegetable crops

Abstract

A urine harvesting system was designed and developed at Federal Polytechnic, Ede, in southwest Nigeria. The stakeholders involved were staff and students. Two urinals, one for male and the other for female teachers were built using local materials. These were connected to a storage tank, which was linked to an experimental farm. The urine after dilution with water 1:4 ratio was used to grow common vegetables, viz. 'okra', maize, 'tete' (green amaranth), and tomato in a greenhouse. The nutritional composition of urine used was also compared with organo-mineral fertilizer and NPK chemical fertilizer, which are commonly used by farmers in the area. The growth characteristics of the test crops were followed for 12 weeks and monitored their height, number of leaves and the girth of the stems. The results indicated that the urine could be a good source of manure as well as irrigation water. Based on these results plots were made and the same crops were planted. The acceptability of the urine harvesting practice and the crops grown for consumption were assessed using volunteers from the school. The results indicated that urine-harvesting system is acceptable and found to be viable at institutional level if stakeholders are involved.

Introduction

Indiscriminate urination is a common practice in Nigeria whether it is a taxi park, market or an institution. In the absence of proper disposal facilities such as public urinals, people have no option but to use any convenient place such as a drain, bush, garbage dump or a stream where there is certain amount of privacy. Nigeria, with a population of about 120 million, urine constitutes a valuable wasted resource. Globally, urine harvesting is catching momentum in view of its manurial value as well as its nuisance potential when indiscriminately disposed. However, its hygienic value, odour problems, culture and attitude of the people who are the end users are yet to be ascertained in many countries (Danish EPA, 2001).

There have been no known reports of direct urine harvesting or utilization in this vast country with 120 million populations except that people use sullage or greywater (which is often mixed with human faeces and urine) for agriculture in major urban centres (Sridhar, 1995; Sridhar, 2000). Only one example is known in Kaduna in Northern Nigeria, where an equipment

fabricator routinely uses urine as a source of ammonia to clean the steel in the thermal processing. This paper describes our experience in mobilizing various stakeholders for urine harvesting in a tertiary institution, Federal Polytechnic, Ede, in southwestern Nigeria and subsequent utilization for farming purposes on the campus. The specific objectives included mobilization of stakeholders, design and construction of acceptable urinals for both male and female participants, a urine storage tank, a mixing tank for urine and water with drainage, and a designated farming area for the cultivation of selected test crops after greenhouse experiments.

Study site and methodology

Study site

The Federal Polytechnic is located at Ede, a small town in Osun State. The Polytechnic was established in 1992 and has staff strength of 3,000 with a student population of 8,000, which can increase up to 12,000 in some sessions. The institution has 14 Departments under five schools, viz. Engineering, Environmental Studies, Applied Sciences, Business Administration and Management and General Studies. Some of the students reside on campus while staff and some students reside off the campus. There is a canteen, which caters to the students. The School has a large parcel of undeveloped land, which is currently being allotted to staff for farming purposes pending the time it would be utilized for Institutional purposes. The major stakeholders in the Institution are: The Rector, The Deans, Academic Board (the highest decision making body), Heads of Departments, Teaching and non-teaching staff, Principal Officers, and students.

Methodology

The experiments were conducted in 2 phases. Phase I comprised of sensitising the stakeholders, identification of the site, designing of the Urine Harvesting System (UHS), construction of the UHS, characterization of urine, greenhouse experiments using urine, organo-mineral fertilizer and NPK chemical fertilizers as sources of manures for growth of okra (*Hibiscus esculentus*), maize (*Zea mays*), 'tete (*Amaranthus chlorostachys,* popularly known as green amaranth), and tomato (*Lycopersicum sp.*) as test crops, and assessment of acceptability by the stakeholders. In phase 2 a small portion of land closer to the UHS was prepared into plots and test crops were planted for growth monitoring studies.

Sensitisation of stakeholders

The concept of starting a 'Urine Harvesting System' (UHS) was mooted through a formal application to the Academic Board through the Dean of Environmental Studies. After a long debate the Board has approved the novel idea with certain amount of scepticism. They further approved a take off seed funding and a parcel of land for the project. A 'Sanitation Club' was started with the student participation. Two casual labourers were also employed by the school to complement the efforts of the students in the day-to-day management of the project such as sanitation of the urinal and irrigation of the farm.

Urine harvesting system

The UHS was designed and constructed with locally available materials with appropriate drainage. The flow was by gravity. In the first phase 2 urinals were built one for men and the other for women. Each unit measured 90 cm X 90 cm fitted with a 10 cm diameter shower rose to serve as funnel. A slope was provided at 1:5 for easy flow of urine. Privacy was provided by 6.2 mm ply wood sheet. The units were under a permanent roof in the corridor and were accessible for the users. These were connected to a PVC storage tank of 500 litres capacity. Appropriate pipelines were provided for dilution with water and distribution on to the farm (Fig. 1).

Figure 1: Urinals connected to a storage tank outside the building

Experiments

For greenhouse experiments, black polythene bags (holding 2.5 Kg soil) were used into which appropriate amounts of soil and manures were placed. The nutrient value of urine was compared with normal organo-mineral fertilizer made from urban municipal solid wastes and NPK fertilizer. The treatments included: urine 260 ml/pot (14,000 l / Ha); organo-mineral fertilizer developed at Ibadan 18 g / pot (2000 Kg / Ha which has 5 % N), NPK (15:15:15) chemical fertilizer 2.7 g/pot (300 Kg/Ha). These application rates were based on the common practices in the region and vary with the nature of the crop being grown. A second experiment was repeated using wide mouthed empty clean paint tubs using 10 Kg soil before translating into field trials. The test crops included 'okra', a fruit bearing crop, maize, a grain yielding and sodium sensitive crop, 'tete', a leafy vegetable, and tomato, a fruit-yielding crop. For the field trials 12 plots measuring 1m X 1m were prepared using random block design and the treatments were appropriately computed. Six to seven seeds were put in the pots and when germinated, they were thinned to 2 per pot.

Samples of soil and urine were analysed for physical-chemical characteristics (pH value, C, N, P, K, and soil parameters) and common parasites (*Schistosoma* ova). The effect of urine and other fertilizers on the plant growth, number of leaves, and stem girth during a 12 weeks growing period was followed. Appropriate controls were used without any amendments and tap water was used to maintain the moisture level of the soils. Standard methods were followed for all the analysis (APHA, 1999; AOAC, 1954).

Questionnaire survey

A questionnaire was developed to assess the cultural beliefs and acceptability of urine separation and use for growing edible crops. Volunteers numbering 21 were randomly picked up from the school and were used for the assessment.

Results and discussion

The composition of urine (Table 1) shows the documented normal values and the percent of people clinically abnormal as seen in Nigeria. While the chemical components do not matter for harvesting and use, the presence of pathogenic organisms particularly *Ascaris* and *Schistosoma* ova is a matter of public health concern particularly when used for farming purposes. Urine is also known to carry other pathogenic bacteria (*Salmonella typhi* and *S. paratyphi*) and viruses whose die off varies depending on the environmental conditions. However, if urine is properly stored and used, the pathogen burden will be considerably reduced (Esrey et al, 1998). There are also methods to treat the urine chemically to prevent any infections to those working on farms. According to Drangert (1998), storage of urine for 6 months should be sufficient to eliminate all pathogens.

The greenhouse experiments revealed that urine is comparable to organo-mineral fertilizer or NPK chemical fertilizer as evident from the plant height and the number of leaves during the 12 weeks growing period (Figs. 2 and 3). More data are needed to find out the rate of urine application, mode and frequency of application. The planting of the crops for plot experiments were initiated and data are being collected.

The population involved in the study and their demographic characteristics are given in Table 2. The respondents are mostly men and follow Christianity as religion. Most of them were married and the educational background is National Diploma certificate or graduates. Very few have completed post graduation. The respondents' attitude towards urination and its utilization are given in Table 3. It is evident that 76.2 per cent of them use toilets for urination even though about 30 per cent of them go to bush. Some of them use both depending on the convenience. All the respondents except one visited the UHS site. The general observations were: (a) urine is comparable to other manures and urine promotes better growth; (b) no body complained of the unpleasant smell around; (c) about 81 per cent of them eat crops grown on urine; (d) about 95 per cent of them were prepared to work with urine if occasion demands; (e) most of them were prepared to use urine diversion toilet if provided; and yet (f) two-thirds of them were afraid of urine for its possible pathogens which may affect their health.

Conclusions

The results obtained in this study revealed that urine is comparable with other chemical fertilizers and organic manures in supporting the growth and yield of food crops. It is a valuable resource and harvesting is viable at institutional level. Similar to ours, Danish experience also showed that culture of the users influences its use for crop growth (Danish EPA, 2001). It is difficult to adopt on a large scale until the acceptance is obtained through continued health and environmental education using demonstration units. A participatory stakeholder approach coupled with effective sanitization of urine is suggested to overcome any taboos in the communities.

Tables

Characteristic	Normal urine (%) (Kolmer, 1944	% Population showing clinically abnormal composition in south west Nigeria
pH value	(pH scale)6,0-7,5	0,00
Water	95,00	--
Proteins, fats and other colloids	0,00	--
Glucose	0,00	--
Sodium	0,35	--
Chloride	0,60	--
Urea	2,00	--
Uric acid	0,05	--
Potassium	0,15	--
Ammonia	0,04	--
Calcium	0,015	(Ca oxalate)34,00
Magnesium	0,006	--
Phosphate (PO_4)	0,15	(PO_4 crystals)42,00
Sulphate (SO_4)	0,18	--
Creatinine	0,075	--
Erythrocytes and their pigments	65.750,0	12,00
Pus cells	Few	66,00
Spermatozoa	Usually absent	16,00
Yeast cells	Usually absent	20,00
Trichomonas vaginalis	Usually absent	20,00
Schistosoma haematobium ova	Usually absent	32,00

Table 1: Composition of normal urine and percent of Nigerians showing abnormal levels of the constituents

Characteristics	Number n=21	Per cent
Demographic		
Age	Between 17 and 50+	
Gender		
Male	12	57,10
Female	9	42,90
Marital status		
Married	13	61,90
Single	8	38,00
Religious affiliation		
Christians	14	66,70
Muslims	7	33,30
Educational background		
National Diploma	14	66,70
First Degree	2	9,50
Postgraduate Degree	3	14,30
Secondary school	2	9,50

Table 2: Demographic characteristics of the respondents

Characteristics	Number* n=21	Per cent
Urination practices		
Urinal	3	14,30
Toilet	16	76,20
Bush / any where	6	28,60
Visit to the urine harvesting site		
Visited	20	95,20
Not visited	1	4,80
Knowledge on whether urine is good for plant growth		
Good (yields better)	21	100,00
Not so good (may damage crop)	0	0,00
Better than others (manures, etc.)	21	100,00
Willingness to use urine		
Yes	20	95,20
No	1	4,80
Reactions to the surroundings of the urine harvesting area		
Smelly	2	9,50
Not bad	19	90,50
Fear of pathogens affecting their health		
Yes	14	66,70
No	7	33,30
Willingness to eat vegetables grown on urine		
Yes	17	80,90
No	4	19,10
Acceptability of urine diversion toilet if installed		
Yes	20	95,20
No	1	4,80
Willingness to grow vegetables on urine, if given an opportunity		
Yes	20	95,20
No	1	4,80

Table 3: Respondents' attitude towards collection and utilization of urine *Multiple responses were obtained

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Further development of urban wastewater disposal systems in conurbation

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End-of-pipe-technology, conurbation, utilization, sustainability, resource recovery

Abstract

Sustainable dealing with resources in the field of wastewater treatment is not only a question for rural but also essential for urban areas. Wastewater treatment technology in conurbation in industrialized countries is a well established End-of-Pipe (EOP) technology with a long history. Finding future solutions shall not focus on finding replacing alternatives but shall include further development of the existing system. For a conurbation in Germany like Hamburg, the highest potential in saving resources can not be found in saving water. This does not fit the boundary conditions of the developed wastewater collecting system based on water as a transport medium. Instead, creating subset flows at the origin of wastewater to recover included resources in human urine e.g. nitrogen or phosphorus is a necessary first step. The question is how to utilize the obtained values. Utilization as fertilizer may be difficult if there is no equivalent agricultural area in the neighborhoods of conurbation compared to the possible amount of recovered nutrients. What are reasonable alternative applications for recovered values from wastewater in conurbation? To raise this question and to search for answers is the contribution of the HSE Hamburger Stadtentwässerung to a worldwide sustainable dealing with resources.

Preface

160 years ago Hamburg started to establish a systematic urban sewage system according to modern standards. It can be considered as one of the oldest sewage systems in continental Europe. The know-how about the handling of wastewater is a valuable legacy for the HSE - Hamburger Stadtentwässerung. Besides, according to the companies philosophy, this is an obligation to look into the future. This is a responsible balancing act between preservation and innovation for over 2 million people in the Hamburg Metropol Region.

The slogan “ecosan-closing the loop” for the Lübeck symposium in the year 2003 is not new. It was discussed in detail already 140 years ago by British agricultural-scientists Sir J.B. Lawes and Sir J.H. Gilbert. At this time there was no artificial fertilizer, but a high knowledge about the nutrient content of urine and feces. Nutrient recovery from human excrements contra improvements in public health and the slowly achieved level of modern convenience were crucial topics at this time. The decision made, led to a sewage system with water as transport medium as we find it today in all industrial countries. The value of human excrements as fertilizer was rated second and the pollution of surface water was accepted because in the beginning untreated wastewater was discharged into the receiving water. The foundation was laid for the EOP-system dominating the wastewater treatment in industrial countries. Experts in Europe at this time were aware of different techniques of wastewater handling for example in

[1] Thank you for translation to: Andrea Klatt, Verena Schultz-Coulon, Hendrik Schurig

India, China, Japan or Africa. The efforts of the above mentioned two scientists are still highly esteemed today.

We will have to answer the question if the present level of knowledge does still lead to the same reasonable answers to the questions asked 140 years ago. Are there unanswered questions? Are there problems in the foreseeable future that require a further development in wastewater handling?

Introduction

The Hamburger Stadtentwässerung HSE is a municipal service provider. The primary tasks are seen in the regional responsibility and not in a profit–minded global market. Water supply and wastewater treatment in the future will be a question to be discussed globally. This is especially the case regarding the newly developed and growing conurbation areas. Progress cannot be achieved with the maxim of profit optimization. The HSE wants to take its stand as a competent and traditional sewage work company with its part to the conference.

The forecasted global population growth until the year 2050 is another 2.7 billion people. This growth will mainly take place in the developing countries especially in urban areas. The HSE has gone through a process of long experience and innovation in the area of wastewater treatment in the Hamburg Metropol Region. It can now be of a growing international interest. What seems to be a solved problem in industrialized nations according to today's standards is a big problem for the large cities in the developing countries. Millions of people die as a result of insufficient wastewater treatment (so called Waterborne diseases).

HSE deals with the evident tasks of an urban precaution of future society as a consequence of the incoherent development of the EOP-system. The reached status quo in global treatment technology is very different. Its universally valid assessment and the necessary, future stage goals make the solution of the problem very difficult. – It will be a reorientation, finding the conscious of the own position. Important right now is to point the way for a sustainable wastewater treatment.

Industrialized countries do not have to replace their existing successful way of wastewater collection and treatment. But it is important to enable changes. Now is the time for innovations to create an advanced picture of urban wastewater collection and treatment that fit the level of today's know-how. Breeding ground for such a sustained progress can be the increasing understanding of global nutrient and energy fluxes. This includes a new assessment of regional circular processes and the effects of climate changes. The resulting action will have to be integrated in long-term strategies.

The point of view represented in this paper may sound provocative to some of the readers. Under the circumstances given in the Hamburg Metropol Region a reduction of the total amount of wastewater produces a conflict. The average amount of water used per person and day in Hamburg is 120 l. Based on the existing EOP-system it is fateful from an ecological and economical point of view to propagate further progress in water saving. To start necessary further development of wastewater technology in the Hamburg region, water saving is the wrong attempt. It is the wrong location at the wrong time.

Analysis

The further development of wastewater disposal is not only an urban concern. In long-term it can become a vitally important problem, if there is no development for the urban future, nowadays. Why that? Because urban sewage disposal results in irreversible losses of resources in numerous ways. On the one hand, the disposal process consists of an energy taking destruction of valuable substances. On the other hand, the EOP technique does not

eliminate pollutants efficiently enough to avoid continuos amount of environmental pollution. In addition supply and disposal in growing conurbation increase the effort for transportation. Some facts help to illustrate the situation in Germany:

- In Germany losses of soluble minerals into the receiving water and therefore into the sea are up to 1 metric ton per hectare and year. In conurbation there are even larger losses up to 5-6 metric ton per hectare and year, e.g. caused by the large urban sewage works. In conurbation and the surrounding this will leave impoverished soil, that is less capable for recyclable biomass production. Elutriation of soluble substances is connected to the enrichment of insoluble pollutants in the soil. The compensation of this effect is very difficult to manage, if at all. The causes themselves have to be changed to limit the damages.
- Besides losses by irreversible dispersion, the losses of valuable substances by elimination in the wastewater treatment process have to be mentioned. On the one hand nutrients such as nitrogen or phosphorus are eliminated with a high energy demand. On the other hand production of these nutrients has consumed a relatively high amount of primary energy. A sustainable dealing with valuable substances does not allow the destruction of value.
- Supply and disposal services for large populations in the conurbation areas generate an increase in transportation effort. The distances covered to supply goods to such areas become ever longer. The total amount of supplied material increases. At the same time due to the high transportation effort the specific efficiency decrease. Each separate substance has a different value that has a different profile of how it can be used. The EOP-System mixes and dilutes these valuable substances, so that no efficient recovery is possible.
- This well established End-of-Pipe-Technology has reached a kind of equilibrium status of positive and negative effects. Adding for example another treatment step to a process may reduce the environmental pollution in the first place but it may be neutralized by negative co-effects resulting from the same step. Additional reduction of surface water pollution is technically possible, i.e. removal of pollutants down to ever smaller concentrations but this can be of a contra-productive effect for environment protection after all. It is important to look at the root causes of environmental pollution. Only recently the maxims of ecopolicy started to consider the roots of environmental pollution, the complex environmental protection, interactions and possible shift effects to fight against. The focus has to be on the total emissions caused by wastewater disposal. This includes direct and indirect gaseous and solid emissions integrated in the assessment of regional and global necessities.
- Problems of growing interest are micro pollutants in the wastewater. Residues of drugs enter the wastewater via human excrements. Other micro pollutants enter via Personal-Care-Products into the wastewater. These pollutants and their metabolites have in common that they have or can have carcinogenic, teratogenic or mutagenic characteristics. It is most probable that these substances are not accumulated in the sewage sludge. A reduction or elimination of micro pollutants in the EOP wastewater treatment process is not possible or at least does have a very poor efficiency due to the high dilution factor. The drugs entering the receiving water of a sewage system also include antibiotics. As a consequence the number of resistant bacteria increase. It is not yet clear if the sewage plants just fail to remove antibiotic resistant bacteria or if they are responsible for the increase of resistant bacteria populations.
- Traditional EOP-sewage systems do have in most cases a mixed sewerage with emergency outlets. Heavy rains can cause emergency overflows. Diluted wastewater enters into the environment without any treatment. The discharged annual polluting load resulting from emergency overflows may reach the amount of polluting load in the treated water leaving the treatment plant. During the last years an increase of heavy rains in Germany could be noticed. Whether or not this indicates a climate change, it seems to have a negative effect on the quality of surface waters. The ongoing decline of consumed fresh water increases deposits in the flush-sewerage-system. As a result more pollution load could enter the surface water by combined sewer overflow during heavy rains.

- The used flocculants and precipitation agents, e.g. help to eliminate phosphorus. But they also bring additional substances into the treatment processes that are showing undesirable side effects.
- Assessment of the resulting residues of the sewage treatment to the current standards of sewage disposal means, that the EOP-system works very powerful. Otherwise the residues, which are not usable are the indication, that the preservation of resources, in particular the recovery of nutrients, are no objective of this technology. The EOP-system is orientated to eliminate and not to recycle valuable components.
- EOP-sewage systems in industrialized countries have a setup that does not favor resource recovery. Treatment technology improvements followed other priorities. The technology and its boundary conditions were developed over a long period of time. For example a fee/tax system that is based on the consumed fresh water, stands in the way of a sustainable sanitation concept. Major goal not only in the conurbation is the level of households connected to the sewer system. In Germany the average connection level is 95 %, in Hamburg it is even 99 %. This is no scope for new alternative concepts but it provides an option for further development of the existing system.

Chain of cause and effect requires further development of EOP-systems

The example of the element nitrogen is discussed in order to clarify the necessity of the further development of the wastewater-disposal system in conurbation.

The enormous growth of the (world)-population during the 20th century from 1.5 to 6 billion people, was only made possible by large-scale industrialized production of nitrogen-containing fertilizers. At present 13 kWh of primary energy are needed for the production of fertilizers containing 1 kg nitrogen. The production of by far over 100 million tons of fertilizer-nitrogen, synthesized by atmospheric nitrogen, currently consumes 3 % of the world-energy-demand.

A nowadays well known but unsolved problem is the insufficient length of stay of synthetic nitrogen-fertilizers within the biomass-producing nutrient-cycle in contrast to naturally generated soil-nitrogen. The rate of loss is about 50 %.

Nevertheless, since the technical triumph in 1915 when artificial fertilizer was produced in unlimited amounts for the first time, it seems to be possible to provide enough food for the growing world population. At the moment 2 billion people owe their lives to artificial fertilizers. Without nitrogen-containing artificial fertilizers the harvest of 1 ha land can feed 10 human beings, with intensive application of artificial fertilizers 1 ha of land nowadays nourishes up to 40 people. It can be calculated that a world-population of about 9.4 billion in the year 2050 can be sufficiently supplied with artificial fertilizers. Limiting factors is not the lack of food but rather negative effects that result from a high consumption of primary energy for the production of artificial fertilizers, a necessary increase of traffic for distribution of food. Another negative effect is the environmental damage by nitrogen losses, among other things caused by an insufficient utilization of organically bound nitrogen. As a result all media are harmed at the same time: climate, water and soil.

From the beginning of the industrialized agriculture during the last 100 years, especially urban population grew tremendously. Looking into the future 80 % of the growth of the world population until 2050 is expected to take place within cities. Urbanization pushed the food-production for urban population further into more remote areas. Within conurbation green space is constantly transformed into settlement area, in Germany about 130 ha per day. Routes of transport for supply and disposal extend more and more by expanding cities.

Because of the reduction of production area for biomass-production inside conurbation, the amount of regional nutrient cycles also decreases, i.e. there are hardly any possibilities for the utilization of nitrogen-containing recycling-material. Recycling of organic nitrogen is firmly

integrated into global cycles. The disposal of organically bound nitrogen or the costly destruction thereof is a step into the wrong direction and on a long term basis “future-destructive”. The ecological agriculture (with utilization of organic matter) reduces the demand of primary energy – with regard to nitrogen-demand this is a improvement of efficiency, a minimization of nitrogen losses.

One of the aims of today’s wastewater treatment in Europe is to remove nitrogen and as a result protect surface water from eutrophication. This is done by nitrification and denitrification, releasing at the end all the treatment steps molecular nitrogen N_2 into the atmosphere. In Hamburg a population of about 2 million people is connected to the central sewage plant. The amount of human excrements into the wastewater system is about 4,5 kg nitrogen per person and year in total 9.000 metric tons reaching the sewage plant every year. Assuming that this amount of nitrogen has its origin as atmospheric nitrogen bound into artificial fertilizer then entering the food chain and finally ending up in the wastewater, this amount of nitrogen has a considerable value. Assuming furthermore an energy ratio of 13 kWh per kg nitrogen (e.g. urea) the amount of 9.000 metric tons correspond to an amount of 120 million kWh per year.

The efficiency of nitrogen removal is currently about 75 %. To remove 75 % of 9000 metric tons = 6.750 metric tons of nitrogen in the wastewater in Hamburg about 30 million kWh per year are required. In total the amount of 150 million kWh is available for (re)utilization. This corresponds with about 17 kWh per kg nitrogen. Instead of using the described effort to transfer the nitrogen back into the molecular status, it is an economical as well as an ecological duty to look for cascades of direct utilization.

About 85 % of the total amount of nitrogen enters the sewage in concentrated form as urine. Sanitation technology offers the opportunity of urine separation from feces. Together with other nutrients contained in the yearly amount of urine per person a cultivation area of about 200 m^2 could be supplied with fertilizer, especially since this form of fertilizer is very well accessible to plants. Compared with other fertilizers, urine concentrate shows the lowest contamination with heavy metals. The values for cadmium and chrome are even below the values for phosphorus fertilizer obtained from mining. The fertilizer potential of the Hamburg urine concentrate is an area under cultivation of about 400 km^2. It is obvious that urine is a worldwide inexhaustible resource. Regarding the finiteness of the phosphate reserves and the possibility to reduce the overall energy consumption this utilization must be reassessed.

Valuable substances in the sewage are not present in an isolated state but mixed and diluted up to the 200 fold. This is a dilemma of the EOP system. How can the resources of sewage be recovered in a usable form? – The first step to a solution has to be a management of the material flows. Creating subset flows at the origin of sewage is the urban form of decentralization This is the key to a further development of EOP-systems and of course the basic condition for utilization of valuable components in wastewater. In addition this separation is an important requirement to improve pollutant removal.

What has to be done, what is possible?

Evolution needs a cause, likewise the initiation for a change of the prevailing waste technology. An analysis of the situation and the chain of cause an effect have shown that there already exists enough pressure for change, which calls for development an adjustment of the EOP-technology. Future "maxims of disposal" demand for the use of original material flows, close to their sources, prior to mixing and their uppermost utilization within the region.

The fundamental questions are: How can the desired subset flow be obtained, where shall it be directed to by which means, and what is the target-utilization?

The driving force is the target-utilization. Where to initialize the formation of subset flows?

Nowadays, in a well developed urban EOP-system for wastewater treatment the incineration of residues from wastewater drainage and treatment is state of the art. The utilization by incineration is the current transient technology before more effective possibilities of utilization will take their place. In Hamburg we have almost a complete utilization of the carbon load of raw wastewater through incineration of sewage sludge and an intelligent energy recovering strategy. The ratio of electricity production and consumption for the wastewater process in the Hamburg Metropol Region lies by over 60 %. By continuous optimization of this process this ratio can even be slightly improved. But there is a limit: with a constant carbon-input into the EOP-system and within strict limits confined carbon:nitrogen:phosphate (C:N:P)-ratio in municipal raw wastewater the utilization/production ratio can hardly be improved. For a waste disposal process with the elimination of nutrients, nitrification, denitrification and phosphate precipitation this improvement can only be achieved by reduction of the energy consumption of this process. Decisive for saving of energy is an influencing control of the C:N:P-ratio primarily by withdrawal of nitrogen, secondarily by phosphate-compounds. This can best be done by urine-separation from the system. This makes clear how complex the preference for urine separation from the wastewater flow is.

An area of about 400 km² of agricultural land can sufficiently be supplied by the fertilizing capacity of separated urine from the city of Hamburg. Within the Hamburg Metropol Region this is by far not possible. In the catchment areas conurbation and megacities there are not enough utilization-areas available for biomass production. Cities grow by conversion of agriculturally used land into settlement area. All these facts stand against the anticipated regional utilization of separated urine. The seasonal appointed fertilizer demand leads to the conclusion that urine has to be processed into a storable product with a low weight/volume that allows the transport to biomass producing areas. Thus the aim of utilization of closing the cycle process within short distances is slightly disarranged.

If the aim of direct utilization of urine is questionable, there is also the possibility of fractionating the separated urine into its different compounds to assemble the recycling process.

With regard to the limited phosphate reserves the phosphorus content of urine has a rising value which is emphasized by the assured availability for growing plants.

The potential for the utilization of the nitrogen in separated urine has not been analyzed yet. There is widespread market for industrially produced urea, where maybe urea from urine can be used as a substitute. E. g. for NO_x-removal of flue gas from incineration processes. There will be an EU-law which will stipulate that SCR-technology, which has become a standard process in industry, will have to be applied in utility vehicles. The flue gas cleaning with the selective-catalytic-reduction-technology (SCR) reduces NO_x in flue gas by use of an aqueous urea solution.

The above described relations of this publication show a clear transitional aim for the further development of the EOP-system. In Hamburg there will shortly be determined how to relieve the wastewater treatment process by urine separation with help of mathematical simulation. The anticipated result of this research should be an optimal C:N:P-ratio at he inflow of the wastewater treatment plant, that can be adjusted by urine separation. The first step is an idealized nutrient elimination by the biological step. By simulation and calculations it will also be analyzed which effects can be expected if in some defined catchment areas urine separation is installed in order to exonerate the sewage plant. How can the composition of the storm-water runoff be possibly affected at defined outlets?

With those assessed results the course can be set with regard to an improvement of the EOP-system e.g.:

- Alternatives for a future extension of the wastewater treatment plant with changed demands can be designed, adjusted to regular renewal-cycles of the equipment.

- For the whole waste process there would be the perspective of a considerable potential for a reduction of consumption of energy and resources.
- Possibilities of a well directed elimination of problematic compounds will arise since the major part of residues from medicine is transferred into the wastewater mainly by urine.
- A promising step for the recovery of phosphorus would be done.

Conclusions

HSE - with a successfully developed EOP-technology - is discussing the conversion of the prevailing wastewater removal system: a quantum leap with regard to health precaution, an all media affecting protection of the environment and saving of resources in Hamburg.

Inevitably there will be solutions for problems of urbanization in emerging nations and developing countries.

Into waterbodies discharged, systeminherent residue loads of the EOP-technology make innovative further development difficult by legally regulated wastewater levy - the EOP-technology is thus dictated. It is a novelty in Germany. It would be a novelty as well to make the wastewater levy available for a start of a change of the EOP-technology, a German contribution to technical development aid.

With the development of the technical wastewater process the basic conditions that hinder the further development of the EOP-system, developed, too. The connection of financing of the waste process and individual water consumption leaves little room for future investments, especially as the prevailing waste technology has a high fix-cost share. The regionally continuing trend towards water saving is based on a misunderstanding of ecological and economical connections and backgrounds. The unlimited propagation of measures for water saving or even subsidization there of is disastrous, because this does not lead to the above mentioned potential for the saving of energy and resources. On the contrary, this door will be closed. Today's blackwater - urine and feces – holds an utilization-potential from more than 100 kWh per person and year. This matter was not completely shown in this paper. In comparison with this utilization-potential the saving-potential due to use less toiletwater is very little and drops to zero because finally maintenance of the EOP-sewage-system will rise.

The efficient use of energy and resources is the key to sustainability. Water-saving - just now - makes incapable of necessary actions. Water saving is affecting the income by charges of a sustainable waste management, finally endangers the already achieved standards of the EOP-system.

To sum it up it can be said that the further development of the EOP-system needs the following investment: subset flows have to be obtained at the origin of wastewater. This enables nutrient recovery in regional cycles. Such a development can be seen as an urban contribution to efficient and sustainable dealing with resources like energy, nutrients and not least water.

The above mentioned British pioneers of urban wastewater management about 140 years ago may well identify with the currently changed targets of a future waste technology. In retrospect it becomes clear that system-developments have to be integrated into long-term directed strategies. The course is set today.

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Implementation of a closed–loop sanitation concept in Yang Song township, China

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Introduction

This paper presents the feasibility study of the GTZ ecosan project for the town of Yang Song Township, located in Beijing province, China. This study was carried out in co-operation with the IEEP, Beijing, and supported by Chinese consultants Wang Gehua, Wang Li Xian and Han Di. From June to October 2002 a baseline data collection was carried out to subsume the development planning and the environmental conditions for Yang Song Township. This is the initial basis for recommendations in the field of integrated ecological sanitation, preferably suitable for innovative technologies.

With urbanization and modernization, Yang Song, like other developing towns in China, is facing a huge environmental challenge, particularly with regard to waste and wastewater treatment. The implementation of flushing toilet systems and the planned construction of a conventional wastewater treatment plant deprives the local farmers, who are still dependent on the traditional use of night-soil, of valuable nutrients. As Yang Song local council is currently considering various treatment technologies for municipal wastewater, this study aims to produce a definition of a jointly developed ecosan-strategy for the urban and rural district. With regard to the model-status of the township and the upcoming Beijing Olympic games in 2008, the GTZ ecosan project expects an announcement effect for other townships and cities in China, and worldwide.

Description of Yang Song Township

Yang Song township is located in Beijing province, 45 km from the Chinese capital. It consists of a city surrounded by 15 villages. It has a total population of 21.00 inhabitants.

Yang Song was named as a "model township" for small-town construction in 1997. This status obliges the government to develop the industrial and urban sector, and to protect and improve the environmental conditions. In the township development plan the government plans to combine the 15 villages into 9, and to resettle the village population in the city by 2010, increasing the total population to 50.000. For this purpose the construction of new apartment houses, in the form of panel buildings, started in 2001. Additionally the government wants to attract middle and upper class Beijing residents to move to this suburb, investing in a new countryside villa-district by providing an environmentally friendly atmosphere.

The economy of Yang Song is still dominated by the agricultural sector. The main agricultural activities are animal breeding, with a projected increase in the number of cattle over the next

years. In addition, there is a turning from classical crop production (corn, hops) to economic plants (medical plants, ging-seng, aloe vera, flower farms, etc.).

Yang Song is located in the main catchments area for water supply to Beijing. The high water demand and consumption in Beijing province leads to serious extraction of the groundwater resources, with levels declining at up to 1.5 meters annually. Yang Song relies heavily on the groundwater resources, as all freshwater for household, industry, greenery and agricultural purpose is derived from that source. Additionally in the last years the flows of 3 rivers in Yang Song area have decreased, even in the rainy summer months.

The construction of sewerage for the city and industrial district finished in November 2002, leading to a site 2km south of the city. Presently there is no treatment of municipal wastewater, and it is discharged onto fields nearby. Yang Song council is seeking a solution, with a capacity of approximately 2000 m^3/day, with the possibility a future increase to 5000 m3/day. All new houses are equipped with modern flushing toilets.

For the villages a sewerage system has not been planned and population relies on on-site sanitation. The design and the hygienic conditions differ with the economic status of the population and the village committee: the poor villagers have simple pit latrines, while the wealthier villagers have squatting toilets connected to septic tanks, and use collected greywater for flushing. In 3 villages a greywater flushing device and a 3-compartment septic tank latrine have been introduced with financial support by the committee. Vacuum tankers collect the content of the tanks, and the night soil is spread on the local fields. The household pays 10 Yuan/m^3 (~1,2 $) to the private collector for this service.

Potentials of ecosan strategies in Yang Song:

Yang Song township represents a closed area, with both urban and rural components, that can guarantee the utilization in local agriculture. Further promotional terms for an ecosan concept are:

Environment:

- Pressure of water saving and groundwater protection in water scarcity area.
- High potentials in substitution of fresh water- groundwater- for example: as irrigation water in gardens, agriculture, city greenbelts and in the existing water park.
- There is a loss of the high organic content (60% and more) in household and market waste, because of landfill disposal. Existing landfills are open pits without drainage, groundwater protection, gas capture, cover or leachate capture.

Sanitation

- Sanitation improvement in the poor villages is demanded.
- A hygienic disposal and sanitary latrines with greywater flushing are already promoted.
- The households of the villa area can decide about sanitary equipment.

Agriculture sector

- Farmers still depend on night soil from village households and manure from breeding farms. No social prejudice about excrement utilization, but an over-fertilization with artificial fertilizer, manure and night soil can be estimated.
- Breeding farms have to comply with a new law on pollution prevention from livestock production adopted in October 2001.
- Increasing demand of fertilizer for economic plants, but under stricter environmental regulations.

Government level

- Existing willingness and public pressure to improve environment ("model character").
- Government is interested to implement advanced technologies and strategies
- is seeking a solution for the treatment of municipal wastewater from existing flush systems and non-polluting industries and offering financial support and free land.

Drawbacks for ecosan

- The construction of sewerage for the town was finished in November 2002. The location is fixed and a modification of the first steps is almost not possible.
- Limited experience with ecosan strategies in urban areas/ large settlements.
- Industrial wastewater has to be treated anyway, and a separation of components is not achievable easily.
- Low water price, which includes fees for wastewater, will not cover the cost for operation and maintenance. Financial support is necessary.
- The future development of the township (construction, agricultural and industrial sector, population, etc.) is strictly connected to the economic development, which makes forecasting and detailed planning difficult.

Other considerations

As the farmers in Yang Song rely on night soil, manure and artificial fertilizer, the need for urine or compost from faecal sludge and organic wastes has to be carefully investigated. Therefore it is important to contact and co-operate with the local Bureau of Agriculture, which can give advice and support.

Urine separation:

Urine separation is a traditional device in China, and even proved their function in modern eco-toilets in Guanxi province. But in Yang Song a separate collection was not found in any part of the township. For implementing urine-separating toilets in the new buildings the panel construction would support a standardized design. On the other hand the small bathrooms limit the installation possibilities, and failures can be expected, because of the high number of inhabitants.

Night soil or compost:

Night soil and manure is still used in Yang Song to fertilize the fields. But nevertheless, no control of the hygienic quality and the utilization of the product are carried out. The existence of the reliable collection business should be considered and integrated in the concept.

The processing and the utilization of compost were not observed in Yang Song. Compost would represent a new kind of fertilizer for the farmers, and it would demand a change from traditional habits. The implementation of a "new" technology, like composting, for Yang Song can be considered as rather extensive.

Water concept

The water concept focuses specifically on water saving, rainwater infiltration, reuse and a discharge control to protect the water resources.

Water saving:

Water saving is possible for the households, industry and farming areas. In the villages, with low water consumption and utilization of greywater for toilet flushing, further water saving is hardly achievable.

Rainwater infiltration:

As rainwater is collected in separate pipes, and precipitation is mainly in the summer months, a separation from the municipal wastewater is very promising. This will minimize the capacity of the plant, and secondly benefit from the recharge of the groundwater.

Discharge control:

For water resource protection, especially of the groundwater, a discharge control is very important. Particular focus should be put on the control of non-point source pollution from agriculture activities, such as fertilizer overspill and the infiltration of manure from animal husbandry, that are responsible for nitrogen eutrophication in the water courses. For the future treatment plant the effluent has to be controlled. This should be done regularly by the Environmental Protection Department of Huai Rou County, and supported by measurements of Yang Song government.

Reuse:

There is a huge potential in the township for water reuse instead of groundwater. Especially in the case of irrigation, groundwater can be replaced to a greater or lesser extent by greywater, process water from industry, rainwater and in the future by treated wastewater. In the summer months, when demand for irrigation water is very high, the greenbelts and the water park can benefit from recycled water. Crops, plants and especially flower irrigation with pre-treated wastewater are possible.[1]

Nutrient concept:

The nutrient concept emphasizes the recovery of nutrients from the urine, faecal sludge and wastewater. The nutrients benefit local agriculture and can support - and to a certain degree substitute- artificial fertilizer.

In the villages the utilization of faecal sludge from latrine pits and septic tanks is still common, and the intention is to guarantee a safe utilization, by approved design and sufficient storage time[2].

For the town, a construction of a conventional wastewater plant will eliminate and not recover the nutrients and the resulting process sludge will have to be disposed of. But in an ecosan concept the production of valuable fertilizer from the treatment process is an important factor. Sludge produced by sewage treatment plants can be used as a soil conditioner-fertilizer after treatment. Composting the sludge will control most pathogens and, if properly marketed, can contribute to the economic feasibility of the treatment plant. However, the agricultural application rate of composted sludge should be carefully calculated. The build-up of toxic metals in the soil can be neglected, because for Yang Song only household water and no hazardous components are considered.

According to agricultural legislation, the treatment of animal manure before use in agriculture is now imminent. Additionally the treatment of a separately collected organic waste fraction of the

[1] *In China irrigation with wastewater has to fulfill the 'national Standards for irrigation water quality [GB5084-92]' that are considering the type of irrigation area, and type of crops.*

[2] *National 'standards for Safe disposal of Excreta' were promulgated in 1987 [GB 7959-87]. 5 types of sanitary latrines are currently promoted in China: three-compartment septic tank latrine, double Urn latrine, Triplex biogas latrine, VIP latrines, urine diversion eco-latrines*

municipal waste can be included either in biogas plants or on separate composting piles that also compost faecal sludge.

Technical and practical proposals

Proposals are made in the fields of sanitary equipment (see table 1) and for the treatment of wastewater streams (see table 2). For a better understanding and to give appropriate proposals a matrix is set up. With respect to the different conditions the township area is divided into village and town (subdivision residential area and industry), and with respect to the development planning into existing, new and planned structure.

Villages

The design of on-site sanitation must be improved to assure a hygienic utilization of night soil. The implemented squatting toilets with greywater flushing and connection to a septic tank are a well suitable technology. For the collection of greywater there are alternatives to the conventional sewerage system: simplified sewerage and settled sewerage. If this household breeds animals, the well-known simple Chinese biogas systems with toilet connection seem to be the best solution.

Recommendations for existing residential areas

For the existing panel building area and the new panel building area only rainwater and household wastewater can be divided, due to economic reasons as the investors are real estate companies and they are not yet willing, without extra subsidies, to invest in two internal wastewater piping systems. All changes will be hardly possible at once, but for further restoration and rehabilitation work ecological solutions should then always be respected. To permit a decentralized reuse of the wastewater combined „Decentralized Wastewater Treatment Systems“ as developed by CEEIC (Chengdu) and HRIEE (Hangzhou) are recommended.

For on-site wastewater effluent improvement, additional anaerobic filter chambers could be constructed for the **villa area**, which is already under construction, treating wastewater after existing septic tanks. The future inhabitants can decide on their sanitary equipment, for example UDS (urine-diversion-System) can be one appropriate solution.

Recommendations for new residential areas

Separated blackwater/greywater collection systems and decentralized wastewater systems with a secondary treatment should be implemented. On-site treatment of blackwater using baffled septic tanks with up-flow anaerobic filters is one of the feasible alternatives with promising high cost-benefit efficiency. After pre-treatment, treated blackwater is discharged through vacuum sewers into sludge post-treatment biogas stations where the organic solids fraction from municipal solid waste are added and than the effluent should be earthed in sludge decomposition lagoons and/or can be used directly as liquid soil conditioner.

Greywater is collected in decentralized community treatment plants, that consist of Imhoff tank / waste stabilization ponds or constructed wetland, integrated into the greenbelts.

	Village	Town			
		Residential Buildings	Communal Buildings	Villa area	Industry
Existing	Improved latrine design: greywater flushing or separation toilettes	(Changes hardly achievable)		Owner can decide about sanitary equipment: Implementation of Urine diversion toilets difficult, vacuum toilets and -sewer system preferable, Separate blackwater and greywater disposal	(Changes hardly achievable)
New		Upgrade toilets with water saving device			Upgrade toilets with water saving device
Planned	-	Separate blackwater and greywater disposal. Toilets with water saving device, greywater flushing			Separate blackwater, greywater and process water disposal. Toilets with water saving device, greywater flushing, process water reuse

Table 1: Recommendations for sanitary equipment

	Village	Town			
		Residential Buildings	Communal Buildings	Villa area	Industry
Existing	Improved pit design with retention time Or: Simplified sewage with biogas or dry separation toilettes	DEWATS Modular expandable		-	Treatment with residential wastewater (Wastewater quality meet household quality)
New		Separate treatment of blackwater and greywater Black water: baffled septic tank with up-flow anaerobic filter, sludge post-treatment biogas stations Greywater: decentralized community's treatment plant. Consisting of Imhoff tank or constructed wetlands		Owner can decide: On-site treatment: Septic tanks with anaerobic filter chambers, dry separation etc.	
Planned					Pre-treatment up to household wastewater quality

Table 2: Recommendations for treatment of wastewater streams

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Implementing large-scale and urban dry sanitation: an agenda for research and action*

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Ecological sanitation, composting toilets, dry toilets, Mexico, peri-urban, program implementation

Abstract

Relatively little is known about modern, large-scale, urban Dry Sanitation (DS) implementation. A broad range of large scale and urban DS experiences in Mexico were studied to assess DS viability in these contexts, with particular emphasis on aspects of program implementation and user satisfaction. Based on the cross comparisons of multiple sites, lessons learned and further research and development needs were identified. Several results and recommendations of this study confirm those from other international experiences. Recommendations for improved program implementation and user satisfaction include aesthetic, operational, and structural strategies. Recommendations offered for DS development include consolidation of baseline information, coordination of research with program implementation, and systematic exchange of information across sites. Suggested approaches to implementing these recommendations include action research; adaptive management; social marketing; participatory technology assessment; externally-facilitated participative, diffusion of innovations; and a willingness to implement intermediate DS options. Whether DS can fulfill its potential will only be known in practice and by testing it under a variety of circumstances. It is our hope that this paper will contribute to these developments.

Introduction

Dry Sanitation[1] (DS) may ease some of the social, economic and environmental challenges faced by centralized waterborne sanitation today (First International Conference on Ecological Sanitation, 2001). Although many have proposed DS as an important strategy for urban areas, experience at large scales and in urban settings is still limited (Holmberg, 1998; Winblad, 2000; Esrey, 2002). This study assessed DS viability in large-scale urban contexts by researching a wide range of such experiences in Mexico. In that country, a large number of dry toilets (DT's) have been installed under a wide variety of program modalities, using diverse toilet models (Cordova, 2001). The diversity of social, institutional, technical, and climatic conditions allowed research on a large set of DS implementation possibilities and the identification and analysis of variables that apply to other settings beyond Mexico. Further relevance of the Mexican results is evidenced by consistency between user satisfaction and program implementation results with those reported from other international experiences (see Cordova, 2003).

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This paper has been peer reviewed by the symposium scientific committee

[1] With this term we refer to on-site sanitation systems, which do not use water or use minimal amounts of water to sanitize excreta and process them into a safe soil-amendment material.

This paper presents results from the analysis of DS experiences in Mexican urban areas and proposes recommendations for research and action in large-scale and urban DS development, with particular emphasis on program implementation and user satisfaction. To focus attention on research and policy needs, this paper does not describe in detail the analyses of the cases that led to these recommendations; those analyses have been presented in Cordova (2003).

Methods[2]

The field research for this study was conducted between August 1999 and December 2000. Research methods included: semi-structured, in-depth interviews with 50 practitioners and professionals associated with DS implementation in various regions of the country; collection of written and video documentation of DS projects; site visits; toilet inspections; informal conversations with dry toilet users; and a quantitative survey among 284 DT users at five urban sites. The initial stage of research included both rural and urban cases of DS, but site visits and interviews with users were limited to six urban sites. These were the largest-scale and most-recent urban experiences identified and include: Acapulco, Ciudad Juárez, León, Puerto Morelos, Tepoztlán, and Xochimilco (Figure 1). Visits to various DS programs in the USA, work with local organizations in Tompkins County, NY (USA), and a literature review of user satisfaction and DS program implementation in urban areas worldwide provided information to complement the analysis of Mexican experiences.

Figure 1: Urban dry sanitation study sites. (Map created by K.A. Schafft)

Results

The analysis of Mexican experiences evidenced that:

a) DS has been implemented widely in Mexico including at a large scale and in a diversity of urban settings. Several organizations (public, private, non-profit, and community-based) as well as individuals have independently created DS programs and diffused this technology and approach.

b) The diversity and number of promoters and participants in DS programs shows that DS implementation takes place over a complex topography of organizational cultures and locally-specific social conditions. Acknowledging and understanding this complexity is important in efforts to advance and improve DS implementation.

c) User satisfaction was high at most Mexican sites –among both high-income and low-income users, in large- and small-scale programs, under different climates and institutional settings, and with various different toilet models. Proper dry toilet (DT) function, user motivation, and creation of demand were important elements in user satisfaction.

d) User satisfaction and acceptance of the technology can be increased by improved DT convenience and aesthetics, operation and end-product management support services, and

[2] For a detailed account of methods, see Cordova (2003).

economic incentives.

e) Programs have faced a number of structural and recurring operational problems, which can be adequately addressed with a comprehensive set of strategies listed below[3].

Recommendations for improved program implementation and user satisfaction

The following recommendations derive from the results of this research.

1. To increase urban users' satisfaction and acceptance of this technology, it is important to improve DT aesthetics, strive for maximum user-friendliness and low user labor, provide effective support services, and develop social and economic incentives.
2. Operationally, program effectiveness can be improved by communicating clearly that a DS program includes the *full* set of stages: toilet model(s) selection; promotion/dissemination; toilet production/construction; toilet delivery; user training/retraining; follow-up and support services; end-product management; and evaluation and feedback. Neglecting any stage can seriously jeopardize program success. Large-scale program success also hinges strongly on maintaining a balance between hardware, software, and program operational capacity. This balance has tended to get lost in large-scale programs as insufficient resources and planning shift emphasis heavily to hardware. DS programs will be more successful if promoted alongside the appropriate provision of greywater and solid waste management systems.
3. Structurally, DS program implementation can be improved by transforming DS from an experimental technology, supported by small or special programs, to formal infrastructure supported by public or utility enterprises. This would be aided by a general sanitation approach that contemplates a repertoire of both wet and dry sanitation systems as adequate and socially-acceptable. To this end it will be important to disseminate information amongst professionals and policy-makers that counter the resistance to alternative sanitation options, and increase the social status of DS through its use by high-income residents, to reduce misperceptions of DS as a second-class technology.

Recommendations for DS development

Cross-comparisons of multiple sites led to the identification of lessons learned and additional development needs. The implementation of the above-mentioned policy recommendations and further development of DS would benefit from a three-pronged approach: a) the consolidation of strong baseline data and identification of information gaps; b) the structuring of research in coordination with program implementation to reveal the effects of important variables on program success as well as clarify knowledge and information gaps; and c) the systematic and timely exchange of information across sites to accelerate learning (Figure 2). Breadth and depth are needed in our understanding of current DS implementation, as well as horizontal and vertical communication within and between DS experiences worldwide. Multi-site research and structured cross-comparisons will help for both purposes. Following is a discussion of the needs identified, particularly

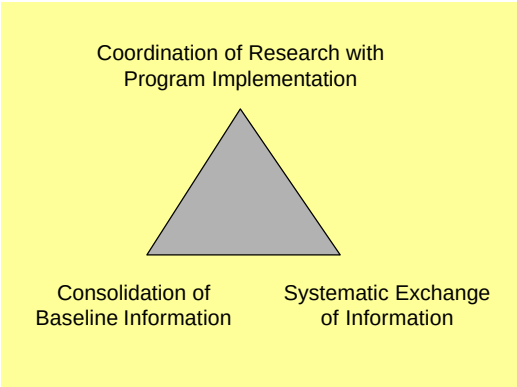

Figure 2: Three areas of dry sanitation research and development needs

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[3] For a comprehensive description of problems and detailed explanation of strategies, see Cordova (2003).

as they relate to program implementation and user satisfaction. Several of these needs have already begun to be addressed in some regions, but they may be further developed and systematized as suggested below.

I. Baseline information

Future research and improvement of programs depends on continued identification and description of DS experiences, by country, by region, and worldwide. The research in Mexico evidenced that there are many DS experiences that are not recorded, reported, or known of by an established DS practitioner network. These undescribed experiences neither have the benefit of joint learning that DS networks and symposia provide, nor do the DS networks and symposia have the benefit of learning from them.

For the consolidation of baseline information we suggest the generation of:

a) Censuses of DS experiences (described by a set of agreed-upon variables which can include program variables such as number of households/individuals serviced, toilet model(s) used, costs to program and to user, program motivation, implementing organization(s), type of setting (rural/urban), type of training used, type of follow-up services provided, date of initiation/program duration, current status of program, and user variables such as income-level, level of choice, level of demand, types of motivation, etc[4]). These statistics on DS should be published regularly and made available.

b) National, regional and worldwide research and literature clearinghouses. Some have already been created (e.g. GTZ Ecosan Project library; RedSeco in Mexico), but extending their geographic and thematic coverage, creating physical libraries/collections in several regions and languages, forming a directory of international clearinghouses, and establishing formal sharing and exchange mechanisms would strengthen these collections.

c) Directories of DS providers, promoters, trainers and funders, internationally and by regions.[5]

As efforts to integrate DS into the mainstream water and sanitation sector continue, the data collection and dissemination channels may be institutionalized (e.g. through World Bank, World Health Organization, and other national and international statistics publications). Through the systematization of baseline information, conceptual and research tools will be developed, including agreement on definitions ('urban', 'sustainable sanitation', 'ecological sanitation'), survey instruments, research protocols, etc. As more experiences are studied, the conceptual and research tools can be refined.

II. Coordination of research with program implementation

a) The set of Mexican experiences studied did not have sufficient overlap to adequately decouple the effects of toilet model, program set-up, and population income-level as factors for **program success**. To tease out the effects of such confounding factors, new DS programs should be set up in ways that allow for testable comparisons between population characteristics (income, education, region, country, ethnicity, etc.); toilet models (self-contained, urine-diverting, etc.); program modalities (user attraction methods, training, support services, etc.); and incentive systems (economic, social, direct, indirect, etc.).

b) To better understand **user preferences, needs and satisfaction**, experiments should be done with different types of incentive programs for users (including combinations of marketing or status-raising strategies, economic incentives and disincentives, regulatory incentives, etc.). Assessment of satisfaction should be routinely included in program implementation and/or elements of satisfaction should be monitored in other types of DS studies (e.g. technical, microbiological, etc). Longitudinal research on what happens at DS sites (with the programs, with the users) after 5, 10, 20 years will also generate important insights.

[4] Such a format has been used to describe Mexican experiences in Cordova (2001).

[5] Several independent websites and clearinghouses include this type of information.

c) To create conditions of appropriate **institutional support** for DS programs, it will be important to: identify information and incentive needs for businesses, public officials, and communities; understand how contextual factors (such as local economic activities, water policy, institutional relations) play a role in the evolution of DS programs; and identify which toilet models and support systems are better accepted in different cultures/regions/socio-economic levels. If users are to be given a choice of the DT model they wish to install, it will be important to assess, both organizationally and technically, how many different DT models it is feasible to service and provide secondary processing for in one area or under one single service provider[6], as well as how many sanitation systems (both wet and dry) are compatible and management-effective in one single site.

d) In the Mexican cases studied, **end-product management** was a commonly neglected program element. The organizational and technical aspects of end-product management can be very susceptible to local conditions, including climate, type(s) of available cover material, type(s) of DT processing system (desiccating/composting/ biodigestion), local feasibility of secondary processing systems, type(s) of soil to which end-product is to be applied, types of crops or vegetation to be grown, and organizational aspects such as collection system frequency, modality (emptied by service providers or households), etc. These conditions can vary even within one large city. In terms of policy and program implementation, local decision-makers must be aware of this number of factors and the need to understand their local feasibility, in order to make informed decisions. To this end, end-product management research must cover a wide range of varying conditions and be translated into formats (flow charts, matrices, etc) and language that local decision-makers can grasp easily.

e) Discussions with city officials, DT developers, and urban residents, revealed **regulations** research and development needs. These included: identifying current regulations for sanitation, sludge, and greywater at each site[7]; identifying gaps, overlaps, consistencies, and inconsistencies vis-à-vis DS; proposing regulations specific for DS; and considering different requirement stringencies for different zoning categories. It was also deemed important to strengthen and standardize criteria for a certification system (or minimum performance criteria) for DS[8], and where DS is not formally supported by a city or utility, develop regulations requiring DT distributors or program implementers to: pilot-test their model(s) at each site (or another site proven to be similar), provide an Regulations would not have the intent to make DS difficult for the users, producers, or promoters but rather to guarantee that the DT's on the market will work, as well as to avert large-scale failures and disrepute for the technology. Regulations may be end-product management plan, ensure commercial and/or local availability of cover or texture material, and provide technical support throughout the life-time of the DT.[9]

f) developed collaboratively, with the participation of users, promoters, producers, and public officials[10], and will likely vary across sites.

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[6] Different container sizes and shapes and different end-product qualities and characteristics could make collective management complex and costly.

[7] found in codes on solid waste, environmental protection, public health, urban development, and/or zoning & building.

[8] These might include technical specifications, required user training (e.g. Washington state, USA was considering permitting DT's if the user took a 2-3 day training course in DT operation and maintenance (Holm, 2000)), minimum specifications for cover material, DT use-intensity, end-product disposal/re-use criteria, and the secondary treatment requirements (if any) for each DT model or system.

[9] This may include investing in a revolving fund and/or training local technicians in case the company goes out of business. This regulation would become unnecessary once DT's are common enough that a critical mass of DT service providers exist in each city (like auto mechanics exist to service cars).

[10] An example of such collaborative regulation development is the USEPA negotiated rule-making for the development of regulations affecting industry.

III. Systematic exchange of information

Because the DS field may not collectively have the funds to set up new experiments to clarify all the knowledge gaps identified thus far, and because each site will likely not be able to conduct in-depth research on all the aspects of DS (program implementation, technical design, economic assessment, epidemiological studies, etc), cross-comparisons between a diversity of well-described programs and sites provides an alternative, complementary means for generating knowledge and improving our ability to influence program success. Such cross-site research will require effective communication and coordination mechanisms between sites. This may be aided by formal and systematized exchange channels that ensure mechanisms to reach all the appropriate stakeholders, from international agencies, to individuals and communities[11].

Suggested approaches for implementing recommendations

Because the research agenda is very ambitious, this field is in rapid development, and the effectiveness of recommendations can only be assessed in practice, we propose that the most effective way to carry out the development of DS will be through parallel action and research, where a diversity of social actors collaborate to design, assess, and carry out actions; where results are communicated within and between programs; and where planning and management are adaptive. To this end, we suggest a combination of complementary approaches, which may offer productive ways to pursue the recommendations proposed thus far (Figure 3). These approaches derive from experiences in various fields and well-developed disciplines, described briefly below.

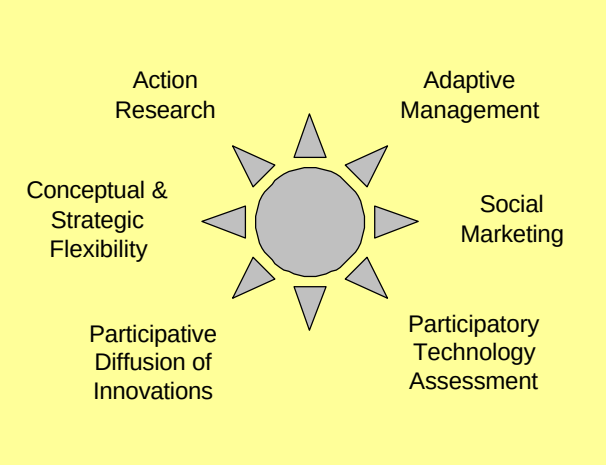

Figure 3: Six complementary approaches to enhancing dry sanitation development

Action Research (AR) emphasizes iterative reflection and action (research and implementation) between collaborating partners, for the purpose of meaningful local change (Greenwood and Levin, 1998). AR can be useful in DS development because it enables us to conduct research *as we implement programs* and *promptly incorporate the findings* of research into the programs as they are being carried out. The timely conversion of research results into action is made possible to a large extent by the involvement of local actors in establishing research and program goals. ***Adaptive Management*** (AM) emerged in the field of natural resources management as an approach to work more effectively in the context of complex, dynamic, heterogeneous, and highly variable ecological systems[12]. AM sees management as always aiming at a moving target, with an awareness that knowledge is always incomplete and the system is constantly evolving (Light, 2001). It proposes that programs and policies are not one-time, final products, but rather *experiments* from which we are to learn and upon which adjustments are to be made (Lee, 1993). AM in DS implementation would increase program responsiveness to locally changing contexts, throughout all program stages described earlier.

[11] E.g. journals, conferences and international meetings for certain stakeholder groups; workshops, training courses and study tours for others; community-based activities and diffusion of simple, basic fact sheets for individuals; academic curricula in many disciplines (engineering, architecture, urban planning, public health, agriculture, etc.), etc.

[12] Sanitation is as much a social phenomenon as it is a natural or technological one and is influenced by many complex, dynamic, heterogeneous, and variable social and institutional systems.

Many DS researchers and practitioners have proposed ***Social Marketing*** in DS (Wegelin-Schuringa, 2000; Winblad, 2000; Breslin, 2002). Particularly relevant principles are: a) a *focus on the target audience*, its needs, perceptions, and motivating factors (privacy, status, economic considerations, hygiene, environmental values, etc.); b) *segmenting audiences* or understanding that populations are not homogeneous but have various perceptions and require different types of incentives[13]; and c) *sustaining demand* once it has been created, which derives from a clear grasp of the dynamic "marketplace" (competing behaviors, obstacles to placing the product, etc.) and makes monitoring, evaluation, and timely adaptation of strategies essential program elements[14].

Scandinavian experiences in ***Participatory Technology Assessment*** and large-scale, externally-supported, ***Participative Diffusion of Innovations*** may also provide insights and tools from which the development of DS could benefit. The Danish Board of Technology, based on an understanding of society and technology as interrelated and framing one another, has sought to build bridges between citizens, experts, and politicians for technology assessments and communication of those assessments (www.tekno.dk). Since 1998, the Board has successfully implemented a range of participatory tools in assessing new technology including Perspective Workshops, Future Searches, Scenario Workshops and Consensus Conferences (www.tekno.dk). Such enriched deliberation might be used in sanitation system selection processes in cities or neighborhoods, or in the assessment/introduction of specific alternative sanitation options not known broadly to the public in various societies.

The state-sponsored Swedish Working Life Fund facilitated a process of diffusion of innovations in industrial organizational development, between 1990 and 1995 (Gustavsen, Hofmaier et al., 1996). The Fund took the roles of advisor, discussion partner, and generator of ideas, as well as provided funds for enterprises to engage in processes of organizational change. It also enabled direct exchanges between participants. Such an externally-supported model for funding and facilitation of change in the DS field could serve as a means to formalize the support structure for exchanges that are currently already taking place between programs at different sites and promote a broader understanding of environmental sanitation (including Bellagio principles) among water sector professionals and local government decision-makers.

Finally, we believe, along with other DS researchers (e.g. Harper and Halestrap,1999; Breslin, 2002), that ***conceptual flexibility*** will be beneficial in DS promotion: steering away from universal, one-size-fits-all solutions, and maintaining awareness that intermediate options[15] are valuable. In many contexts, intermediate options may achieve significant savings of water or retention of nutrients, which would mitigate strongly the impact of sanitation. If such options increase user adoption significantly, they may be more effective than the implementation of a "pure" DS solution that only few users would accept. Throughout the research and development process, DS would need to be compared continually to other sanitation options within a framework that considers the environmental, economic, and social implications of each.

Conclusions

Modern, large-scale, urban DS is still in its infancy and shows signs of great promise. Based on our research of Mexican experiences we have proposed a set of policy and research recommendations to strengthen and further develop urban DS implementation. Whether DS can fulfill its potential will only be known in practice and by testing under a variety of circumstances. The social and natural complexity of sanitation systems warrants the adoption of approaches

[13] This particularly important at increased scales of DS operation.

[14] rather than unattended "add-on's" that programs do not have the time and money to carry out.

[15] Intermediate options include possibilities such as: a) urine-diversion from conventional sanitation and b) dry toilets as complementary toilets in homes which also have conventional sanitation. In our survey we found that several homes wished to have a DT as a complementary option. Even if only some of the residents of a household used a DT or if the DT was used only for urination or only for defecation, water savings and nutrient retention would be achieved. This phased introduction would also allow users to gradually assess the technology, without having to risk an all or nothing situation.

that share concerns of iterative reflection and action; a focus on target audiences; the involvement of stakeholders; and the integration of institutional learning and adaptiveness into policies and programs. An awareness of these approaches and tools and the willingness to implement intermediate options (both in sanitation technologies and in strategic approaches) will likely be beneficial in developing the field of DS and carrying out the recommendations of this research.

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Innovative sanitation concept shows way towards sustainable urban development. Experiences from the model project "Wohnen & Arbeiten" in Freiburg, Germany

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Keywords

Case study, biogas, vacuum-toilets, membrane-filter, participation

Abstract

In Vauban, a suburb of Freiburg, Germany, a new model house built in 1999 combines highly innovative energy, waste and sanitary concepts with a framework for a comfortable social environment.

Social, legal and financial framework of the project "Wohnen & Arbeiten"

Figure 1: The Model-House "Wohnen&Arbeiten"

The special situation in the Freiburg Vauban district is that citizens are encouraged to form groups and to apply for plots of land in the new district. The association "Forum-Vauban e.V., Freiburg" [http://www.forum-vauban.de/], founded by citizens of Freiburg, is the legal organizing body of the extended citizen participation. It has been successful with its concept to give the land in the Vauban district to groups of citizens with clear priority, while only a small part of the land will be given to conventional building constructers.

The group "Wohnen & Arbeiten" is one of about 30 such groups of citizens having developed houses according to their wishes and ideas [http://www.vauban.de/wa].

In order to develop an innovative energy concept and an innovative sanitation concept for "Wohnen & Arbeiten", an Association had to be formed being able to cooperate with research partners. Therefore, the "Ökobauverein e.V., Freiburg (Association For Sustainable Buildings)" [http://www.vauban.de/oekobau.html] was founded. This association is able to apply for funds and to handle the financial aspect as well as to run the experimental project phase. All future residents of the model house became members of the "Ökobauverein" and signed a contract that they will cooperate with the research projects.

Funds for the development and implementation of the innovative energy concept were allotted by the DBU (Deutsche Bundesstiftung Umwelt). "Wohnen & Arbeiten" implemented this project

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jointly with the Fraunhofer ISE, Freiburg.

Funds for the development and implementation of the innovative sanitation concept (vacuum plant, biogas plant, water filter) were allotted by the DBU (Deutsche Bundesstiftung Umwelt), Fraunhofer Institute ISI in Karlsruhe, and TBW GmbH in Frankfurt. TBW and Fraunhofer implemented the project jointly with Ökobauverein e.V., Freiburg. A subcontract was given to the company Roediger, Hanau, for the construction and maintenance of the vacuum system. The biogas tanks were developed with and built by Mall-Umweltsysteme who also sponsored parts of the greywater filter.

General Data:	
dwelling and effective space	1.500 m^2 (16.250 squ. feet)
number of flats	20 (incl. 4 offices)
number of residents	40 (incl. 10 children)
co-generation plant:	
electrical power production	5,5 kWh
heat energy production	14,5 kWh
Solar power :	
photovoltaic device	3 kWp*
thermal solar installation	15 kWp* (45 m^2 = 475 sq. ft.)
Triple-glass windows:	
k(or u)-value**	0,7
g-value***	0,6
Energy consumption:	
heating energy consumption per m^2 and year	13,2 kWh/m^2a (= 1,4 kWh/square foot*a)
total energy consumption for heating	20.700 kWh/a
total energy consumption for warm water	23.500 kWh/a

* = kilo watt peak ** = heat loss *** = light loss

Table 1: Technical and general data of the solar-passive house “Wohnen & Arbeiten“

Sustainable energy management

Due to the energy concept, residents need only 20 % of the primary energy (electricity and heating energy) used in conventional houses. All energy saving investments is strictly controlled by the cost-efficiency ratio. The costs are only about 7 % higher than in conventional houses and amortize over 10 - 20 years, which makes the house affordable for average German citizens.

In summer, hot water consumption is 100 % provided by a thermal solar installation, in winter it is supplemented by a small co-generation plant using natural gas.

Electricity is 60 % provided by the co-generation plant (50%) and a photovoltaic device (10 %). Optimal insulation, the utilization of active and passive solar energy, the triple-glass windows, and an 80 % reduction of aeration heat loss save 85 % of the heating energy over the year, compared to conventional houses (Fraunhofer ISE, Gruppe Solares Bauen 2001).

Sustainable water management

A combined vacuum sanitation system was projected for the model house. The idea of the sanitation concept is that biological waste, faeces and urine (the so-called "blackwater") are

transported from the water saving vacuum-toilets to a biogas reactor with vacuum pipes. The reactor produces liquid fertilizer as well as biogas used for cooking. After having been cleaned in a grey-water-filter, the remaining wastewater from kitchens and bathrooms (greywater) is used again for flushing the vacuum-toilets and rinsing the garden. Rainwater flows through open gutters and is collected in two ditches. These two ditches are connected to the groundwater strata with packages of gravel, so the rainwater is filtered before reaching the ground water.

Some data and experiences for the development of the Biogas-Bio-Fertilizer Module were gained with the help of a pilot plant. This experimental Biogas plant was operated during 6 months in preparations of the Project “Solar-Siedlung, Freiburg Vauban”. (Lange 1997, Müller 1997)

A detailed analysis (Schneidmadl et al. 1999) compared conventional and sustainable water management and assumed the following reduction of water consumption and emissions into water:

- water consumption is reduced by about 50%
- carbon emissions by about 70%
- nitrogen emissions by about 90%
- phosphorus emissions by about 60%
- AOX (absorbable, organic halogens) emissions by about 48%, respectively, and
- copper emissions by 47%

The separate treatment of grey and blackwater and the recycling of nutrients to agriculture could be an energy-efficient long-term solution for water management.

The Primary-Energy-Consumption of the innovative sanitation concept in the Model House “Wohnen & Arbeiten” was analysed and compared to the situation in Lübeck Flintenbreite and in conventional houses (Peters 2002).

Experiences gained in the project "Wohnen & Arbeiten"

The experiences gained during three years with the vacuum-system and the greywater filter, as some information on the biogas plant are given below.

The grey-water-filter

The grey-water-filter was implemented in 1999 in form of an aerated sand filter and its performance was monitored (Steeger-Ballbach 2001). Due to technical problems, this filter is now replaced by a membrane-filter-module (Ultra-Sept-Pendelmodul) provided and co-sponsored by the company Mall-UMWELTSYSTEME (Donaueschingen, Germany).

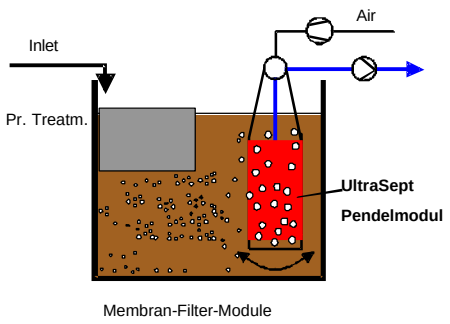

Figure 2: The UltraSept Pendelmodul

The vacuum-system

The vacuum system has been working since 1999 with hardly any technical problems. The acceptance of the vacuum-toilets by the residents is very good. In the initial stage of the project, the residents assumed, that the unusual noise of the vacuum-toilet could be a problem but this aspect turned out to be absolutely uncomplicated.

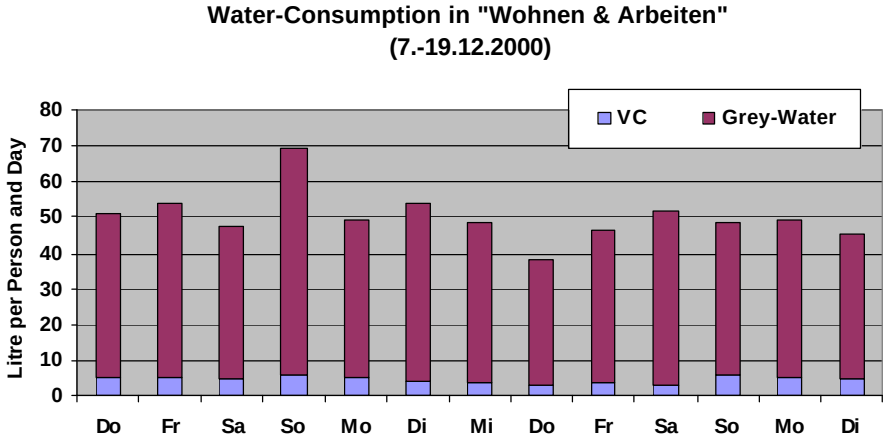

Figure 3: Daily water consumption in the model-house “Wohnen & Arbeiten”

Figure 4: Vacuum pumping station (left) and vacuum-toilet of the model-house

The Vacuum-System is maintained by the company ROEDIGER, (Hanau, Germany). It reduces the amount of Black-Water produced per person and day to about 6 litre - which is a reduction of 80% if compared to an average German household.

The biogas-bio-fertilizer module

The first biogas plant for an apartment building in Germany consists of a concrete digester for treating blackwater and organic household waste, a post treatment with an internal plastic bag gas storage and a storage tank for the fertilizer.

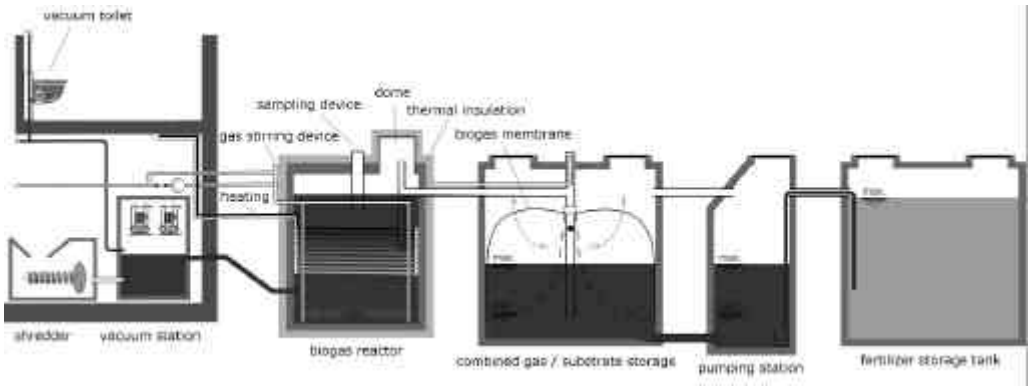

Figure 5: The Biogas-Bio-Fertilizer-Module projected for „Wohnen & Arbeiten“ in Freiburg, Germany

The biogas plant is connected to the internal gas system of the house; it will provide cooking gas for the 16 households. The plant is almost ready – only the automatic regulation of the gas pressure and the feeding device for organic household waste need modification and adjustments.

The following table summarizes general and technical data of the sanitation concept of the model house “Wohnen & Arbeiten” in Freiburg Vauban, Germany.

Number of Residents	40 (incl. 10 Children)
Vacuum-System	
number of Vacuum toilets	25
amount of water needed for flushing	1 l
amount of air used for flushing	20-40l
Biogas-Bio-Fertilizer-Module:	
Biogas-Reactor	6 m^3
Bio-Fertilizer Storage-Tank 1	3 m^3
Bio-Fertilizer Storage-Tank 2	14 m^3
Bio-Gas Storage-Tank	9 m^3
Bio-Gas Production (anticipated)	2-3 m^3/d
Black-Water input per day (anticipated)	0,24 m^3/d
Organic Waste input per day (anticipated)	0,02 m^3/d
Bio-Fertilizer Production (anticipated)	0,26 m^3/d
Grey-Water-Membrane-Filter :	
grey-water-input per day	2 m^3/d
Membrane surface	16 m^2 (Mall Ultrasept)
primary treatment	1 m^3 (Mall Ultrasept)
sludge treatment	4,5 m^3 (Mall Ultrasept)
power for aeration pump	500 W
Black-Water-Production reduced by:	**80%**
Black-Water-Production (average German Household)	35 l/d***
Black-Water-Production (Model-House “Wohnen & Arbeiten”)	6 l/d

*** = Data from: „Bundesverband der deutschen Gas- und Wasserwirtschaft, KA 12/97“

Table 2: Technical and general data of the sanitation concept of “Wohnen & Arbeiten“

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Wet or dry ecological sanitation in periurban areas

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Keywords

Africa, ecological sanitation, periurban sanitation, promotion, waterborne alternatives

Abstract

Doubtlessly, “do and forget” is the preferred solution for most people. Lack of space or talent for urban agriculture reduces motivation. In many periurban settings municipal rather than individual solutions are preferable.

This paper presents three periurban cases in Africa where waterborne sanitation seems to be the more realistic approach to ecological sanitation. The author questions the “don’t mix” rule as a holy principle in ecological sanitation as the sector might become insensible to felt needs, user friendliness and demand sensitivity.

Excluding waterborne sanitation as an alternative to dry “don’t mix” approaches may lead to slow progress, where conventional waterborne solution become the preferred alternative, with no ecological benefits.

Figure 1: Dry ecological sanitation can be made comfortable and look urban, but there may be an emptying and collection problem and surviving germs.

Introduction

What is the promotional value of the WC?

In order to protect the ground water and reduce water consumption, we have opted for dry sanitation. For ecological sanitation the “don’t mix” approach has become a golden rule. An evaluation of alternative sanitation technologies in Luanda (Angola) low-income areas caused the author to question dry sanitation as the appropriate solution. Waterborne sanitation may at

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times be a solution, which could save the environment. Similar conclusions could be drawn from the situation in other cities like Antananarivo (Madagascar) and Nampula (Mozambique).

Findings in this paper are based on discussions, observation and experience. The author has over the last 25 years had the opportunity to visit some 20 developing countries as a sanitation adviser. The clear trend is to become more and more sensitive to demand and consumer participation.

Three case studies

Three cities have been chosen as examples of where waterborne sanitation could be a necessary approach in order to achieve a sustainable sanitation development.

Figure 2: Space is a common problem in many low-income settlements.

Luanda

Luanda is the Capital of Angola and has approximately 5 million people. The town is situated on the coast of the Atlantic Ocean. The profile of the town is characterised by high-rise buildings in the downtown, which have deteriorated during three decades of civil war, financial difficulties and mismanagement, surrounded by well built and well maintained 1-2 storey houses embedded in green trees, and of high density slum areas from the colonial time where not a single green leaf can be spotted. The outer fringe where the majority of the population lives is characterised by simple houses with unplastered cement walls, stagnant dirty pools or dust (depending on the season), and mountains of garbage.

Due to a long and violent civil war Luanda has had a substantial urban growth due to influx of rural people leaving war and landmines behind. It is anticipated that the population growth will slow down but that the vast majority of the new inhabitants will stay, as they have adapted to the urban life.

Existing practices

The vast majority of Luanda's population are defecating in hidden places and "defecation fields". Waterborne conventional sanitation using sewers or septic tanks was introduced by the Portuguese before independence. The Portuguese also introduced the simplified flush water toilet with a soak away pit "pia com posso roto" as a solution for the indigenous population. Garbage collection is a serious problem aggravated by the fact that faecal matter is deposited with the garbage.

Introducing dry sanitation

Water supply is a serious problem in Luanda as the water table is low and the ground water quality generally unsuitable. The piped water system is from colonial days and is “leaking as a sieve”. A big business has developed selling semi treated surface water, which is trucked out to the consumers around the city. Families commonly spend up to 50 % of their cash income on water. In spite of this water flushed latrines are preferred before dry ones.

Figure 3: Luanda dry latrines are converted to pour flush, and they are impressively clean.

Figure 4: A short tube connects the latrine to an off set pit, which later can be connected to a small-bore sewer.

For 15 years the Angolan Government and NGOs have been struggling to break the trend of water-flushed sanitation in periurban areas. For 15 years people have rebuilt the provided dry latrines changing them into pour flush toilets, this in spite of that water supply in Luanda is a disaster and that water is trucked out into the periurban areas and sold for prices that may amount to 50% of the cash income of the families.

The resistance to dry latrines is best understood when looking at the dry latrines which has been provided free of charge by Government and NGOs. 90% of them have been converted to pour flush latrines. Reasons mentioned are that:

1. The faecal matter is not seen by others
2. Less smell
3. Less flies
4. Longer durability
5. Higher status (dry latrines are “rural”)

Alternative solutions

Given that there is a massive resistance against dry latrines principally because of the visibility and status problem alternative solutions have been discussed. Dry ecosan latrines with urine diversion are one of the options. It is felt though as if the status aspect, mimicking the conventional WC, is the strongest one. In many areas the problem of space for replacement latrines and access roads for emptying vehicles, asks for permanent solutions. Waterborne alternatives can therefore not be ignored in the discussion.

Given the need for permanent solutions and that the population has a great resistance to handling, and even seeing, faecal matter one solution may be to connect existing pour flush latrines to small- bore sewer systems. where the old pit latrine/soak away become the retention tanks and emptying is made with waste water and stirring, converting sediment to suspended solids that travels with the waste water to ecological treatment plants where the fertile value is recuperated for compost, production of bio fuel and food, eventually feeding the city.

Amtananarivo

Antananarivo is the naturally ecological city. It is the capital of the great island of Madagascar and has approximately one million inhabitants. The presence of water and rice fields is one of the characteristics of the city. Water supply is not a problem. After more than 40 years of independence the city practically looks the same as during the colonial time. Even the City Centre is characterised by low buildings built in local bricks. Burnt clay bricks is the most common (and cheapest) building material.

Discussing alternatives

During a sanitation seminar in Antananarivo last year a number of sanitation options were discussed. The dry ecosan toilet with urine diversion got especial attention. The key question, however, was: Do we need it? What does it offer to Antananarivo more than the novelty of a modern solution? It is low cost. It looks like a WC but it isn't.

Naturally fertilized ground water and rice production in urban marchlands

The city is crossed by a number of watercourses and marchlands, which are explored to the last square meter. Water is abundant and, to a high extent, people use water-flushed toilets with septic tanks or soak ways pits. The ground water is being fertilized by the decomposing human waste and filtered by the soil before reaching the rice fields, which feed the city. The rice husks are used as bio-fuel for making burnt bricks and roof tiles. Burnt local clay, fired with rice husks, is the principal building material in the city.

The ecological loop is already closed

In Antananarivo the ecological loop has already been closed and introducing the dry ecosan toilet with urine diversion may result in problems more than benefits. By dissolving the human waste in the water and allow it to seep through the ground to the rice fields is a solution which is feeding the city since its beginning.

Nampula

Nampula is a military city in central Mozambique with around 0.5 million people. It is the third largest city in the country. The population is predominantly Muslim and the use of water for anal cleansing is general in the periurban areas. Latrines are problematic due to poor soil stability, religion and traditions.

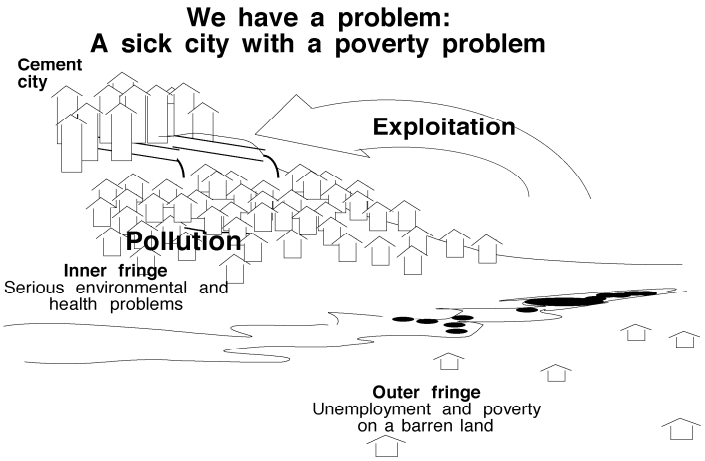

Figure 5: The existing city is an ecological parasite on the hinterland consuming fertile value and creating pollution and disease.

The city

Nampula town was built on top of a plateau, where the sewers ended at the hillsides. Unaware or ignoring the risks a fast growing periurban population has chosen to establish itself on the hillsides, close to job opportunities. Regular cholera outbreaks are the proof of serious sanitation problems.

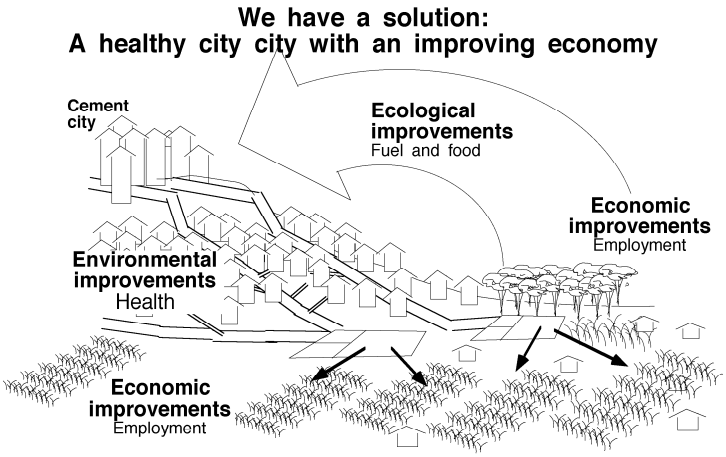

Figure 6: The ecological city is s resource to the hinterland producing fertile water for irrigation resulting in food, fuel, health and wealth

A logical solution to the sanitation problem of Nampula seems to be to establish treatment ponds and wetlands at the bottom of the hillsides for ecological treatment of sullage water, producing wood fuel, compost and eventually food for local consumption and export and eventually create plenty of job opportunities.

Small lined pits connected to trunk sewers would be an economic and feasible solution.

Conclusions

Space for building and emptying of latrines in periurban areas is a serious problem. Land for urban agriculture is rarely available and the crops are difficult to protect from animals and hungry visitors. “Do and forget” is the preferred solution by most people.

In the case of Luanda, trying to reintroduce dry sanitation resulted in a conflict with the population, which triggered the need of rethinking sanitation approaches for the periurban areas.
In Antananarivo the existing system using soak ways and septic tanks is ecologically sound, producing food and building material for the city. Trying to change would lead to problems rather than benefits.

In Nampula introducing waterborne small-bore sanitation systems might create enthusiasm for latrine building, as the technology is adapted to the traditional use of water and the ambition to adopt an “urban” lifestyle not to forget the ecological and economic benefits it may have for the city.

In many cases municipal sanitation solutions can be privatised and made economic if the scale is feasible. Small-bore sewers are excellent for transporting suspended solids, also longer distances. Technologies for ecological treatment of sullage water are well known and can be adapted to serve large communities.

Figure 6: "Do and forget" is the preferred solution by most people. Using a low volume flush and a small retention tank, the rich fertilized water can be used after ecological treatment

Using the "don't mix" rule as a mantra for ecological solutions may lead to conflicts with the population and lack of progress. The solution to hygiene problems, which is a basic need, must not be jeopardised.

There is a strong tendency among the periurban population to copy the patterns of the "cement cities" where status is linked to an "urban" lifestyle often leading to major environmental and hygienic problems.

The status of the WC is cemented in the urban culture. Wisely used it may become a promotional asset.

There are two alternatives:

1. Attempting to introduce ideal solutions
2. Accepting people's preferences and do the best of it.

Research on dry and wet ecological sanitation needs to be carried out in parallel to find solutions that also match people's preferences and culture.

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Subterra–constructed wetlands for wastewater treatment (examples and experiences)

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Keywords

Constructed wetlands, subterra, ecological village, highway service station, hotels

Abstract

Planted soil filters or reed-bed purification systems are one of the oldest and most natural means of purifying wastewater. They are mainly installed in urban areas. These constructed wetlands have been built for more than 40 years. In the same way as water in nature seeps into the soil, flows along roots, is filtered by various sand- and gravel layers and is purified by micro-organisms. Constructed wetlands have been a mayor part of scientific studies during the last 15 years – today they are accepted as state of technology. Implementations for small households as well as for large communities and Tourism are common.

This paper informs about "*subterra*"-constructed wetlands, which use a special subterranean system for the distribution of the wastewater. Several examples of implementation under different conditions and climates show how the system works, experiences made and which applications are possible.

Method

Modern reed-bed purification systems use a combination of mechanical and biological resources to process wastewater. There is a difference between vertical flow, horizontal flow and combined systems. All systems have the advantage to offer a huge buffer capacity and an enormous surface on their filter media for the microbiological population. Vertical flow systems have to be designed with a surface between 2 and 4 m² per 150l daily load depending on the climate. Horizontal flow systems require more space – they have to be designed with 5 to 8 m² per 150l daily load. The German water authorities publish technical descriptions for the construction of wastewater treatment facilities. Constructed wetlands are specified in work sheet A262 of ATV (Abwassertechnische Vereinigung) and in legal regulations of the German states. These descriptions are the basis for the design of applications but have to be adopted to other than European climates. Local resources have to be taken into account as well.

The *subterra* reed-bed purification system is a pure vertical filter system with a subterranean high-pressure distribution system. It can be installed for houses or communities of 4 to 10000 inhabitants. Besides that, there are further advantages, which are of particular importance to rural communities with specific local requirements:

- Low construction costs
- Low operation and maintenance costs
- Long life-expectancy of the system

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- System can easily be maintained
- No smell or mosquito problems on account of subterranean treatment
- Especially suited for seasonal influent quantity changes and resorts
- Local resources can be used to minimise the part of imported technology

The mechanical pre-purification of wastewater takes place in a multi-chambered pit. The minimum size is 4 m³, but it ultimately depends on the number of connected households or the daily wastewater quantity. Otherwise, constructed according to the German water authorities inflow specifications of 150 litre per person and day. The subsequent transport of wastewater to the reed-bed is brought about by a pressure pipe system, which guarantees an even distribution of effluent over the filtration bed. The bed consists of different layers of sand and gravel and is planted mainly with reeds, e.g. phragmytes.

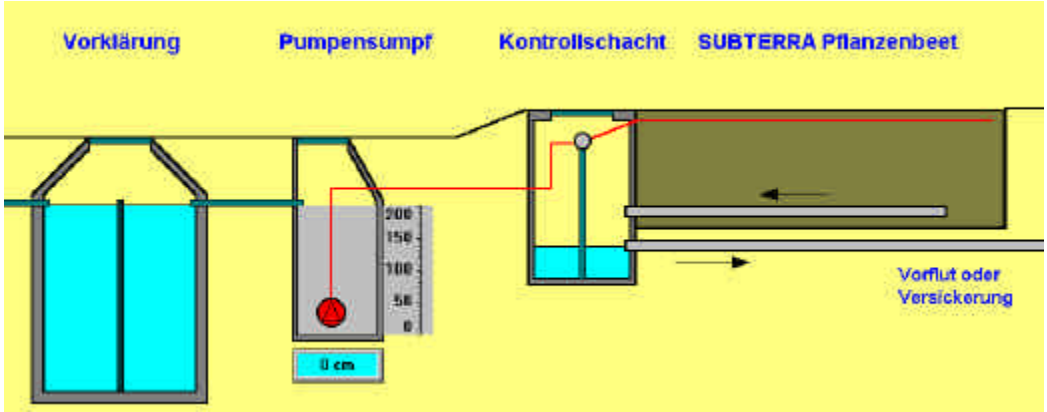

Figure 1: Technical principle of the subterra vertical soil filter system

The root system of the plants, i.e. the rhizomes, ensures an aeration into the soil for aerobic microorganisms. Soil aeration results from the oxygen inflow via the vascular system of the roots and the loosening of the soil by root development, which allows far going diffusion between the irrigation intervals. The rhizomes also ensure the hydraulic flow-through on a long-term basis. A layer of microorganisms forms on the roots. Nitrifiers and denitrifiers break down organic components. The purified water is then collected in pipes, from where it flows to a control tank, where it can be monitored. After that it is discharged to a river, pond, to the ground or reused in a secondary water circle.

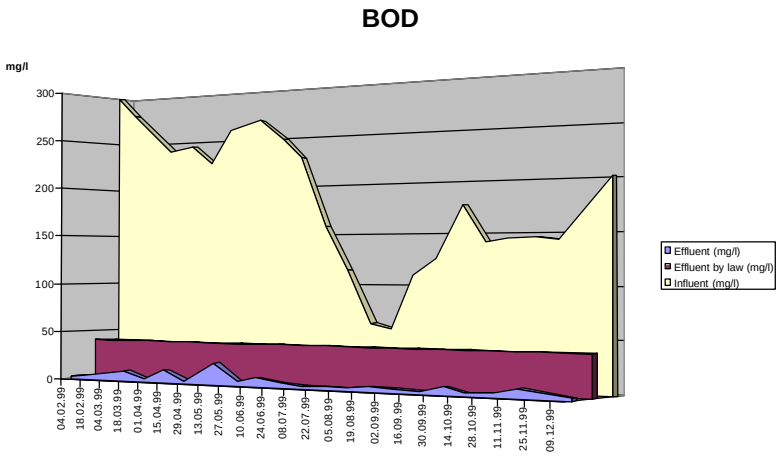

Figure 2: Typical effluent values of *subterra*-systems at hotels

Seasonal fluctuations have minimal effect on this process and therefore a satisfactory quality of effluent is also guaranteed during European winters. Central to the system are the subterranean

high-pressure inflow pipes, made of high grade EPDM, and high-pressure distribution fittings of refined steel. The pipes can be individually closed and back-washed. Influent quantity fluctuation do also not harm the system because of the huge buffer capacity of the planted soil filter. The soil filter has an average depth of approximately 1,2 m, what means that 1,2 m³ are available for an average hydraulic load of 50 litres per day and square meter. For a period of several weeks this amount can be doubled or reduced without harming the microorganisms activity. This advantage in comparison with compact wastewater treatment stations leads to implementations at touristical applications and at places with high influent fluctuations, like hotels, water parks, highway service stations and holiday bungalows. More than 100 stations have been installed in the past years – below you will find some examples of installations in Germany, Greece, South Africa and Thailand:

Ecological village "Wohnhof Braamwisch", Hamburg / Germany, 54 p.e.

Figure 3: View on the *subterra* reed-bed and the solar equipped house

In this case the treatment of wastewater is done in two separate ways. Composting toilettes are used which reduces also the water consumption. The greywater of the households is handled by a septic tank for the mechanical pre-treatment and a planted soil filter for the biological treatment. The *subterra* reed-bed has a surface area of 90 m² only. The effluent is led into a storage tank for irrigation purposes.

The effluent values reached are usually: BOD_5 5 mg/l and COD 40 mg/l. Very low values have to be met for phosphate and total nitrogen. The energy consumption is about 400 kW/h per year. Due to the subterranean wastewater distribution system no smell comes from the reed bed itself and the treatment station is located with an average distance of 3 m to the houses.

Highway station „Dwarsfontein", Mpumalanga Province / South Africa, 300 p.e.

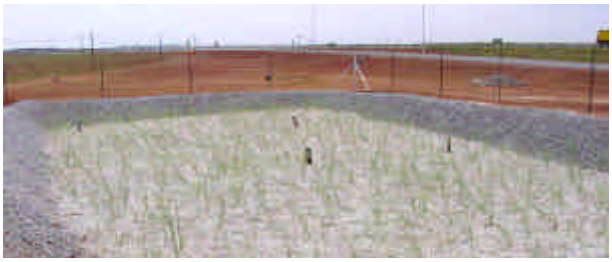

Figure 4: View on the *subterra* reed-bed and the exit road to the highway

At South African highways petroports offer petrol pumps and restaurant services to the public. At Dwarsfontein between Johannesburg and Witbank a *subterra* wetland has been installed to purify this very difficult sewage with high urinacid loadings under the semi arid climate. It was constructed according to German standards for vertical flow filters.

High evapotranspiration had to be taken into consideration: Up to German standards 20 % evapotranspiration is calculated – in the south African region up to 50 % is reached. As water is the main problem, the reuse and re-circulation of biologically treated

wastewater is most important. Roughly 60 % of the treated water is reused for toilet flushing and irrigation on site. The *subterra* system has to handle high fluctuations of influent quantities. It was designed for an average load of 48 m³ daily and has to handle up to 90 m³ per day on weekends and holiday peaks. The effluent values vary between 40 to 60 mg/l COD related to an influent between 400 and 800 mg/l. Faecal coliform bacteria are reduced down to 5 per 100 ml. These results show, that even under arid climate and high ammonia loadings constructed wetlands are highly efficient.

Hotel „ALFA BEACH“, Kolymbia, Rodes / Greece, 500 p.e.

This *subterra* station treats the wastewater of a four star hotel at one of the most favourite beaches on the island of Rodes. The construction includes the landscaping of the hotel area and integrates the wastewater system. The system is made to look like a typical Rodian river and is installed along the borders of the site, as the available space was limited. The surface of the reed beds is appr. 1.000 m². They are located very close to the apartments and the swimming pool as no smell disturbs the guests. Average effluent values: BOD_5 3–10 mg/l and COD 30–50 mg/l.

Figure 5: View on the subterra reed-bed alongside the apartments

The seasonal changes of wastewater quantity and quality were taken into account – during off-season no sewage is discharged into the system. The treated wastewater is used for irrigating the hotel garden and public eucalyptus alleys. The energy costs only € 250, - per year.

Dealing with hotels and the wastewater of restaurants it is most important to plan for the right size of the grease traps to hold back the fat from the biological reactor “reed bed”. The water consumption of hotels depends on the standard, its technical equipment and water saving facilities. At Alpha Beach the consumption is reduced to 250 l per person. In other cases up to 500 litres per person are being used.

Hotel „PP Princess“, Phiphi island / Thailand, 750 p.e.

This hotel is situated on one of the most beautiful islands of Thailand. The *subterra*-purification system located at seven different places on the premises, done to reduce the piping length and integrate the sewage works into the gardens. The reed beds are in the back or at the side of groups of bungalows and near public buildings like restaurant and wellness facilities. The effluent values vary between 3 and 15 mg/l for BOD_5 and 30 to 50 mg/l for COD.

The seasonal fluctuation of wastewater quantity and quality is lower than in other hotels as the PP Princess is booked between 60 and 100 % throughout the year. Again the treated wastewater is used for irrigation. The reed-beds treat all types of sewage: normal household blackwater, kitchen and laundry water with high loads of tensides.

Figure 6: View of the *subterra* reed-bed no.4 in direct neighborhood of the bungalows

The survey of the treatment plant is effected by a GSM telematic control system, which allows to control the station even from Germany. There has been training of the maintenance staff and engineers of local consultants on the handling of this natural treatment system. We learned, that it is not enough to just export technical equipment from Germany. Local resources and products as well as training should be major part of the installation, which makes it easier to introduce advanced European technologies.

Solar-autarkic highway stations "Warnowtal", „Quellental" and "Selliner See" near Rostock/Germany, 50 p.e.

As the construction of sewer systems and electrical grids in urban areas is not economical for small consumers, new ideas had to be put into action. Three parking and resting areas at the highway A20 in northern Germany stand for a new approach to solve a common problem at highways not only in Germany. These resting areas are equipped with a combination of several renewable energy installations. It consists a photovoltaic system, solarthermic collectors, small-sized wind power generator, bio-diesel co-generator and solar-architecture. The wastewater treatment is done by a 8m³/50p.e. *subterra*-system. Again the *subterra*-installation was chosen because its buffer capacity and ability to handle high ammonia loadings.

Figure 7: view from the pergolas to the solar toilet

The technical details for energetically compounds are:

- 26m² solarthermic collectors
- 10m² Photovoltaic panels

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- 4kW wind Generator
- 15kVA Bio diesel co-generator
- 1500Ah battery station
- low energy well system
- 150m² *subterra*-wetland

The solar-autarkic highway stations are in operation for two years now. The smooth operation proves that new technologies like those are sustainable, applicable and efficient.

Greywater treatment in combined bio-filter/constructed wetlands in cold climate

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Keywords

Greywater, bio filter, constructed wetland, cold climate

Abstract

In Norway systems consisting of an aerobic bio filter followed by a subsurface horizontal flow constructed wetland has been very successful in reducing organic matter, indicator bacteria, nitrogen and phosphorus in greywater. Because of phosphate free detergents are used in Norway and no toilet waste is included, the average influent total phosphorus concentrations (measured as septic tank effluent-STE) are about 1mg P/l and the average influent total nitrogen concentrations are in the range 8-10 mg N/l. The aerobic bio filter prior to the wetland is essential to remove BOD in a climate where the plants are dormant during the cold season. When combined with a horizontal flow constructed wetland the concentrations of indicator bacteria in the effluent meets European standards for swimming water quality. The effluent concentrations for phosphorus are generally < 0.2 mg P/l and for nitrogen < 5mg N/l. The combined bio filter /constructed wetland systems require 1-3m^2 surface area per person. The compact design opens for urban use.

Introduction

Norway has substantial experience from using source-separated systems for wastewater treatment (Jenssen and Skjelhaugen 1994, Jenssen 1996, 1999, 2001). In traditional sewer systems greywater constitutes 60-80% of the wastewater volume flow. In a recycling system based on source separation of wastewater fractions, water saving or dry toilets are used, hence, the greywater volume increases to >90% of the total wastewater flow. The toilet waste contains the majority of the nutrients and only 10% of the nitrogen, 26% of the phosphorus and 21% of the potassium is found in the greywater (Vinnerås 2002) . Nutrient removal then becomes a minor issue. However, greywater may contain more than 50% of the organic matter in wastewater (Rasmussen et al. 1996) and a substantial amount of bacteria and viruses (Ottosen and Stenström 2002). Systems that can remove organic matter and pathogens are therefore needed in order to facilitate discharge or reuse of the greywater.

The extent of greywater treatment will depend on the final discharge and use of the water. If discharged to the sea, no treatment or maybe only a primary treatment step is required. If discharged to lakes or rivers a secondary treatment step is often needed. Before discharged to streams or use in irrigation or groundwater recharge, the hygienic parameters must be reduced. For in-house reuse and drinking water, sophisticated tertiary treatment may be necessary. Wherever natural conditions allow, soil infiltration is a cost-effective option for greywater treatment (Westby et al. 1997). Norway has developed its own set of sizing and design criteria for greywater soil infiltration and sand filter systems (Jenssen and Siegrist 1991, MD 1992). This

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paper describes design details and performance of constructed/constructed wetland systems for greywater treatment in cold climates.

Greywater composition

Representative data for wastewater production and composition on the household level are scarce and more data are needed to reliably predict the pollution potential from greywater. Rasmussen et al. (1996) performed a literature survey of greywater composition and found total phosphorus concentrations varying from 1,4–18,1 mg/l. The highest concentration is from Sweden (Olsson et al. 1968). In Olsson's study, it was stated that the detergent contributed with 2,5g P/person and day or 912 g/person and year, this alone explaining the high phosphorous concentration. The total nitrogen varied from 6,7–42 mg/l. Vinnerås (2002) has studied the present day wastewater composition in Sweden and showed that heavy metals in greywater seem to have decreased over the last years, but the mass discharge of nitrogen and phosphorus is somewhat underestimated compared to Naturvårdsverket (1995). After 1997 more data on greywater composition has accrued in Norway due to building of several larger systems. It is therefore interesting to compare some data on greywater composition (Table: 1).

Source	Phosphorus		Nitrogen	
	g/p and year	mg/l	g/p and year	mg/l
Torvetua*	58	1,07	406	7,1
Kaja*	56	0,97	470	8,2
Vinnerås 2002	190	5,0	500	13,2

*Measured in septic tank effluent (STE)

Table 1: Mass (g/person and year) and concentrations (mg/l) in greywater.

The data from Kaja and Torvetua in Norway are based on average flows and adjusted to 100% presence assuming 70% of the wastewater production occurring at home. For nitrogen the values from Torvetua and Kaja are somewhat lower than the Swedish values (Vinnerås 2002), however for phosphorus the Norwegian values are only 1/3 of the Swedish. The Norwegian values are based on STE. 5-20% removal of nitrogen and phosphorus may occur in the septic tank (Pell and Nyberg 1985), hence, the difference in mass nitrogen may be due to the septic tank. The most probable reason for the difference in phosphorus content is the cloth- and dishwashing detergents. In Norway the majority of the cloth- and dishwashing detergents sold are phosphate free, whereas in Sweden they contain phosphorus.

When looking at the average concentrations of Norwegian greywater in samples taken after 1996, the average STE concentrations are 1,03 mg P/l for total phosphorus and 8,4 mg N/l for total nitrogen. These samples reflect the greywater composition from nearly 200 people. This means that the nitrogen meets the WHO drinking water standards of 10mg/l without any treatment. The Norwegian discharge consent for total phosphorus for many small chemical precipitation plants releasing their effluent to inland waterways is 1mg N/l. In many cases greywater meets also this requirement with no or only primary treatment.

Bio filter and horizontal flow constructed wetlands-design and performance

The general concept (Figure: 1) consists of pre-treatment of the wastewater in a septic tank, pumping to a vertical down-flow single pass aerobic bio filter followed by a subsurface horizontal-flow porous media filter. The bio filter may be integrated (Figure: 1) or located separate from the horizontal flow section. The wetland section is usually vegetated with common reed (*Phragmites)*. Evaluation of the role of plants in these systems when treating wastewater (including toilet waste), both in field and mesocosm scale systems, showed that the

root-zone had a positive effect on N-removal, but no significant effect on P and BOD removal (Zhu 1998, Mæhlum and Stålnacke, 1999). Some of the later systems have therefore been built with grass over an insulating soil cover. The grass-covered systems do not fulfil the strict definition of a wetland, although the filter is water saturated.

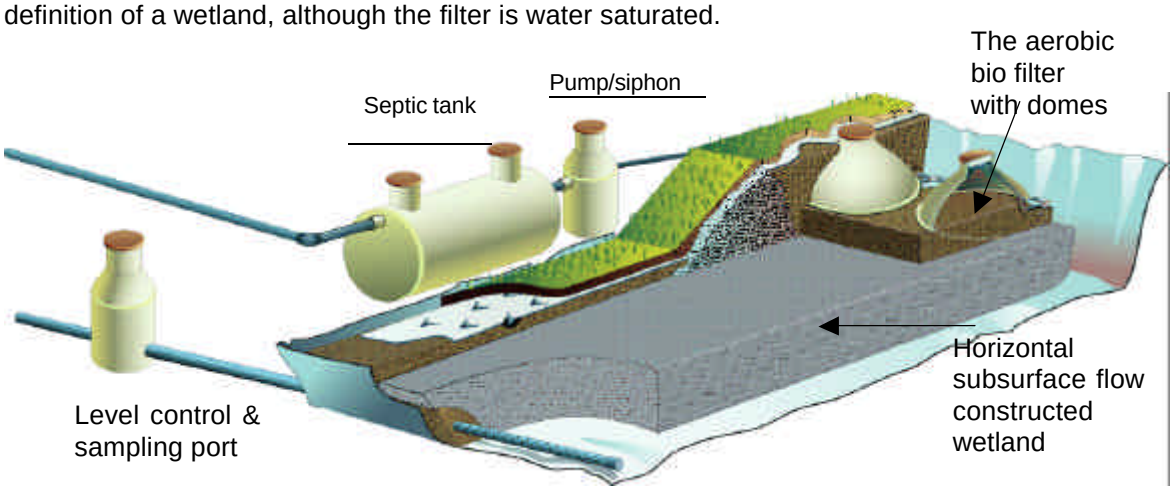

Figure 1: The latest generation of constructed wetlands for cold climate with integrated aerobic bio filter in Norway.

The aerobic bio filter

The bio filter (Figure 1) is covered by a compartment (e.g. a hemispherical dome), which facilitates spraying of the STE over the bio filter surface. The bio filter has a standard depth of 60 cm and a grain size within the range 2–10mm is recommended. In Norway lightweight aggregate (LWA) in the range 2-4mm is the most common filter media, but gravel or other type media in the above size range may be used. The effect of filter depth on removal of BOD and bacteria in LWA and sand filters was studied by Rasmussen et al. (1996). The study concluded that BOD removal was independent of filter depth for LWA filters in the range 20-60cm, but the bacteria removal was lower for the shallow filter depth. [MA1]

Bio filters and constructed wetlands using lightweight aggregates (LWA) or similar porous media are pioneered in Norway (Heistad et al. 2001, Jenssen and Krogstad 2002, Mæhlum and Jenssen 2002). The single pass bio filter aerates the wastewater and reduces BOD and bacteria. Using such bio filters for treating greywater more than 70% BOD reduction and 2-5 log reduction of indicator bacteria has been obtained at a loading rate for greywater up to 115 cm/d. Assuming a greywater production of 100 day/person/day a bio filter of 1 m^2 surface area can treat greywater from about 10 persons, hence, very compact bio filters can be made. Clogging has not been observed even at loading rates exceeding 100cm/d, however, earthworms are observed living in the bio filter. Their grazing of the bio film probably reduces clogging and enhances the hydraulic capacity of the filter. The key to successful operation of the bio filter is uniform distribution of the liquid over the filter media and intermittent dosing (Heistad et al. 2001). In order to further improve the quality of the effluent, the bio filter can be followed by a subsequent sand filter or a constructed wetland (Figure: 1).

The horizontal subsurface flow constructed wetland

According to the Norwegian guidelines (Gaut and Mæhlum 2001) the recommended depth of the horizontal subsurface flow constructed wetland is minimum 1 m. This is more than suggested in other guidelines (Vymazal et al. 1998, Kadlec et al. 2000). The reason is the cold climate. In Norway the systems are sized so that the upper 30cm of the system can freeze while

still leaving sufficient hydraulic capacity to transport the water below the frozen zone. The final geometry (length, width) of a system is based on hydraulic considerations, but for systems treating combined grey- and blackwater, sizing also depends on the phosphorus sorption capacity of the media. For commercial systems treating greywater the resulting surface area is 2-3m^2/person. For systems treating combined grey- and blackwater the recommended surface area is normally in the range 7-9m^2/person. In experimental systems treating combined black- and greywater and for greywater systems only, more compact designs are being examined. All present systems in Norway are built with an aerobic bio filter preceding the horizontal subsurface flow constructed wetland (Figure 1). Some systems use sand in the horizontal flow section, but the majority of the systems in Norway use lightweight aggregates (LWA) both in the bio filter and the horizontal flow section.

Combined aerobic constructed/constructed wetland systems

Three large combined constructed/constructed wetland systems are in operation in Norway. (Table: 3) The first system built according to the configuration (Figure: 1) is the plant at Kaja that treats greywater from student dormitories at the Agricultural University of Norway. (Table: 2) The Kaja plant has 2-4mm LWA (Filtralite^{TM}) in both the bio filter and the horizontal flow wetland section.

Parameter	Average concentration out of each unit				Percent removal %	Percent removal %	Total removal %
	Unit	Outlet Septictank	Outlet Prefilter	Outlet Wetland	Biofilter	Wetland	Biofilter and Wetland
pH		6,72	6,78	7,43			
Total phosphorous	mg P/l	0,97	0,32	0,07	67,0	78,1	92,8
Ortho phosphate	mg P/l	0,56	0,10	0,04	82,1	60,0	92,9
BOD 7	mg O/l	130,7	38,2	6,90	70,8	81,9	94,7
Total nitrogen	mg N/l	8,20	5,00	2,50	39,0	50,0	69,5
Ammonium	mg N/l	3,2	2,4	2,3	25,0	4,2	28,1
Nitrate	mg N/l	<0,03	<0,03	<0,03			
Termotol. Colif. Bacteria	TCB /100 ml	106	10^3-10^5	0-10^3			

Table 2: Average concentrations and treatment performance (%) for the Kaja greywater treatment plant, fall 1998 and spring 1999 (n = 11).

Table 2 shows the performance of the Kaja system during its second year of operation. For total phosphorus and total nitrogen the effluent from the bio filter is very low. However, in order to reduce BOD_7 to below 10mg O/l, and to meet the present European requirement with respect to indicator bacteria in swimming water (<1000 termotolerant coliform bacteria/100ml) the horizontal subsurface flow wetland is needed. With a retention time of 6-7 days in the wetland (Gulbrandsen 1999) the fluctuations in the outflow concentrations are small. Figure 2 also shows that the BOD removal does not vary significantly with season. This may be attributed to the long retention time, but also the high greywater temperatures. During the winter the STE temperatures varied from 10-15°C and the temperature drop through the wetland section was 2-3°C (Gulbrandsen 1999). Nitrate is not detected. This may indicate that nitrification does not occur or that the produced nitrate is immediately denitrified.

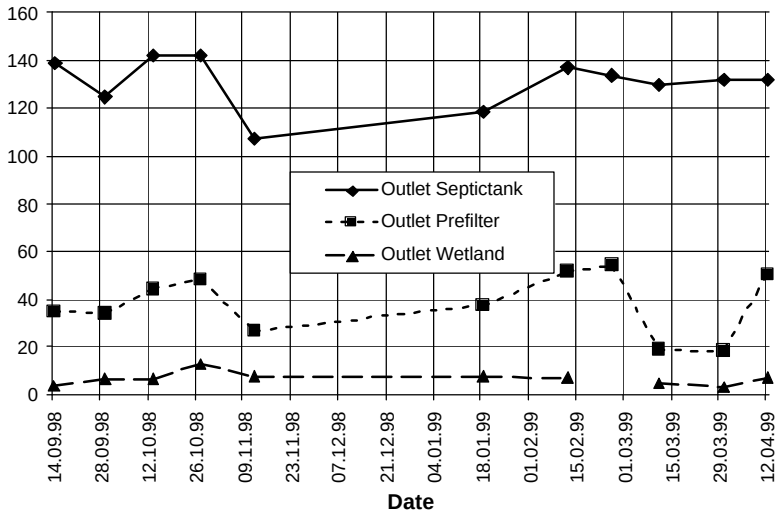

Figure 2: BOD_7 concentrations vs. time in the STE, bio filter effluent and wetland effluent.

The high phosphorus sorption of the system (Table 2) is due to the sorption capacity of the LWA used. Phosphorus sorption in the bio filter is only expected in the initial years. The wetland has a much higher total sorption capacity than the bio filter because of more volume. With the type of LWA used high phosphorus removal can be expected for 10-15 years.

The Kaja system is now running on its 6th year and no decline in phosphorus or nitrogen removal is observed. The last winter the BOD_7 was <3mg/l in all 3 samples in the outlet which indicate that the performance regarding BOD_7 may have improved. The Termotolerant Coliform Bacteria (TCB) counts in the outlet are generally below 100 TCB/100 ml and 7 out of 21 samples have shown 0 TCB/100ml.

The two treatment systems at Torvetua (42 condominiums) and Klosterenga (33 apartments) show very similar treatment values to the Kaja system. (Table 3)

System	Persons connected	Built year	TP		TN		COD		BOD_7 [a]		TCB [b]
			%	Cout	%	Cout	%	Cout	%	Cout	
Kaja	48	1997	94	0,05	70	2,6	94	15,8	94	5,6	sw
Torvetua	140	1998	79	0.21	60	2.2	88	41,0	97	5,5	sw
Klosterenga	100	2000		0,03		2.5		19,0			0

a) 7-day BOD is standard in Norway, b) Termotolerant coliform bacteria

sw = swimming water quality < 1000 TCB/100ml

Table 3: Average outlet concentrations and treatment performance (%) for 3 combined constructed/constructed wetland systems. Average over total service time.

At Klosterenga, in the city of Oslo, the greywater is treated in the courtyard of the building. The space required for this experimental system is about 1 m^2/person, and the treatment area is also used as a playground. The compact design is due to making the horizontal flow section 1,8m deep instead of the standard 1m, thus saving area and still having sufficient porous media volume in the horizontal flow section. Additional aeration, in the summer season, is provided by a flow-form system (Wilkes1980). No inlet samples are presently available at Klosterenga. The outlet samples show better performance with respect to phosphorus and bacteria than the systems at Kaja and Torvetua (Table 3). This is due to a new LWA, FiltraliteP ™, which has very

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high phosphorus sorption and bacteria reduction capabilities. It is estimated, assuming similar inlet phosphorus concentrations as for Kaja and Torvetua that saturating the wetland media with phosphorus will last more than 40 years at Klosterenga. With such high qualities of the effluent water, as shown in (Table 3), the need for a secondary sewer collection system is reduced because local streams or water bodies can be used for receiving treated water even in urban areas.

The excellent effluent quality (Table 2 & 3) facilitates reuse of the water for irrigation, groundwater recharge or for in-house applications. For flushing toilets and car wash it may be possible to use the effluent water (Table 3) without further treatment. However, recent results show that greywater may contain virus and bacterial pathogens that are not represented by the indicator bacteria (Ottosen and Stenström 2002). This may call for further treatment before use as suggested above. In order to upgrade to drinking water quality or for washing, micro filtration, reverse osmosis or carbon filtration may be needed as a single step or in combination.

Conclusion

A combined vertical flow bio filter followed by a horizontal flow wetland filter is developed. More than 70% BOD removal and up to 5-log reduction of indicator bacteria is possible in the single pass porous media bio filters using about 0,1m^2 surface area/person. For the combined bio filter /constructed wetland system the total area requirement is 1-3m^2/ person and the effluent meets European swimming water standards with respect to indicator bacteria and WHO drinking water standards with respect to nitrogen. The low area requirement of the system and the high effluent quality facilitates use in urban settings, discharge to small streams or open waterways and subsequent treatment producing water for in-house use.

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Community based sanitation program in Tangerang and Surabaya, Indonesia

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Keywords

BORDA, Community Sanitation Centre (CSC), participation, informed choice, Indonesia

Abstract

The City of Tangerang with it's 3 Mio. inhabitants is one of the big satellite-cities of Jakarta and with more than 1000 factories Indonesia's biggest Industrial agglomeration. Close to factories, next to the wall of neighbouring production lines, more than 250 000 inhabitants live in poor worker's settlements, not providing even a minimum of basic sanitation facilities.

Together with the Indonesian NGO "BEST" and user participation, community sanitation centres "MCK plus++" have been developed. They provide facilities such as bathrooms, toilets, washing facilities as well as drinking water through a community "water point". Furthermore, they integrate underground wastewater treatment with part-stream treatment of "black" and "greywater" from toilets and bathrooms. Since 1999, 35 units have been implemented the city centres of Tangerang and Surabaya with a demand driven approach. Operation and service is provided by full-time staff on-site. Maintenance is secured by BEST sanitation experts. User fees cover operation and maintenance. Today, recycling is practiced for digested sludge, biogas utilisation and irrigation of surrounding gardens.

The "MCK plus++" have proven to be an ideal community sanitation solution for densely populated urban low-income settlements where toilets, bathrooms and drinking water facilities are not available in private households. However, more research is needed in order to elaborate a catalogue of solutions complying with ecosan principles, where users can choose. A co-operation with the Technical University Hamburg-Harburg (Prof. Otterpohl) and local Partner Universities has started, aiming at further improvements and new solutions like urine diversion and market analysis for recycled products. New developments have to cope with socio-cultural reality, user acceptance and financial viability. New partners a welcome to join.

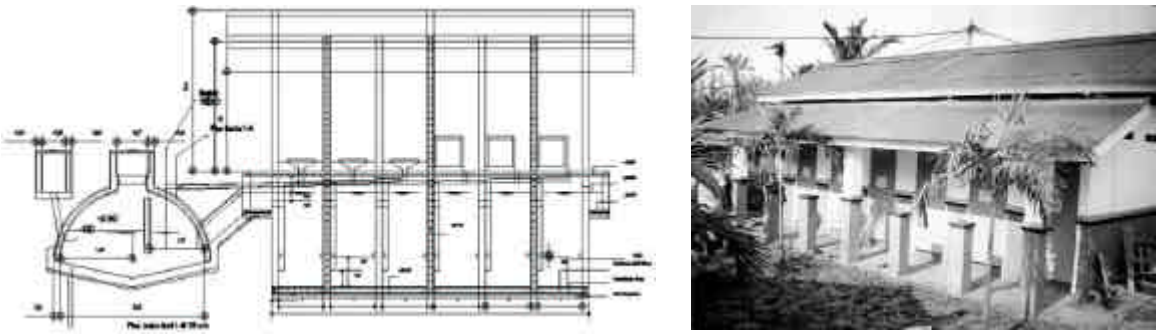

Figure 1: Technical design of community sanitation centre "MCKplus++"

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Introduction

The islands of Java and Bali are among the most densely populated areas in the world. 125 Mio people living on 150.000-km² discharge about 10 Mio m³ wastewater/day or 3,65 Billion-m³ wastewater/year into the environment. According WHO standards, well and tap water in most Indonesian cities does not fit human consumption due to e.coli contamination. Only 6 major Indonesian cities do have centralised wastewater treatment plants. However, it's sewerage systems serve only 10-15% of the population. Sceptic tanks, often in neighbourhood to boreholes are currently the state of the art of wastewater treatment on community level. Most on-site sewerage systems do not function efficiently. Like in most South-East Asian mega-cities, livelihoods and natural resources especially in poor urban settlements are increasingly threatened. People from low-income classes often live under conditions characterised by an extreme deficiency of drinking water supply and sanitation infrastructure. The few existing facilities are inadequate and not acceptable in terms of hygiene, dignity and ecology.

Community Sanitation Centres (CSC)

Since 1999, BORDA in co-operation with the local Indonesian partner NGO "Bina Ekonomi Sosial Terpadu" – BEST (Institute for Integrated Economic and Social Development) has implemented the construction of 35 "MCKplus++" (Community Sanitation Centres) consisting of toilet, bathroom and washing facilities including an integrated community "water point" for drinking water supply. The beneficiaries are inhabitants of densely populated low-income workers' settlements located in urban areas of industrial concentration near the conurbations of the cities Jakarta and Surabaya, Indonesia.

Before CSC were introduced, the existing sanitation infrastructure mainly consisted of open rainwater drains and empty lots, which were used for defecation and the disposal of other waste. As municipal water is rarely piped to the rapidly growing settlements, most of the inhabitants have to buy drinking water from itinerant water sellers or fetch it over long distances from municipal water taps.

Figure 2: Biogas Digester (left) for part-stream treatment of "blackwater", brick construction with waterproof airtight plastering. Baffled reactor (right), based on anaerobic up-flow principles.

Technology

35 CSC are built and operating successfully in urban areas of Tangerang and Surabaya. Each unit has about 1 000 visitors daily. The advantages of this system are:

- Integrated underground wastewater treatment with part-stream treatment of "black" and "greywater" from toilets and bathrooms.

- Anaerobic treatment processes work without external energy inputs.
- Low maintenance costs, no high-tech equipment/movable parts required.
- Spare-parts are locally available.
- Wastewater pollution is reduced by up to 90% (BOD/COD), thus reducing surface water pollution caused by untreated wastewater emission (Table 1).
- Groundwater is not polluted as the wastewater treatment plant is waterproof and airtight.
- Treated wastewater is safe to be discharged into the environment, and is partly reused for gardening or fishponds – according to customer demand. Volume ≅ 35 m³/d.
- Emerging Biogas is captured and used for cooking in neighbouring households.
- De-sludging measures are long between; de-sludging is required every 2-3- years only.
- Sludge is collected and treated by the municipality and reused for soil improvement.

LOCATION	MONTH	PARAMETER							
		pH	BOD5			COD			TSS
			Influent mg/l	Effluent mg/l	% reduction	Influent mg/l	Effluent mg/l	% reduction	mg/l
Alam Jaya	09.02.2001	7,28	310,89	49,52	84,07%	729,79	116,53	84,03%	48
	07.02.2001	6,34		45,60	85,33%		107,30	85,30%	28
	20.04.2001	6,78		32,90	89,42%		77,60	89,37%	36
National Water Discharge Standards (mg/l)									
Class B			50			100			200
Class C			150			300			400

Note: BOD_5 = Biological Oxygen Demand (5 days), COD = Chemical Oxygen Demand, TSS = Total Suspended Solids

Table 1: Laboratory analysis of wastewater treatment efficiency

Operation and maintenance

Operation and maintenance are provided by BEST as turnkey operator.

- User fees between 0.05 and 0.1 US$ cover operation and maintenance costs, and in addition are used for social development contributions to local community self-help groups.
- On-site staff is responsible for cleanliness of the facilities.
- BEST Sanitation experts ensure service and maintenance of the system components.

Costs

Costs are given based on CSC implemented in Tangerang:

- **Primary Investment** per CSC (land + construction): US$ 12000 –15000
- **Annual** turnover (user fees): US$ 2000 –2500
- **Annual operation costs:**
  - Salary for cleaning staff : US$ 500
  - Electricity : US$ 250
  - Cleaning Materials : US$ 100
  - Social Contribution : US$ 150
  - Overheads : US$ 500

  Total annual operation costs: **US$ 1500**

Once investment is done, no further financing is required, even in poor workers settlements. Scaling up the number of units will bring the costs down. Implementing CSC on more profitable locations (markets, railway stations, main roads) could lead to pay back periods of 10 years.

Participatory implementation of CSC projects

Participation of target groups in planning and implementation of projects constitutes one of the conceptual mainstays of BORDA's approach. However, local cultural perceptions concerning decision-making processes on group level have to be taken into account.

In practice, it is proven that community-based sanitation systems are significantly more sustainable, e.g. have a longer lifetime, function more efficiently and are better maintained, if they fully reflect preferences of communities and local stakeholders.

In the following will be demonstrated the course of measures undertaken in the participatory implementation process of CSC introduction.


Figure 3: Community-planning sessions with women and men groups

Methods

Before a participatory decision-making process can be initiated, certain indispensable facts and figures have to be ascertained (baseline data), consisting of:

Official Data

- Demographic data
- City Development Plans (especially plans on sewage and sanitation)
- Political guidelines and declarations of intent in the framework of regional development

Based on these macro-data, micro-data have to be found out by way of realising

Exploratory Surveys

Inspection by technical staff and social workers on <u>objective situation:</u>

- identification of apparent needs indicated by
  - density of population
  - inadequate or total lack of sanitation
  - low income strata of inhabitants
  - general neglect of environment
- topographic situation
- technical situation (existence of drains, sewers, piped water, electricity)
- land tenure

- composition of inhabitants regarding geographic, ethnic and religious background (homogeneous or heterogeneous)

Preliminary findings: area and sites are physically, technically and socially eligible for CSC introduction.

Interviews by social workers/facilitators concerning subjective situation:

- demand exploration with pre-constructed random-sample questionnaires:
  - respondents are stakeholders
    - members of the target group (beneficiaries according to gender/age)
    - members of the local administration
- demand exploration by qualitative interviews:
  - interviewees are stakeholders
    - individual prospective beneficiaries
    - key informants (e.g. local officials, informal leadership)
    - focus groups (e.g. women's groups)

Both quantitative and qualitative surveys should include the mentioning of possibilities of change and remedy of the situation, eventually touching on solutions (social marketing), and induce opinions and comments.

If and when the analysis of all baseline data lead to a defined eligibility of areas and communities (e.g. neighbourhood units) the subsequent step will be entering into the concrete form of the

Planning and decision making process

Participation of stakeholders, especially members of the target groups (beneficiaries), during the planning stage is the main key for successful program implementation.

In response to objective needs and subjective demands community members are approached by BEST for "socialisation", i.e. the imparting of educative explanatory information on sanitation, hygiene and health on the one hand, and the possibilities of solution on the other.

The method of choice is the arrangement of group meetings with participants from eligible communities.

From a wider range of technical and social solution possibilities, a pre-selected catalogue is presented (technically and socio-culturally impracticable varieties have been omitted beforehand), from which the target group members can choose the proper technical option, including infrastructure, maintenance and cost factors completed by information on

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opportunities, merits and risks of each technical option (informed choice). Furthermore, informed choice is offered concerning the management of the completed installation, i.e. technical, economic and social operation.

The benefits of elaborating and working with an "Informed Choice Catalogues" (ICC) can be summarised as follows:

- it informs about major component options of sanitation systems – Toilets, Collection System, Treatment System and Disposal/Re-use – and thus helps to identify suitable options
- facilitates the assessment of different sanitation system components with regard to stakeholder preferences
- is a powerful tool for technical bottom-up planning
- serves as reference to get overall information about technical options at a "glance"

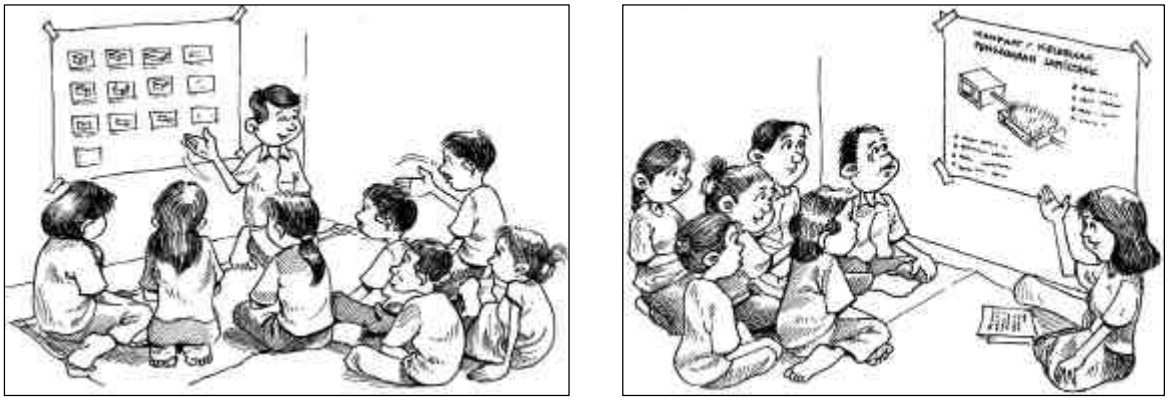

Figure 5: Informed choice catalogue, a powerful tool for bottom-up planning

After in-depth discussion among the participants, when needed interspersed with additional explanations from BEST staff, the forum decides on a feasible option. In order to forestall future constraints only unanimous decisions are accepted. Even one single substantiated dissenting opinion can give cause for the cancellation of CSC introduction in a specific area. However, further explanations from BEST and fellow occupants of the area can help to overcome dissenting opinions. This is one of the reasons why the BORDA/BEST project has been acknowledged as extremely successful.

According to evaluators commissioned by the Federal Ministry for Economic Cooperation and Development (BMZ), the BORDA-project is one of the rare examples where such an approach really works[1].

In the present case, the communities have decided to choose the MCKplus++ model as described above. Concerning the management, communities decided on varying approaches; at least one community decided to manage the daily operation on their own, relying only on technical control by BEST. However, most of the communities decided to leave the daily management to technical and social experts from BEST, i.e. the implementation of a "user model" which includes technical control, supervision of operation and maintenance, and the accountancy of user fees.

In the further course of action, the target groups take part in the technical planning, organised in an elected implementation committee, like choosing eligible sites for construction, and the planning for operation (fulltime personnel for operation and maintenance, decision on user fees

[1] Report on the partial evaluation "The Activities of Bremen Overseas Research and Development Association (BORDA) in Indonesia", BMZ, Bonn, December 2001

and their utilisation etc.).

Implementation

- acquisition of land for building site (BEST assisted by suggestions from the target group)
- construction planning (technical staff from BEST)
- construction (local building contractor, construction supervision by BEST)
- operation and maintenance (selection and employment of fulltime caretakers by Committee and BEST)
- inauguration (formal and informal leadership)
- utilisation of user fees (surplus used for development of local community self-help groups, e.g. “Posyandu” = Information and treatment centre on health and hygiene).

After-care and Follow-up

Possibilities of appeal to BEST are:

- for complaints
- for suggestions
- for replication (Requests/proposals from other communities)

Dissemination

- in other areas, in the present case realised in Surabaya
- taking-up of the model by government institutions (Municipality of Tangerang, Ministry of the Interior)

Results

Since 1999, the main results are:

- 35 Community Sanitation Centres “MCKplus++” built in poor urban communities
- Sanitation facilities cover the needs cover the needs of 17.000 persons
- About 13.000 m³ domestic wastewater is treated every day
- 80 households and the CSC use biogas for cooking (user fee = 2US$ per month)
- All sludge, after treatment on municipal sludge treatment plants, goes back to farmland
- Permanent/part-time employment created for over 100 staff and many craftsmen.

Furthermore, capacity building for the partner NGO in the field of dissemination and implementation of CSC, training of trainers, social activities such as hygiene and awareness training with the target group and last but not least contributions to local community self-help groups resulted in broad acceptance and utilisation of the CSC.

Impacts

Implementation and utilisation of the CSC do have a positive impact on the community while motivating the neighbourhood to improve their living environment on their own. Main impacts to be registered are:

- the renovation of houses,
- repairs of alleys, gutters and ditches and
- the construction of sport facilities (badminton court)

Conclusions

The present project of introducing “MCKplus++” has proved to be an ideal community sanitation solution for densely populated urban low-income settlements where toilets, bathrooms and drinking water facilities are not available in private households. However, “conditio sine qua non” is the participation of the beneficiaries.

The technical design of the “MCK plus++” integrates underground wastewater treatment with part-stream treatment of “black” and “greywater” from toilets and bathrooms. Since 1999, 35 units have been implemented the city centres of Tangerang and Surabaya with a demand driven approach. Operation and service is provided by full-time staff on-site. Maintenance is secured by BEST sanitation experts. User fees cover operation and maintenance. Today, recycling is practiced for digested sludge, biogas utilisation and irrigation of surrounding gardens.

More research is needed in order to elaborate a catalogue of solutions complying with ecosan principles, where users can choose from. A co-operation with the Technical University Hamburg-Harburg (Prof. Otterpohl) and local Partner Universities has started, aiming at further improvements and new solutions like urine diversion and market analysis for recycled products. New developments have to cope with socio-cultural reality, user acceptance and financial viability. New partners a welcome to join.

Introducing urine separation in Switzerland: NOVAQUATIS, an interdisciplinary research project*

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Keywords

Alternative wastewater treatment, consumer attitudes, No-Mix toilet, technology transfer, urban sanitation concepts, wastewater professionals

Abstract

Successful urine source separation (NoMix technology) poses a challenge to scientists, stakeholders, and society. Low-tech approaches are appropriate for rural areas; for large urban areas – in Europe and fast-industrializing countries – other solutions are needed. NOVAQUATIS focuses on NoMix technology in modern households, transport strategies, methodology to eliminate micropollutants (pharmaceuticals, hormones), and technologies to produce a fertilizer. First results are promising: feedback from consumers and farmers was positive, provided that high safety and comfort is maintained at low costs. To overcome the lock-in effect of the present system, technologically advanced transition strategies are needed, which allow to gradually implement NoMix technology into the urban wastewater system. Computer simulations of a strategy with small urine storage tanks integrated into the toilet indicate a positive effect on nitrification capacity (+30%) and emissions from combined sewer overflows (-50%). Results from experiments and modeling of precipitation in urine conducting pipes will help solving maintenance problems of NoMix toilets due to clogging. So far, engineering technologies for urine stabilization, nitrification, denitrification, and P-recovery via forced struvite precipitation have been proposed. Hopefully, the early implementation of NoMix technology in pilot projects and the integration of emerging countries into our scientific research will enhance successful technology transfer.

Introduction

Traditional and modern approaches to urine source separation.

Urine source separation (NoMix technology) has been proposed by different authors as a promising option to introduce the concept of sustainability to urban water management (e.g. Larsen and Gujer, 1997; Otterpohl *et al*., 1999; Larsen *et al*., 2001a). This idea is receiving increasing interest from large water authorities in Stockholm, Wuppertal, Basel, Berlin, and Hamburg, which is resulting in different pilot projects (Johansson, 2001; Bastian *et al*., 2002; Kühni *et al*., 2002; Peter-Fröhlich, 2002; Rakelmann, 2002).

Low-tech approaches to urine separation with nutrient re-use in agriculture have been carried out in rural areas of various cultures. In China, urine separation with simple toilets and application of raw urine as fertilizer has been practiced for millenniums (Esrey *et al*., 1998). In Denmark and Sweden, simple urine separating toilets were used in the mid-19th century, a tradition that

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This paper has been peer reviewed by the symposium scientific committee

was revived in the 1970s to solve sanitation problems of remote holiday houses (Johansson, 2001). It was also in Sweden, where modern urine separating toilets (NoMix toilets) were first invented and installed in pilot projects in the 1990s (Hellström and Johansson, 1999). However, to date even the modern approaches to urine source separation have only limited applicability in large urban areas.

We believe that urine source separation offers many advantages, not only for rural, but especially also for urban areas with a modern wastewater system – both in Europe and in fast-industrializing countries. However, in such a situation, modern, highly-advanced technological solutions are needed, and acceptance of the idea by important stakeholders such as consumers and wastewater professionals is essential (Larsen and Lienert, 2002). The development of new technology, the integration of the NoMix technology into the existing urban wastewater system, and the participation of society poses a challenge to all involved actors. These are the topics of the interdisciplinary research project NOVAQUATIS.

Why urine source separation?

Closing nutrient cycles: The traditional reason for urine separation is nutrient recycling to agriculture. Urine contains most nutrients excreted by humans: ca. 85–90% of nitrogen (N), 50–80% of phosphorus (P), and 80–90% of potassium (K; Larsen and Gujer, 1996). In modern agriculture, nutrient re-use from urine could partially replace synthetic mineral fertilizers; in Switzerland, this would amount to ca. 37% of N, 20% of P, and 15% of K (Lienert *et al*., 2003). A second main argument is the limited availability of phosphate rock, which could be depleted in 200–300 years (based on Jasinski, 2002). Already today, science and the phosphate industry aim at recycling P from wastes; recycling from urine might prove to be far easier than from wastewater treatment plants (WWTPs). Moreover, the production of mineral fertilizers produces problematic wastes and consumes large amounts of energy. Recycling of N from urine might prove to be advantageous also from an energetical point of view (Maurer *et al*., 2003).

Saving water: NoMix toilets help saving large amounts of drinking water, since little or no water is needed for flushing away urine. Many emerging countries face severe water shortage problems, whilst water flushing toilets are desired as symbols of progress. Because the expansion and maintenance of sewers and WWTPs often does not keep up with the growing use of flushing toilets, the export of the conventional western technology can result in increased water shortage, severe hygienic problems, and eutrophication of surface waters. In the long term, the introduction of a water saving toilet is beneficial for industrialized and emerging countries alike.

Advantages for the urban wastewater treatment system: NoMix technology offers several advantages: (1) urine constitutes ca. 1% of the wastewater, but necessitates large elimination steps because it contains most nutrients in wastewater. Nitrification and P precipitation would become superfluous with effective urine separation (Larsen and Gujer, 1996) and would allow downsizing WWTPs. (2) Most industrialized countries transport waste- and rainwater in the same sewers and discharge this mixture directly to surface waters via combined sewer overflow (CSO) during rain periods. Separate collection of urine could reduce chronic and acute toxicity due to N compounds, eutrophication due to P and N, and oxygen depletion due to nitrification. (3) Micropollutants (pharmaceuticals, hormones) are not completely eliminated in WWTPs. To date, over 80 compounds have been found in sewage effluents, surface waters, and even in ground waters (Heberer, 2002). Although the potential impact on the environment is largely unknown (Länge and Dietrich, 2002), micropollutants are giving rise to increasing concern. Since many pharmaceuticals from the human metabolism are excreted via urine, NoMix technology would improve water pollution control also in respect to micropollutants, especially when combined with other source control measures, for instance in agriculture.

Methods

The interdisciplinary research project NOVAQUATIS

NOVAQUATIS focuses on NoMix technology in modern households, transport strategies for large urban areas, methodology to eliminate micropollutants, and technical solutions to produce an attractive nutrient product from the raw urine for agriculture or industry. It includes socioeconomic research, natural sciences, engineering technology, and a cooperation with the emerging country China. Strong interactions with local water authorities and sanitary firms are maintained, and participatory research is conducted with important stakeholders such as consumers, farmers, and wastewater professionals thus paving the way for a large-scale implementation in Switzerland. NOVAQUATIS is organized around the nutrient cycle in eight workpackages (fig. 1).

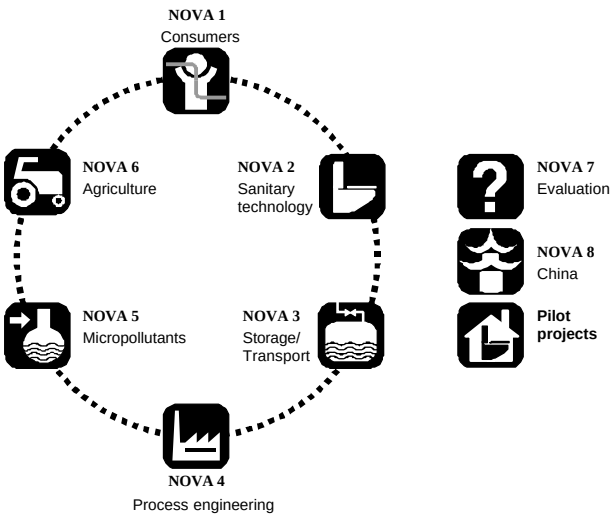

Figure 1: The anthropogenic nutrient cycle as it would arise if urine were separated at the source and returned to agriculture as fertilizer. NOVA 1–8 are workpackages.

The concept of NOVAQUATIS is to allow for conventional disciplinary research in projects assigned to the different workpackages (NOVA's; Table 1) with subsequent integration of the results at an interdisciplinary level. Associated pilot projects enable real-world testing of urine separation and in turn profit directly from the research results gained in NOVA 1–8. The integration of emerging countries into scientific research at an early phase aims at enhancing successful technology transfer. NOVAQUATIS runs from 2000 until 2005. This paper gives a first overview of the results obtained so far (see Lienert and Larsen, 2002 for a summary in German).

Results

Acceptance of NoMix technology by important stakeholders (Nova 1, 6)

Preliminary investigations revealed a high acceptance for urine separation and re-use of nutrients among consumers (NOVA 1) and farmers (NOVA 6). The attitude of Swiss citizens was assessed with focus groups (Pahl-Wostl *et al*., 2003). The 44 participants informed themselves on NoMix technology with a specifically developed computer tool (www.novaquatis.eawag.ch/NoMix Tool) and visited the NoMix toilets at EAWAG. The groups met twice for discussions and answered a questionnaire. They generally had a positive attitude towards NoMix technology: 89% women and 71% men regarded the NoMix toilet as a good or very good idea. A majority would move into an apartment with a NoMix toilet (79% women, 88% men), and many were willing to purchase such a toilet (63% women, 42% men). They were very interested in practical aspects of NoMix toilets (e.g. design, cleaning) and men were particularly intrigued by technical details. Interestingly, only 16% of the men regarded it as problematic to sit when urinating. Proper functioning of today's NoMix toilets depends on this condition and it is often a prime argument against their introduction. These results are not representative because the participants had a higher environmental awareness than average citizens. However, they do indicate that

NOVA	Workpackage	Project partners
1 Consumers	**Acceptance of the NoMix technology.** Which are the consumer attitudes towards the NoMix toilet and a urine-based fertilizer product? Traditionally, specialist engineers developed new wastewater technology without participation of the public. Obviously, this is not adequate for urine separation in households. Therefore, NOVAQUATIS involves relevant stakeholders already in an early phase of the research process.	• Prof. Ruth Kaufmann-Hayoz, IKAOE, Univ. Berne, Switzerland • Pilot projects
2 Sanitary technology	**Does the sanitary technology work?** Sanitary appliance manufacturers – in cooperation with EAWAG – explore design issues related to the NoMix technology in bathrooms. Additionally, the problem of precipitation, which can lead to clogging of urine conducting pipes, is investigated in detail at EAWAG. This workpackage also relates information between manufacturers and the project participants.	• Prof. Ralf Otterpohl, Tech. Univ. Hamburg-Harburg, Germany • Sanitary firms • Pilot projects
3 Storage / transport	**Storage and transport of urine.** Open questions regarding the storage and transport of urine still need clarification. Research mainly focuses on transition scenarios, which enable integrating the NoMix technology into the current urban wastewater management system without necessitating the renewal of the entire system. Therefore, NOVA 3 investigates different strategies of urine transportation in the existing sewers.	• Prof. Wolfgang Rauch, Dep. of Environmental Engineering, Univ. Innsbruck, Austria • Pilot projects
4 Process engineering	**Processing of urine and production of a fertilizer.** Different procedures to stabilize urine, to reclaim the nutrients (N, P, K), and to eliminate micropollutants are being developed and tested. Possible technologies are biological processes (e.g. biofilm reactors), chemical processes (e.g. precipitation in fluidized bed reactors), and physical processes (e.g. membrane technologies).	• Univ. of Applied Sciences Basel (FHBB), Switzerland
5 Micropollutants	**Are micropollutants in urine a problem?** Micropollutants are pharmaceuticals and hormones excreted via urine. The ecotoxicological effects of single substances and mixtures are analyzed with in vitro biological test-systems. Advanced analytical-chemical methods allow quantification of the degradation process of micropollutants in urine samples treated by different process engineering methods in NOVA 4.	
6 Agri-culture	**Urine as fertilizer?** It was planned to estimate how large the demand for a urine-based fertilizer product in agriculture could be – especially in organic and integrated farming – and to generate nutrient balances. The attitude of farmers towards such a new fertilizer product is also investigated in NOVA 6.	• Only a very limited part will be realized due to lack of financial resources
7 Evaluation	**Evaluation of the NoMix technology.** NOVA 7 integrates the research results generated in the other workpackages and covers some additional topics. The goal is to comprehensively evaluate the consequences of urine source separation. The NoMix technology will be evaluated with help of a scenario analysis, which assumes varying levels of implementation. This evaluation will provide important information to decision makers, and will allow customization to different contexts.	• Pilot projects
8 China	**NoMix technology also for emerging countries such as China?** In emerging countries, the introduction of flushing toilets often has severe impacts on the environment, because it is only rarely accompanied by adequate water pollution control measures. NOVA 8 adapts the results of the other workpackages to this special situation and investigates whether the implementation of urine source separation technology in emerging countries could contribute to improved surface water conditions.	• University Kunming, China • Swiss National Science Foundation (SNF) • Swiss Agency for Development and Cooperation (SDC)
Pilot projects	**Does NoMix work in real life?** To test the NoMix technology in reality, several pilot projects are performed in both private and institutional settings. Four apartments of a housing estate in a larger Swiss city were equipped with NoMix toilets in 2001. Additionally, EAWAG and the FHBB are testing some NoMix toilets. Larger pilot projects are planned by the AIB in the canton Basel-Landschaft (BL). For instance, it is planned to fully equip the cantonal library in Liestal with NoMix toilets.	• ?Bau- und Umweltschutzdirektion? (BUD), BL • ?Amt für Industrielle Betriebe? (AIB), BL • Univ. of Applied Sciences, Basel (FHBB)

Table 1: The workpackages of NOVAQUATIS (NOVA's) and associated project partners of EAWAG

there is goodwill and interest towards NoMix technology and that it is possible to inform a lay public on complex technology issues. Furthermore, consumers are not willing to carry additional costs and maintaining today's level of comfort and esthetics is essential. The participants were also questioned on their attitudes towards food fertilized with a urine-based fertilizer. Indeed, 72% were willing to regularly purchase such food, even though nutrient recycling was not a major argument for technology acceptance, whereas they regarded the short-term positive impacts on ecosystems (i.e. water pollution control) as especially convincing aspects of NoMix technology. Absolutely essential for the acceptance of a urine-based fertilizer was a hazard-free product. Hence, adequate hygienization and elimination of micropollutants will presumably be extremely important for the widespread introduction of a urine-based fertilizer product.

This opinion is shared by 127 Swiss farmers of a mail survey (Lienert *et al*., 2003). Again, results are not quite representative, because the response rate differed among groups of farmers. The 467 randomly sampled farmers were informed with a letter and answered questions on personal details, their opinion towards a urine-based fertilizer product, and nutrient demands. Acceptance of the NoMix technology was surprisingly high: 57% thought it was a (very) good idea and 42% would purchase a urine-based fertilizer product if it were cheap. Market chances are highest among farmers with large nutrient demands (i.e. integrated production, vegetable production). They preferred an ammonium nitrate fertilizer and a grainy, rather than a liquid product. Like consumers, farmers were worried about hazardous substances in the fertilizer: 30% of all farmers mentioned concerns regarding micropollutants. Hence, our first surveys indicate that the NoMix technology is acceptable for Swiss people provided that the costs are low, but comfort and safety standards are high. Whilst the attitude of consumers and farmers is important, a recent analysis indicates that it is not the driving force for the successful introduction and fast diffusion of the NoMix technology (Larsen and Lienert, 2002). The main decision-makers are wastewater professionals (e.g. engineers, wastewater authorities) and *their* opinion is absolutely crucial. *They* will have to introduce the new concept and carry consequences of drawbacks. Hence, a strong commitment from the part of wastewater professionals is needed. Our analysis indicates that the technologically advanced transition strategies, focusing on a gradual implementation of NoMix technology into the existing wastewater system, might be far more attractive to wastewater professionals than the more low-tech approaches (see NOVA 3).

Sanitary professionals and sanitary technology: precipitations (NOVA 2)

NOVAQUATIS has several years of contact with sanitary professionals. Different NoMix toilets are available on the market today; however, our ongoing surveys with users indicate that various design-related problems still need to be solved. The main problem is clogging of urine-conducting pipes due to precipitation, which would hardly be accepted by users of NoMix toilets in Switzerland. Presumably, sanitary professionals will only carry the costs for the necessary technology development if there are high market chances (Larsen and Lienert, 2002). Precipitations were intensively investigated (Udert *et al*., 2003b,c,d). A high fraction of phosphorus is incorporated into the precipitates. The main crystalline compounds are struvite, hydroxyapatite, and calcite. The composition depends on dilution with flushing water; computer simulations indicate that dilution diminishes the precipitation potential and thus the risk of blockages. Rainwater is more effective than tapwater. Microbial urea degradation triggers precipitation; the bacteria mainly grow in the pipes and are flushed into the tank. In undiluted urine, a degradation of only 8% urea resulted in 95% of the maximum precipitation potential. Few days are necessary for complete urea depletion, and precipitation begins soon after ureolysis has started. Struvite and octacalcium phosphate are the precipitating minerals in undiluted urine. The results show that there are no easy solutions to overcome the clogging problems in urine conducting pipes. Effective handling of precipitates from urine still demands large efforts and technological ingenuity.

Integrating the NoMix technology into the urban wastewater system (NOVA 3)

The ultimate aim of the NoMix technology is to gain an attractive nutrient product for application in agriculture or industry. NOVAQUATIS proposes to collect the urine at the source in households and to use the existing sewer system for transport at nights without rainfall (Larsen and Gujer, 1996). Real time control would ensure that urine arrives as concentrated as possible at the WWTP, where it could be treated separately. To bridge rain events, a tank for storage during 3–7 days would be necessary. Such a system enables a cost-efficient, stepwise introduction of the NoMix technology, which allows for technological learning and gradual development.

Adequate technologies for processing the urine into an attractive nutrient product have not yet been developed (but see NOVA 4, 5). Therefore, NOVAQUATIS also proposes a transition scenario, which allows integrating NoMix technology into the current system, hereby improving the capacity of WWTPs. A possible scenario consists of a very small urine tank integrated into the toilet for storage during 1–2 days. Transport of the urine is also via the existing sewers, albeit without further processing into a nutrient product. Here, the main goals are (1) leveling out the nitrogen dynamics at the WWTP caused by diurnal variations in urine production (peak shaving), and (2) avoiding urine in CSO during rain events (Larsen *et al*., 2001b; Rauch *et al*., 2003). Stochastic modeling with realistic storage tank volumes (10 liters/toilet) provided promising results: over 50% of urine released via CSO could be avoided, and the ammonia peak loads at dry weather could be decreased by ca. 30%. The latter increases the nitrification capacity of the WWTP in the same dimensions (Rauch *et al*., 2003). Because this version only involves a new toilet, but not new tubing, large storage tanks, and complicated processing plants, it could be implemented very quickly and at fairly low costs. This allows a faster diffusion of NoMix technology, with minimal risks and – again – ample room for technological learning. Therefore, we regard this transition scenario as the most promising solution for the immediate introduction of NoMix technology in a modern, urban context.

Urine processing to produce a urine-based fertilizer without micropollutants (NOVA 4, 5)

Fresh urine (pH 6.2–6.8) has a high amount of biodegradable substrate, which triggers rapid microbial growth. A dominating reaction is the microbially catalyzed hydrolysis of urea, which results in ammonia production and a pH increase (>9). As a result, the saturation for several phosphate minerals is exceeded and they precipitate (NOVA 2). This would enable to recover nutrients (P, some N) as solids. Various elimination technologies for nutrient solutions exist, but the adaptation to urine needs efforts (Larsen and Boller, 2001; Maurer *et al*., 2003). Different procedures to stabilize urine, reclaim nutrients, and eliminate micropollutants are being developed (NOVA 4). A first proposed technology is based on known biotechnology (Udert *et al.*, 2003a): with aerobic biological treatment of urine (including partial nitrification), the pH was stabilized, which helps avoiding corrosion problems and evaporation of ammonia, thus enabling an application in agriculture. As further option, the urine was denitrified via nitritation and anaerobic ammonium oxidation (Annamox). A possible technology for the recovery of P from urine is presented separately: forced struvite precipitation ($MgNH_4PO_4$; Ronteltap *et al*., subm.).

Further processing technologies and analytical methods to detect micropollutants in urine are under development. The ecotoxicological risk of micropollutants (NOVA 5) is assessed with a mechanism-based test battery. It includes nonspecific test systems, which allow quantifying the overall cytotoxicity and estimating the total molar load of toxicants (Escher *et al*., 2002). It also comprises tests for specific modes of toxic action (e.g. endocrine disruption, inhibition of photosynthesis, DNA damage). After validation with single compounds and designed mixtures, the test battery is used to test the ecotoxic potential of the treatment products of NOVA 4. Two chemically-oriented projects in NOVA 5 are closely cooperating with European research projects (Eggen *et al*., subm.) and adapt analytical methods from wastewater to urine. This allows quantifying the degradation process of micropollutants in urine samples processed by NOVA 4.

Could NoMix technology be an option for emerging countries such as China (NOVA 8)?

Source control could also offer an alternative to the conventional end-of-pipe wastewater management in emerging countries. NoMix technology has great potential for improving desolate conditions of surface waters. In cases where the sewer system is not yet established, there are more degrees of freedom in the planning process than in a typical European country. Kunming was chosen as pilot region. First results of a methodology for wastewater and pollutant mass flux analyses in emerging countries are presented separately (Huang *et al*., subm.). The challenge here is to take into account the specific uncertainties, most importantly the lack of data and the rapid urban development. The methodology is tested in Zürich and will then be implemented in Kunming. The results will be the basis for an additional project that investigates the institutional and technical possibilities for introducing source control measures in wastewater management in South East Asia.

Pilot projects to test NoMix technology in the real-world

Currently, several small pilot projects are performed in private and institutional settings in Switzerland: (A) four apartments of a municipal housing estate in a large city were equipped with NoMix toilets in 2001. The main idea is to assess social acceptance and design-related problems of NoMix toilets in households, and to test their functioning in daily life (NOVA 1). Additionally, a stochastic model for simulation of the at-source urine occurrence is being developed to understand storage and transport-related processes (NOVA 3). (B) Several NoMix toilets and waterfree urinals are installed at EAWAG since 1997, mainly to collect urine samples (NOVA 4, 5) and data on precipitation in urine-conducting pipes (NOVA 2). The NoMix toilets were also used for the sociological surveys with focus groups and currently with long-term users (NOVA 1). (C) The University of Applied Sciences Basel (FHBB) installed some NoMix toilets and waterfree urinals in a vocational college in 2002. The main goal is to test the sanitary models available on the market and to gain experience with the urine-conducting pipes and storage tanks. The attitude of the users is being assessed with quantitative surveys (NOVA 1). (D) Finally, the wastewater authorities of canton Basel-Landschaft (BL) have initiated a large urine separation project (Kühni *et al*., 2002). The general aim is to evaluate more flexible and sustainable alternatives in urban wastewater management, with special focus on waste design and urine separation. Based on experience from other pilot projects, the NoMix technology will be fully implemented on a technical scale in the cantonal library in Liestal (BL) in 2005. Currently, a microsimulation model is being constructed to simulate material flows and direct costs associated with different scenarios of NoMix market penetration (NOVA 7). The model is based on Swiss residential census data in an urban and a rural model region. It simulates the spatial and temporal distribution of urine yield and the adoption of NoMix technology over time (Peters *et al*., 2002). (E) Given successful results of the real-world tests and the computer simulations, NoMix technology will be implemented in the entire catchment area of a small WWTP in BL.

Conclusions

Interdisciplinary research is a challenge and chance alike. Detailed disciplinary research within NOVAQUATIS has provided some promising answers to major questions of engineering techniques and sociology associated with urine source separation. For instance, feedback from consumers and farmers was positive, under condition that high standards of safety and comfort are maintained at low costs. Although these stakeholders are important, a third group might prove to be absolutely crucial for the successful introduction and fast diffusion of urine source separation: the wastewater professionals. Technologically advanced transition strategies, which allow for a gradual implementation of NoMix technology into the existing modern wastewater system, will help to overcome the current lock-in situation. NOVAQUATIS proposes such transition scenarios. By realizing pilot projects in an early phase, the NoMix technology can be directly tested in

the real-world. Likewise, the early integration of emerging countries such as China into the research process might enhance successful technology transfer from industrialized regions to fast-industrializing ones; whilst successful technology transfer in turn can strongly promote the idea of NoMix technology in our highly industrialized urban centers. Continuing disciplinary research with integration of the results at an interdisciplinary level will help finding sustainable alternatives in urban wastewater management.

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Practical examples of DESAR concepts in urban areas in the Netherlands

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Keywords

Decentralised sanitation and reuse (DESAR), source separation, urban areas, practical examples, monitoring programme

Abstract

This paper contains a short summary of case studies into the realization of Decentralised Sanitation and Reuse (DESAR) concepts based on source separation in urban areas and highlights several organisational and technical aspects that play a role in implementation and operation.

Introduction

Decentralised Sanitation and Reuse (DESAR) concepts based on source separation enjoy increasing attention in The Netherlands. Since the beginning of the 1990s several urban projects were initiated in which various forms of source separation were considered and taken into practice. This paper highlights a monitoring programme into the realization of these projects. The programme is aimed at increasing the knowledge on practical implementation and management of DESAR concepts. Information on technical, institutional and legislative aspects is collected through interviews with local stakeholders and a review of available literature and Internet sources. In addition several workshops and symposia are organised in order to disseminate the collected information and increase the chances of success of future projects.

Overview of practical examples of DESAR concepts based on source separation

Table 1 gives a brief overview of urban source separation projects in The Netherlands that have been identified within the monitoring programme (update January 2003). The paper describes three projects with different wastewater collection and treatment systems in more detail.

The table shows that application of source separation in The Netherlands is at this moment (January 2003) mainly limited to local greywater treatment by, in most cases, constructed wetlands. The treated water is discharged into local water systems that are usually part of the architectural design as a measure to create an attractive urban environment. Two projects use this 'urban water' as a source of second quality water for toilet flushing and washing machines after a simple treatment step (filtration). The application of local blackwater treatment in city areas has so far been limited to one project with composting toilets. However, several projects are in preparation in which vacuum and urine separating toilets will be applied.

Name of area and year of construction	Characterization of DESAR concept					web address
	Local greywater treatment and infiltration	*Blackwater, compost toilet*	*Blackwater, vacuum toilet*	*Urine separation toilet*	*Local rainwater infiltration*	
Current projects						
Groene Dak, Utrecht (1993)	X	X			X	www.groenedak.nl
Drielanden, Groningen (1995-1997)	X				X	www.drielanden.nl
Lanxmeer, Culemborg (1999-2003)	X				X	www.eva-lanxmeer.nl
Schutterstraat 1, Delft (1995)	X	X			X	
Polderdrift, Arnhem (1996)	X				X	
Waterspin, The Hague	X				X	
Projects in preparation						
EcoPark, Emmeloord (2003-2005)	X				X	www.ecopark.nl
Wageningen (2004-2005)	X		X		X	
Water Museum in Arnhem (2003)				X		www.watermuseum.nl

Table 1: Overview of DESAR projects in urban areas The Netherlands (January 2003)

Het Groene Dak, Utrecht

Residential area 'Het Groene Dak' is an ecological housing project in Utrecht that was completed in 1993. It consists of 40 rental and 26 private-owned houses. The project was initiated by some of the current inhabitants through Foundation 'Het Groene Dak'. Major attention in the project has been put on the usage of sound construction materials and energy and water saving measures.

The area contained an experiment with ten houses that had no connection to the sewer system. Physiological (black) waste was collected with composting toilets. The collected wastes were composted in the basement of the dwellings combined with kitchen wastes. Moisture was drained off through a sieve and led to the greywater treatment system. After seven years of operation the experiment was stopped by urgent request of the inhabitants. Unfortunately (and for reasons not clear) the moisture drainage appeared not sufficient and the composting process became severely disturbed for some years. Despite huge affords of the inhabitants, anaerobic conditions prevailed in the composting room and led to severe nuisance and potential risk through the formation of methane and ammonium gas. The composting toilets were subsequently replaced by conventional (water saving) toilets that were connected to the city sewer. The removal of the accumulated black 'cake' got national attention because of the suspected danger for an explosion and the evacuation of the whole block (which appears quite unlikely since a strong ventilator had already been installed years before).

The greywater was (and is) treated in an oxidation bed with carrier material followed by a sub-surface reed bed filter (5 houses) or a wetland in a greenhouse (5 houses). A measurement campaign by the University of Amsterdam (Matthijs and Balke, 1997) showed that very acceptable treatment results are obtained that comply with the effluent discharge standards.

De Drielanden, Groningen

This housing project was initiated by a group of ecologically interested citizens, united in the *Vereniging Ecologisch Wonen* (VEWG - Ecologically Living Society). In cooperation with the Municipality Groningen and the local housing agency the settlement Drielanden (166 dwellings;

both rental and private-owned) was established in 1995-1997. The houses have advanced isolation measures, are located favourable to the sun and have water saving devices. The Dutch Ministry of Housing, Spatial Development and Environment awarded a prize to the project in 1997 as being an innovative example of a sustainable and energy saving residential area.

The largest part of the settlement (110 households) is equipped with grey and black wastewater separation and greywater treatment. Blackwater is discharged into the central sewer system. The VEWG had originally proposed to implement composting toilets. However the constructor, the architect and the municipality objected to this idea because of proposed high costs of creating extra composting room in the household's basements and expressed doubts concerning the long-term operation of these systems. After thorough debate it was ultimately decided to install water saving toilets of 4 litre per flush. Unfortunately, in practice it appeared that more flush water was required to prevent clogging of the blackwater gravity sewer pipes.

The greywater of 110 households in De Drielanden is treated in a free surface constructed wetland system. The effluent is discharged, along with rainwater, into the surface water basin in the residential area. The constructed wetland system consists of a 30 cm deep horizontal-flow canal system that contains reed. It is constructed as a carrousel and has a hydraulic retention time of 18 days (ca 10 m^2 per person). Because the system is open to the surface, it is located outside the residential area and is not open to the public. It is only operated in the summer, because of possibility of freezing in the winter. The municipality provides the system operation and management.

Extensive monitoring of the constructed wetland system and the urban surface water system was done by Van Dijk (2002). The wetland system shows a very good treatment performance as illustrated by table 2. A remark is made by the author (who is inhabitant of the neighbourhood) about malodour due to the direct contact between wastewater and open air. However, no official complaints on this have been received until now. Long-term measurements have shown that the water quality of the urban water basin is of constant and good quality.

Parameter	Influent (greywater)	Effluent 1996	Effluent 1997	Effluent 1998	Effluent 1999
COD (mg O_2/l)	550	38	51	44	45
BOD_5 (mg O_2/l)	298	2	7	4	2
N-Kjeldahl (mg N/l)	12,6	1,7	2,4	2,0	1,6
NO_3-N, NO_2-N (mg N/l)	< 0,03	< 0,03	< 0,02	< 0,17	0,11
P-total (mg P/l)	1,8	0,24	0,49	0,31	0,31
pH	7,1	7,6	7,6	7,4	7,3
Chloride (mg/l)	68	52	55	27	51

Table 2: Influent en effluent of the grey wastewater treatment system (yearly averages) (van Dijk, 2000)

Lanxmeer, Culemborg

A recently developed project with alternative sanitation is the residential area Lanxmeer in Culemborg. This project was initiated by the EVA Foundation (Ecological Centre for Education, Information and Advise) and the Municipality of Culemborg and is based on an integrated approach towards sustainable urban development. The Lanxmeer district will ultimately consist of 200 houses and apartments, a number of company offices, workshops, an ecological city farm and a conference and hotel centre of the EVA Foundation. A large part of the area has been built in 2000; the remaining parts will be constructed in the coming two years. The water situation of Lanxmeer is special because it is situated on top of a water abstraction area. In order to protect the ground water special measures have been taking to avoid ground water pollution.

Domestic wastewater is collected separately in a black and greywater sewer system. The houses in Lanxmeer are equipped with water saving toilets. This toilet type uses 4 litre to flush faeces and 2 litre to flush urine. To minimize the chance of clogging of the blackwater sewer a so-called booster is installed for temporary storage of the blackwater. At this moment the blackwater is brought into the central (back up) sewer system. The future objective is to digest the black wastewater in the area in combination with kitchen wastes and recover energy through the production of biogas. The grey wastewater in Lanxmeer will be treated in three vertical flow reed bed filters (2 m^2 per person) that are embedded in the innovative urban architectural design. Rainwater is locally collected and stored in five retention basins that are spread throughout the area.

Some conclusions regarding system choice

Practical application of source separation in The Netherlands is at this moment (January 2003) mainly limited to local greywater treatment by, in most cases, constructed wetlands (designed as open air or sub surface system). The treated water is discharged into local water systems that are usually part of the architectural design and contribute to an attractive urban water environment. The experience with application of constructed wetlands in or close to urban residential areas is largely developed and positive although figures on the monitoring of the effluent quality are scarce. Monitoring results in Groningen show that greywater treatment in (in this case an open air) constructed wetlands is effective in removing BOD and nutrients and ensuring good local surface water on the long term.

The (limited) experience with separate collection and treatment of blackwater shows that the choice of the toilet system has major influence on local transport, treatment and potential of reuse. A project with composting toilets had unfortunately to be taken out of practice after some years of operation. Experience with low water consuming toilets in combination with separate blackwater collection show that there is a high risk of clogging of gravity sewers. Ultimately the quantity of water used will also determine the feasibility of on-site digestion of blackwater (Zeeman and Lettinga, 1999). However, recent developments and experience in vacuum and urine separating toilets offer new possibilities. Several projects with application of these alternative toilet systems are in preparation, visibly in urban (Wageningen, Water Museum in Arnhem) and rural areas (Swichum, Reeuwijk).

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The Skogaberg Project – a blackwater system with waste disposers under development in Göteborg, Sweden

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Keywords

Blackwater, dual piping, gravity flow, nutrient recovery, waste disposer

Abstract

The Skogaberg housing area is being built with a wastewater system that can recycle plant nutrients back to the farmland. The Skogaberg project is a pilot project initiated by the City of Gothenburg in order to create a closed loop in the wastewater management. From every household in the Skogaberg area there are two separate pipes collecting blackwater (i.e. urine, faeces, toilet paper and flush water) and greywater respectively. Every household also has a waste disposer for organic wastes, which is grinded and flushed into the blackwater pipes. There is a small local treatment plant that will treat the blackwater and the organic waste from the waste disposer. It is important to notice that this blackwater system is not totally optimised regarding the technique but rather an attempt to build a system balanced between the Real Estate Company's requirement about a marketable housing area and the objective to recycle nutrients. Hence an important aim of the study has been to browse a selection of suitable techniques and to evaluate them in terms of estimating what level of nutrient recovery to adopt in the construction of the pilot plant. The study is followed by a detailed projecting and by the building of the actual pilot facilities i.e. wastewater system and local treatment facility.

Introduction

This pilot project has been initiated by the City of Gothenburg (Recycling Office, Egnahemsbolaget Real Estate Company and the Water and Sewage Works) as a step towards building a sustainable society. There is an agreement in The City of Gothenburg to build and evaluate pilot projects that are considered most suitable for urban areas. Virtually all municipalities in Sweden are struggling with this challenging question of how to recycle nutrients from urban areas to the agriculture in a safe, cost-efficient, and by other means appropriate way. The Skogaberg Project is a contribution to the extensive research that this challenge requires.

Gothenburg, as all other Swedish towns, has only one wastewater system, in which the nutrients coming from society, mainly from toilets, are mixed with contaminants from households, industries, landfills etc. This mix is then discharged to the local sewage treatment plant, Ryaverket, where separation of pollutants takes place. The sewage sludge produced on Ryaverket stays below national limit values for contaminants, stipulated to secure that critical loads of heavy metals and organic pollutants are not exceeded in farmlands fertilised with sludge. Even so, a widespread apprehension is topical amongst the Federation of Swedish Farmers (LRF) and the Food Industry for farms using sewage sludge as fertiliser. Due to the intense debate concerning enrichment of pollutants in food products from such farms, a need to try separating wastewater system in a large-scale facility became obvious. Hence the Skogaberg Project developed.

The reason for having two separate pipes for the household wastewater is to only take care of what is desirable i.e. the urine, faeces, toilet paper and the food leftovers. From a number of studies it is already known that most of the plant nutrients are found in the blackwater and that most of the unwanted pollutants (derived from household detergents etc.) are found in the greywater. The separated flows in this dual piping system also leads to a nutrient solution that will be diluted to a lesser extent than a mixed flow. By excluding greywater from a nutrient recycling system like Skogaberg, that which is taken care of and treated by the system then contains as much of the nutrients as possible and as little of the contaminants as possible. Although this blackwater system is not totally optimised regarding the technique, it is a system balanced between the efforts to recycle a sludge with as much nutrients as possible but with a minimum of pollutants and at the same time fulfil the Real Estate Company's requirement about a marketable housing area. This means that some compromises with reference to the dilution of nutrients in the blackwater were necessary to make due to the resistance against installing vacuum piping. Water pipes and installations in the houses will be non-copper, to avoid copper pollution in the sludge create a possibility to evaluate a copper-free system through measurements.

Methods

The City of Gothenburg through the Recycling board has the main responsibility for the project managing, co-ordination and financial follow up. A preliminary study is performed concerning treatment facilities and utilisation of blackwater sludge and nutrients in farmland by means of literature studies, excursions, calculations, interviews and meetings with parties concerned. A student, Kristina Fermskog, at the Swedish University of Agricultural Sciences (SLU), Department of Agricultural Engineering, is performing this study. After that a detail projecting takes place followed by building the actual pilot facilities i.e. wastewater system and local treatment facility, later on building the houses and follow up reports.

The system and the treatment

The Skogaberg area, northwest of Gothenburg is a small valley that slopes gently towards a little creek where the housing area is under construction. In 2005 the area will consist of 110 small houses and 17 flats in three apartment blocks. According to the Real Estate Company's time-schedule all flats are ready for occupation at the time of the ECOSAN-conference and about 50 of the houses will be ready for occupation by the start of 2004.

What characterises the main structure of the Skogaberg system is in the first place that there will be two separate pipes collecting blackwater (i.e. urine, faeces, toilet paper and flush water) and greywater respectively. Transportation of both black- and greywater is managed by the use of gravity flow. The reason for the choice of gravity flow to transport the black- and greywater is, among other things, that this valley makes it possible, and will be an excellent site to evaluate the combination of blackwater system and gravity flow.

For future research purposes the greywater passes a control point where e.g. samples can be taken for analysis, and then the greywater is connected to the regular waste pipes leading to the conventional local treatment plant, Ryaverket.

Every household will also be equipped with a waste disposer for the organic wastes, which can be grinded and flushed into the blackwater pipes. The waste disposer in every household is a very convenient way for the residents to handle the food wastes, otherwise brought to compost. Waste disposers are not very common in Sweden today and using waste disposers in Skogaberg gives an excellent opportunity to evaluate this technique in prevalent circumstances.

The third characteristic element in the system is the small local treatment plant that will treat the blackwater and the organic waste from the waste disposer. What happens at the small local

treatment plant is primarily that plant nutrients are separated from the blackwater. The purpose is not to treat like conventional plants do, with the objective to protect the environment, but rather to optimise nutrient recovery. Subsequently the rest of the blackwater follows the greywater to treatment at Ryaverket. Incoming blackwater is diluted since transportation occurs by gravity flow and this creates a great challenge for the local treatment plant.

Considerations

Instead of using the small local treatment plant to treat and prepare the sludge for agricultural use there is a second alternative, namely co-treating the blackwater with other organic wastes at a central plant. These other organic wastes originate from food industries, food stores, and restaurants in and around Gothenburg. It would be a large benefit to integrate these wastes in the Skogaberg system, which has the mission to deliver it to farmland, and close the circuit between the urban and rural nutrient flow.

A main purpose of the study has been to browse a selection of suitable techniques, adoptable to both the local treatment plant and the central treatment plant, and to evaluate these techniques in terms of estimating what level of nutrient recovery they will provide and from that get a guideline in the constructing of the pilot treatment plant.

At present there is still an investigation going on to decide what kind of treatment technique to set in Skogaberg. Alternatives under consideration are based on a wide range of techniques, from relatively simple, mechanical separation and chemical precipitation, to more complicated ones like ultra filtration and ion exchange. Further on there are treatment alternatives that also give hygienisation of the obtained blackwater sludge. Aerobic treatment by wet composting or aerobic thermopile digestion, heat and pH treatment by lime stabilisation, complete hygienisation in Super Critical Water Oxidation and anaerobic digestion.

Different techniques give different results and to evaluate the outcome, a number of parameters are balanced against each other. Besides nutrient recycling, economy is an important parameter as well as management of resources (chemicals and energy). It is also of great importance that the pilot plant can be reliable to run and at the same time be flexible in the meaning that adjustments can be made by relatively small efforts. These adjustments could be for instance to alter the facilities to better match the characteristics of the incoming blackwater.

At a local treatment plant it is very valuable to avoid exposing the residents to odour, which may occur. In analogy with disturbing odours, operating this plant should not have to be dependant on a large number of transports with trucks. Trucks carrying chemicals to or sludge to and from the pilot plant site would of course not only be disturbing for the residents but also lead to air pollution and most probably carry a large part of the costs for a small pilot plant. This line of argument implies that co-treating the blackwater with other organic wastes, originating from other parts of Gothenburg, is preferable at a central plant and that other organic wastes should be treated at a local plant only if it is needed to manage and improve the process.

Considering what technique to adopt is also based on what terms and conditions the farmers and the Food industry has on fertilising with a sewage product like the one from Skogaberg. For this reason a part of the study has been to look into this line of business policies and demands on the build-up and management of a system like Skogaberg. At a preliminary basis the Skogaberg system comes to terms with these demands (regarding factors like hygienic safety, pollutants, origin of the nutrients, management etc.) and there are no great obstacles to deliver the Skogaberg product to farmland.

Conclusions

The Skogaberg housing area is still under development and any final conclusions are difficult to draw. However, conceivable conclusions will be possible to draw from the use of waste disposers, the dual piping system with gravity flow, running stoppage from the small local treatment plant, the behavioural aspects in association with technical function in the future use of the system. The conclusions can then take into account if the techniques are successful or not and if they should be modified in some way.

To ensure the quality of the sewage sludge, it is necessary that the house-owners/tenants use the system in the intended way. Most importantly, harmful substances may not be introduced into the system, i.e. into toilets or waste disposers. Therefore, an agreement will be made between the Recycling Office and the house-owners/tenants to clarify how the blackwater system is to be used.

These experiences will reveal if a system like Skogaberg is viable to adopt elsewhere in Gothenburg and Sweden where a closed loop in wastewater management is the objective.

Low flush toilet systems for water saving, nutrient recovery and soil improvement in Hamburg and Berlin

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Keywords

Saving water, nutrient recovery, low flush toilet systems

Introduction

The necessity of saving water, especially in using water for flushing toilet waste, is a primary task and a postulate for recovering human-borne nutrients and organic matter as well as to improve health aspects and the quality of drinking water. During the last twenty years, mainly Swedish inventions took part of these aspects, offering a variety of intelligent solutions. Some of them are in use in Germany for many years, so effects, experiences and technical development can be shown.

Methods

Beside the possibilities of using rainwater or greywater for flushing conventional toilets with 6 or 9 litres, the technique and the acceptance of the user itself is significant for the effect in water saving. So the best technique might be the one, where the user has not to change any habit and even does not notice any change in using the toilet.

The technique and practises of different Low Flush Toilet Systems are introduced in urban settlements in Hamburg and Berlin, using 1 to 4 litres for flushing. Further urine diverting flush toilets, also in combination with separating devices for faeces, are presented. In this way, water still remains as a medium for transport human waste with all its positive and negative aspects, but offers new possibilities and options for the further treatment and recycling of less contaminated waste water.

Results

Costs of investment, installation and operation of the different Low Flush Toilet Systems are evaluated and compared with conventional Flush Toilet Systems in Germany. Effects on discharge, treatment systems and environment are described, as far as possible. Based on these ecosan modules, different scenarios for different requirements can be projected.

Conclusions

Learning from our own experience should be determining for future concepts in ecological sanitation, before transferring them to other countries that need new solutions. Nevertheless, we have to consider other cultural, social and technical circumstances, so development and improvement of ecological sanitation systems has to take place together with the future user and controller from the beginning. In this way, we all can learn from each other to help good things going.

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Local recycling of wastewater and organic waste - a step towards the zero emission community

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Keywords

Blackwater

Abstract

If blackwater and wet organic household wastes are source separated and co-treated, more than 90% of the nitrogen, 80% of the phosphorus and 60% of the potassium can be reclaimed and recycled. Blackwater is collected with a vacuum toilet. More than 4-years experience with vacuum toilets (in two housing developments, 48 and 120 persons) has provided data on their effectiveness. The latest toilet development is vacuum on demand (VOD), i.e. vacuum is generated only when flushing. The system is more robust than earlier vacuum toilets and consumes less energy (<10 kWh/person/year), with solar powered systems under construction. Food waste is collected via a kitchen grinder and discharged to the blackwater storage facility. The amendment increases dry matter, nutrient, and energy content of the effluent for recycling. A liquid-composting (aerobic) reactor sanitizes the effluent. The reactor operates on a semi-continuous mode and generates energy, which may be extracted as heat. It is suggested to use algae or bacteria to produce hydrogen for increased energy production. The deodorized waste meets European standards for sanitation. Seven aerobic reactors are currently operating in Norway, and a small-scale biogas reactor designed for cold climates is being developed. The end product is a nutrient-rich liquid intended as fertilizer. The liquid is injected into the ground using tractor-mounted equipment, which is well suited for stony soils and consumes less energy than many other fertilizer application systems. By use of algae the recyclable waste also has potential for conversion to fodder for aquaculture.

Ecosan-options for single households

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Keywords

Ecosan-technologies, wastewater

Introduction

Purpose of the work is to demonstrate the applicability of EcoSan – Technologies aiming at avoiding any discharge of wastewater from single households. Basic principle was to proof that this is possible – in the contrary to what is often assumed – without any reduction in the standard of living.

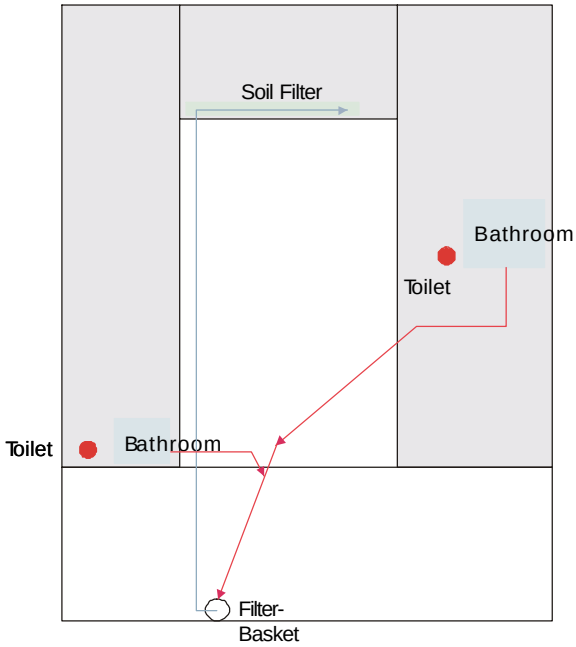
Methods

The strategy was to prevent the production of wastewater as far as possible at the source and reuse the remaining greywater within the house.

The house, an old farmhouse constructed around 1850, consists of two wings (one used as an office and the other for living) connected by a roofed gate which was, by simply closing the open south oriented side with glass, transformed into a living room, connecting now both parts of the house. In total there are three toilets and as many bath rooms.

Results

To avoid the production of blackwater completely in order to reduce the quantity of wastewater to be treated, increase it's initial quality and allow optimal nutrient recycling dry toilets are foreseen. Urine is stored in two separate tanks, one on each side of the building, and used for gardening. The faeces are stored in a textile (air permissible) sack, which can be simply changed, the available storage volume thus becoming variable (compared to a concrete chamber only). The initial problem was the availability of sufficient storage volume since no basement exists thus limiting the available space. With the chosen system the storage volume is extended by simply transporting filled sacks out of the house.



The remaining greywater from kitchen and bathrooms is collected in a conventional plumbing system. For further treatment / use of greywater various options exist. Reuse in agriculture (subject to sufficient quality) would

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be an appropriate way but requires storage for a min. of 5 months considering the climatic conditions in Austria. Treatment in, e.g. reed bed filters, to a quality sufficient for discharge is also an option but not reuse-oriented as postulated for the proposed solution.

Therefore treatment and reuse options were combined by pumping the water after mechanical pre-treatment (filtering) to a 5-m² soil filter located in the living room of the house. The soil filter is constructed comparable to a vertical flow constructed wetland and shall be planted with elephant grass, papyrus, etc., aiming at achieving a sufficiently high evapotranspiration rate to reduce the effluent to near zero. Studies carried out over the last 4 years on constructed wetlands in Africa showed that under conditions of average annual temperatures of 25°C and hydraulic loading rates of 200 l/m² evaporation rates of more then 100 l/m² can be achieved.

The house is presently under construction, first practical results will be available beginning of 2003. Technical data and construction details will be presented in the paper, at the time of the conference operational data shall be available.

Conclusions

Technologies focusing on prevention and reuse applied in-house have quite some tradition in industrial pollution mitigation (and are legally enforced in Europe) but although theoretically legally required are only rarely applied in households. One main reason is the existence of projects demonstrating the possibility and practicability of such solutions. At present all these technologies are viewed as exotic solutions for a peculiar minority. This project is meant to help overcome these prejudices.

Decentralised water sanitation loop – a case study from Bangalore, India

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Keywords

Bangalore, rainwater, eco-san, sewage

Abstract

Bangalore, India needs to move to Eco-San quickly. Water demand is increasing rapidly, there is a shortage and a limit to the availability of fresh water and 'fouling the nest' is happening with surface water bodies and groundwater bodies. As wastewater is not being managed properly valuable water and nutrients are getting lost and polluting water. The movement towards Eco-San will need to be managed and phased into the city's conventional wastewater management system. Information dissemination and implementation of pilot projects from the household to the neighbourhood level will become essential for the transition to Eco-San. A current example of the transition is the movement towards decentralised wastewater management and individual household treatment of wastewater. (Figure: 1). More such examples and a thorough documentation are needed quickly to scale up and popularise Eco-San. An example of a decentralised system in a suburb called Vidyaranyapura is documented and presented as a learning model.

Introduction

Bangalore, India situated at an average elevation of 920 metres above sea level has certain unique features placed as a demand on its water requirement and sewage treatment. 1500 million litres per day of water needs to be pumped into the city from a river Cauvery 95 kilometres away and 300 metre below. Ceiling in availability of fresh water for the city is likely to be reached by 2011 when the population of the city will be 7 million. In terms of a water sharing agreement with the neighbouring state no further water can be expropriated from the source river unless a reallocation is made from agricultural use to urban use. After the water is consumed in the city, sewage flows out in 3 major valleys and is treated at the outlets of these valleys. Only primary treatment is possible and it is estimated that less than 50% of the sewage from the city receive this primary treatment. Within the city itself surface water bodies like lakes and tanks are on the decline from impacts of urbanisation such as encroachment by houses, their numbers coming down from 262 to about 80 and almost all of them are polluted with sewage. This pollution of lakes has had its impact on ground water. Over 50% deep bore-wells report nitrate contamination, which is a result of collected untreated sewage in the lakes percolating down to the groundwater.

The suburban colony of Vidyaranyapura in Bangalore has seen some attempts at sustainable management of water, sewage and the conservation of lakes, which may be a forerunner for future directions to the cities water management.

Method

Ecological-sanitation or Eco-San has been defined more as a process than a technique. It is the process by which water and nutrients are recovered from human waste in a hygienic manner and used as a resource. Pollution impact especially on water bodies is eliminated due to Eco-San thus ensuring sustainability. "…every approach that ultimately leads to closing the loops and to reuse of nutrients, water and energy should fall under the term 'ecosan'." (Werner, Christine–2000).

A progress towards eco-san in the city context of a developing world could entail the following steps:

- Existing centralised sewage collection and treatment systems or septic tanks/pit latrines
- Decentralised conventional sewage systems linked to constructed wetlands and surface water bodies
- Household and apartment level mechanical treatment of sewage and recycling of wastewater alone
- Household and apartment level digesters and biological filter systems. Reuse of wastewater and nutrients
- The twin leach pit combined urine and faeces digestion and reuse system
- Household level urine segregation and reuse and faeces collection and composting in dry toilets

The steps above would suggest a more holistic perspective and would also open up choices to individuals and communities. The horizon would also broaden to include protection of surface and ground water resources as well as reusing nutrients. One example of perhaps the first step is cited below:

The colony named Vidyaranyapura has a geographical spread of about 4 square kilometres and typical residential houses, which are two storied and about 2500 in number. Taking advantage of the topography of the suburb, which represents a shallow valley, 2 artificial lakes called 'tanks' in local parlance have been created by the Forest Department of the State government. The 'tanks' are named as Narsipura –1 and Narsipura-2. Narsipura –1 receives fresh rainwater in its catchments and stores the water primarily for purposes of recharge of the ground aquifer. Narsipura-2 stores the overflow of rainwater from Narsipura-1 as well as is the area for location of a domestic effluent treatment plant. All the sewage received from approximately 2500 houses in the colony is collected and subjected to sludge removal and aeration using a 4 floating aerators. After passing through a constructed wetland acting also as a biological filter the treated sewage is stored in the 'tank' again to recharge the aquifer below.

The entire water supply to the colony of 2500 houses is through a battery of 25 bore-wells mainly located adjacent to the tanks.

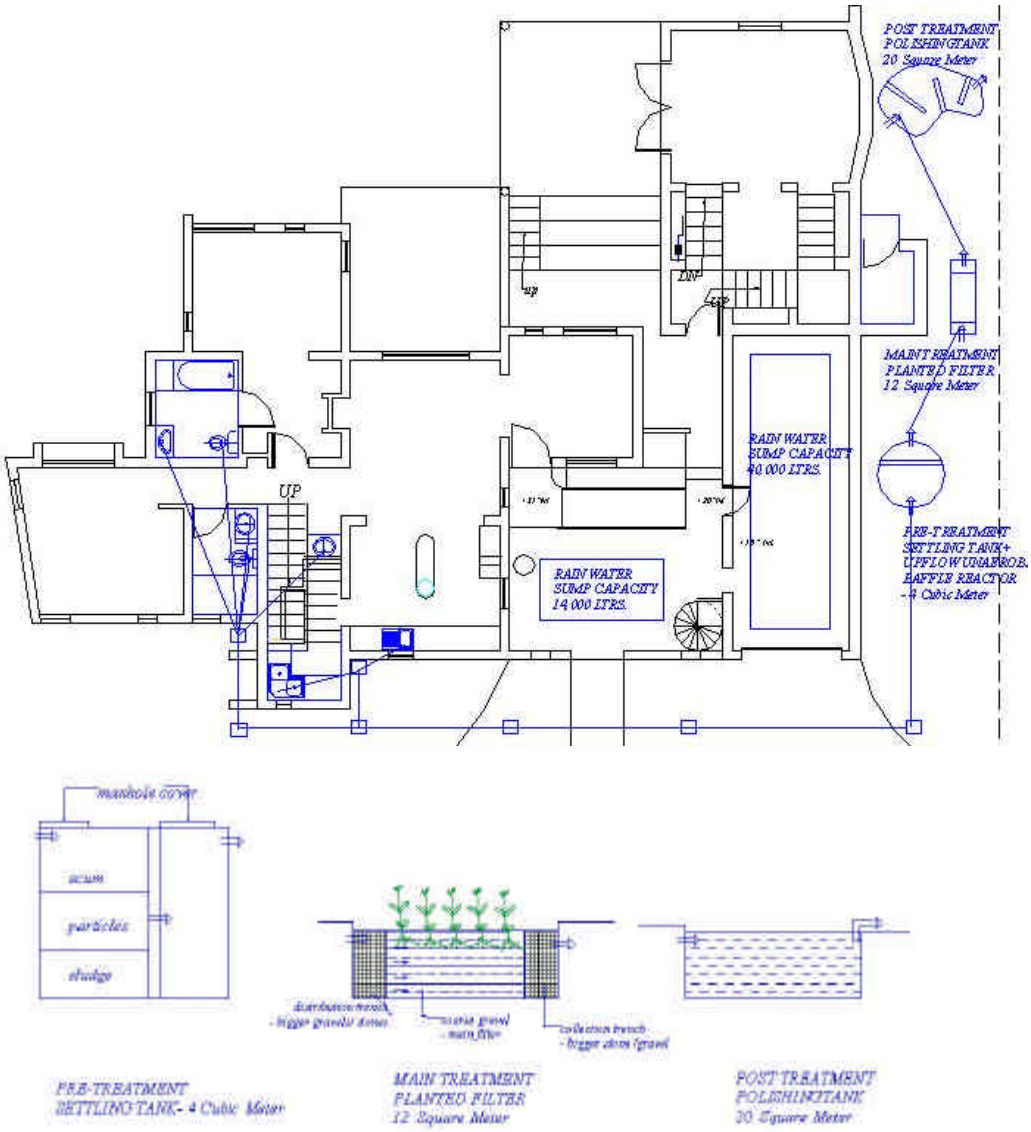

Figure 1: EcoSan using planted filter, house at Vidyaranyapura, Bangalore, India

Results

The colony has been able to cater to the water demand of an expanding suburb for the last 18 years. Though water supply to houses is limited to about 1 hour every alternate day it is possible to supply an average of 100 litres per person per day. Families store the water in underground sump tanks and in overhead water tanks for use during the time of non-supply.

All the sewage generated from the houses is treated though only to primary levels. With 100% primary treatment followed by a constructed wetland the colonies level of sewage management is far superior to that of the city. The cost of supply of water to every household is about Rs 5 a kilolitre again cheaper than the city's cost of water, which is about Rs 15 a kilolitre. Water tariffs are set in an annual general body meeting of the society on a year-to-year basis and based on actual costs incurred in the management and distribution of water and treatment of sewage. This is a more democratic and decentralised process. The integration of rainwater, surface

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water bodies, ground water and sewage treatment has resulted in the surface water bodies - the' tanks'- being preserved and used also as recreation places and for ecological biodiversity. These water bodies are unlikely to be filled up with debris and converted into other land-use because they represent a water lifeline to the colony.

Individual houses are now harvesting rainwater from terraces to augment their water supply. With an annual average rainfall of 920 mm it is possible to harvest nearly 82800 litres per year from a 100 square metre roof. A 100 square metre roof is typical for the colony. Harvested rainwater is enough for a family of 4 for 207 days of its water requirement given an average year of rain. Storage of the harvested rainwater is also easily possible since a sump tank in each house is the norm rather than the exception and a 6000 litre sump tank is the average size for new houses.

Greywater reuse is also being practised in some houses with clothes wash water being used for flushing toilets. Water efficient flushes are being used extensively.

Urine segregation and composting dry toilets are being introduced in 2 houses to explore the feasibility and to introduce the concept to the neighbourhood.

Conclusion

Integration of rainwater, surface water bodies, ground water and sewage treatment is critical to establishing sustainability of water demand of cities. Given the principles of 'subsidiarity' – meeting requirements and addressing issues at the smallest possible scale- each house can harvest rainwater, recycle greywater and nutrients, reduce demand through water efficient devices and possibly take care of its sewage. Closing the loop at the household level and at the neighbourhood level is possible and is a viable cheaper alternative to city level management of water. If sewage treatment is managed at residential colony levels, since the sewage is free from industrial pollutants it is relatively easy to treat. Treated sewage can also be used to be stored in lakes and make possible that water is available in the lakes throughout the year. Perennial lakes prevent encroachment into the water spread by houses. This decentralised method is also likely to provide the cheapest water for a neighbourhood and be the most cost effective in ecological management of water and reducing the ecological water footprint of cities.

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