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Design of highly efficient Source Control Sanitation and practical Experiences

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Abstract

One person produces about 500 litres of urine and 50 litres of faeces per year (=blackwater). Today, the same person, having access to tap water, produces in a range of 20.000 to over 100.000 litres of wastewater (=greywater if not mixed with blackwater). Black- and greywater have very different characteristics. If the blackwater would be collected separately with low dilution it can be converted to safe natural fertiliser, replacing synthetic products and preventing spreadout of pathogens and water pollution, too. If toilet waste is mixed with a lot of water, the large volume turns to a potentially dangerous flow of waste that has to be treated at high costs. At the same time this mixing makes simple treatment and higher quality reuse impossible because of faecal contamination and excess of nutrients. The reason for this inappropriate handling of important resources is the long lasting lack of technical developement of flushing toilets. Flushing faeces to surface waters helped spreading diseases and devastating epidemics in 19th century europe (Evans, 1987) and in more and more developing countries around the world in the last decades. According to WHO around 4 million people die from polluted water every year.

Separation of different qualities and their respective appropriate treatment for reuse is common in industrial wastewater management. This type of source control thinking is fundamental for new concepts. Due to the very different characteristics of blackwater (from the toilets) and greywater (household wastewater without blackwater) new sanitation concepts will produce fertiliser from blackwater and give a good opportunity for reuse of treated greywater. Blackwater has a composition where most of the organic matter and particulate nutrients are in the solids (brownwater). In contrast, the yellow water (urine) contains nearly all of the valuable soluble nutrients as N, P, K and others.

New promising sanitation systems are built in several countries as pilot projects. A pilot project for a vacuum-biogas system for 350 inhabitants is built in Lübeck, Germany. This semicantral system is capable to realise resources and energy recovery in more densely populated areas of house-blocks of up to 5.000 people. Larger populations could be served by additional systems because of limitations in the length of the vacuum pipes.

Another advantageous sanitation system for smaller villages and single houses is based on urine-sorting flush toilets (no-mix-toilets). Yellow water is collected with low or better without dilution and can be used directly on brown land - the nutrient composition suits many types of soil. Brownwater is converted to small volume by a two-chamber composting tank with a filtration system, where each chamber is used for a year and left without further charge the other year. The compost can be used for improvement of long term soil fertility. A pilot project is operating in the rural water-mill museum 'Lambertsmühle' in Germany.

Desiccation on-site toilets with two solar heated chambers can be excellent solutions for countries with warm climate under different social and geografical conditions. Furthermore implications of

regional planning and conversion of existing systems have to be considered for further dissemination of new sanitation concepts.

1. Welcome to the Future - Zero Emissions in Municipal Wastewater Management

If natural processes would generate unusable waste there would probably be no higher life possible any more. We can contribute to the emerging change from the current technology with excessive waste generation to the future no-waste technology. Renewable resources are renewed by the sun and provided by fertile soil and the surface waters (besides direct energy use). Ecological wastewater management will play a key role in the quest for an efficient use and reuse of water, long-term soil fertility and protection of the natural wa-ters. ’Zero Emissions’ technology aims at 100% reuse of all material, this concept has been developed at the UN-University in Tokyo, Japan for industrial production (Pauli, 2000). The same principles can be applied to municipal wastewater management, ending the concept of ’Wastewater’. Sanitation systems can be de-signed for high efficiency, old and new technology can be applied in source control systems. We can consider sanitation as a production unit that can provide high quality reuse water, safe fertil-isers and soil improving material (including processed biowaste where appropriate). We may name this ’ Resources Management’ because there will be no wastewater any more. Today such approaches exist and can be applied. We are in a phase of fast development and there are many pilot systems planned, built and operated. They can well be more economic than end-of-the-pipe systems, too. Welcome to the future!

2. What is wrong with conventional Sanitation?

The traditional sanitation concept is "end-of-the-pipe"-technology. Acute problems (not the long-term-ones) are solved instead of avoiding them from the beginning with appropriate systems. This situation has become the standard approach in industrial wastewater treatment and resulted in technologies of source control with appropriate reuse technology. In the field of municipal waste-water treatment the discussion about this has just started (Henze, 1997). The first installations of the water and nutrient wasting WC and sewerage systems were criticised by many people, but alternative systems had not been reliable enough at that time (Lange, Otterpohl, 1997; Harremoës, 1997). Easy availability of water for a formerly small population in humid countries, mining of fossil nutrients and cheap energy stopped the development of systems with source control.

Sanitation concepts should take responsibility for the future of nature as well as human beings into con-sideration. There is no reason to wait for public or political pressure, because the public relies largely on the experts. Basic facts for sustainable systems are obvious, nevertheless pilot-projects for new approaches are necessary. Serious planning might end the common practice of the auto-matic installation of the water closet - sewerage - wastewater treatment plant (WC-S-WWTP) systems without any consideration of alternatives.

Agenda 21 of the United Nations includes no accounts of sustainable sanitation concepts (Agenda 21, 1992) although water and fertile land are core subjects for survival of future generations. Sanitation is not specified without consideration of the consequences of the implementation of the conventional system world-wide. Many experts of sanitation agree on the possibility of resulting disasters even in a short time-span in economically poorer countries.

An assessment of the amazing variety of technical options and their respective economic and social implications will be necessary in order to get to a further development of sanitation. A collection of some source control solutions was given by Henze et al. (1997) and Otterpohl et al. (1999).

Efficient sanitation concepts will mostly have to co-operate with agriculture in order to avoid emissions and allow for reuse of water and nutrients. Sustainable agriculture has to be water-friendly and improve or at least maintain soil quality. Industrial agriculture results often in degradation of fertile top-soils with alarming progress (Pimentel, 1997). Organic fertilisers produced by sanitation and waste management can help to care for maintaining and improving the fertile topsoil.

If faeces are mixed with the wastewater by the usage of conventional flush toilets this results in a high water demand, spread out of potentially dangerous pathogens and micropollutants (residues of pharmaceuticals) in a large volume of water but also a loss of an option for economic reuse of greywater and to produce fertiliser. The initially small amount of faeces could be hygienised easily and with cheap methods. For the strange mixture called municipal wastewater hygienisation is an expensive further treatment step.

Conventional sewerage systems have a couple of severe disadvantages although they are a very costly part of the infrastructure (if rehabilitation is done). Combined systems emit raw wastewater into receiving waters with the overflows, storage tanks are very expensive if the number of overflows shall be low. Separate systems are often not better or even worse because of the large number of wrong connections. Sewerage systems usually drain large amounts of water from the region, even in industrialised countries the drainage often amounts to the same volume as the total amount of wastewater. This water dilutes the wastewater and the resulting lower concentrations in the effluent of a treatment plant looks like low emissions, although loads may be high. In many cases sewerage systems are exfiltrating raw wastewater into the ground with a potential for pollution.

Discussion on hormones, their mimics and emission of medical residues by the users includ-ing hormones from widely used contraceptives are showing another weakness of sanitation systems. These substances reach receiving waters easily especially because of their polarity (easity soluble) in combination with often very low degradation rates in conventional treatment plants. Another potentially very im-portant issue is the possibility of the transmission of resistances against antibiotics through their uncontrolled release to the environment. (Daughton and Ternes, 1999) Biological reactors are an excellent environment for exchanges of resistances while very few plants hold back all bacteria.

3. Regional Planning in Wastewater management

Regional planning has an important effect on the economics of the wastewater system. Costs for the sewerage system are on average 70% of the total of sewerage plus treatment plant costs in more densely populated rural and periurban areas in Germany. This figure can well be exceeded a lot if circumstances are less favorable. Since some years decentral on-site treatment is accepted as a long term solution in many countries. However, legal requirements are very low compared to those for larger WWTPs. It can easily be calculated that on-site plants can contribute far over their population proportion in loads. On the other hand it would be relatively simple to implement new on-site sanitation systems with full reuse of nutrients.

Proper decisions on where to connect houses to a sewerage system and where to build on-site facilities or small decentral plants are important. Good regional planning can avoid the deadlock of specifically very expensive sewer-age systems that use all the money that could serve the environment in highly efficient decentral treatment and collection systems. There are cost calculation procedures that include long-term development in the balance of operation- and investment costs and products (reuse water, fertil-iser, soil improver). The price of secondary products can be very relevant in economically weak and water scarce countries where water and industrial fertilisers are not subsidised. Source control sanitation can exceed the performance of the most advanced large end-of-the-pipe plant many fold at often much lower costs.

Drawbacks for decentral plants with proper technology are lack of maintenance. Legal conditions of responsibility and check up periods are essential, however this should be organised in a cost efficient way. Design of decentral systems could be in a way that collection of fertiliser and maintenance could be combined with periods of 6 or 12 month. Local farmers may be appropriate partners.

4. Basic considerations for the Design of Source Control Sanitation and proper Management of Water

Design of source control sanitation aims for a high hygienic standard and full reuse of re-sources. This is exactly what can be reached by clever source control. However, design has to be checked to the ability of achieving these goals. It is almost sure that strange concepts will come up from those who do not understand the simple basic principle: "No waste, full reuse". Naturally socio-economic conditions have to be taken very seriously. The background of the new systems has to be explained to the users. The fundamental step is the identification of the very different characteristics of the main components of household wastewater that are presented in Table 1. There is a certain variation as conditions are different, Table 1 gives a typical range of values.

Table 1: Characteristics of the main components of household wastewater

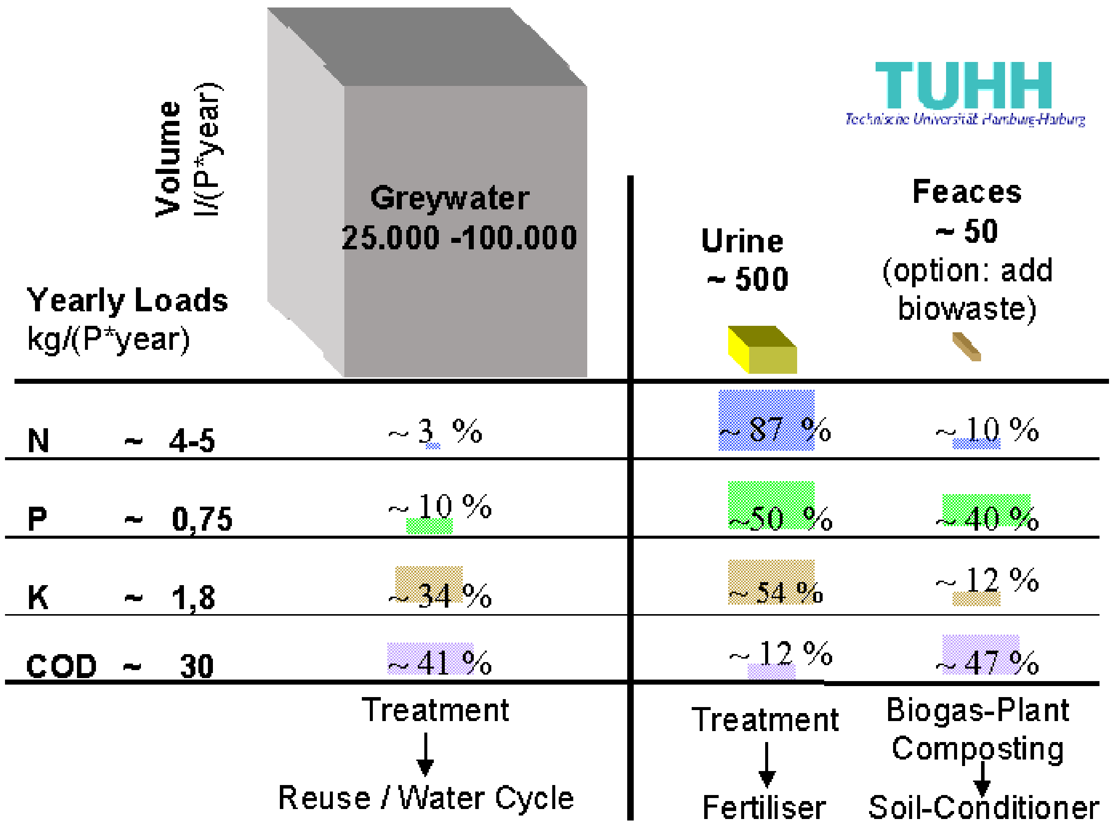

Table 1 suggests the following conclusions:

- Most of the soluble nutrients are found in urine. If urine is separated and converted to agricultural usage, the biggest step towards nutrient reuse and highly efficient water protection will be taken.
- The hygienic danger of wastewater comes almost exclusively from faecal matter. Separation and low or no dilution opens the way to excellent hygienisation with the end product 'organic soil improver'.
- Wastewater that is not mixed with human 'waste' (faeces and urine) is a great resource for high quality reuse of water. Bio-sandfilters and membrane technology open cost efficient ways of production of secondary water - on-site, local or regional scale can be appropriate.
- Source control should include evaluating products that end up in the water. High quality reuse will be far easier when household chemicals are not only degradable (original substance disappears, even if metabolites do not degrade) but can be mineralised with the available technol-ogy. Pipes for drinking water should not emit pollutants (e.g. copper or zink)
- Rainwater runoff is one of the reasons for building sewerage systems. If decentralised systems are built rainwater runoff has to be taken care of. Economic reasons will often prohibit to construct sewers for rainwater if decentral sanitation systems are to be installed. Local infiltration or trenches to surface waters for relatively unpolluted rainwater is often feasible and can be combined with usage, too. Prevention of pollution includes avoiding copper or zink gutters and rainwater pipes that can cause heavy metal pollution.

At the Global Water Forum in The Hague, 2000 there were big disputes about water scarcity. One nearly unheard voice from CSE (Centre for Science and Environment, Delhi, India) presented a different opinion: "There is no water scarcity, only mismanagement". They have strong evi-dence from incredible success of decentralised rainwater harvesting on local scale. In times of dev-astating draughts in Gujarat in 1999 there where many villages that had enough water. These vil-lages had introduced many fold measures to direct rainwater to the aquifers with small check-dams, directing rainwater runoff to the wells and filling cisterns (Manish Tiwari, 2000). We can add that the introduction of conventional sanitation can well be mismanagement, except where reuse of the mixed wastewater in a combination of irrigation and fertilisation can be done around the year. Source control sanitation and greywater reuse can probably bring the demand of new water (e.g. from the cistern) down to low figures as to 10% of what is considered efficient today.

5. Development Line 1: NoMix-toilets and Gravity flow

This concept is suitable for single houses and rural settlements based on no-mix toilets (often called separating toilets, more correctly sorting toilets). System 1 aim is to provide a low-cost and low maintenance system with a potential of full resources recovery. The system collects the yellow-water (urine) over a separate pipe in a storage tank until it is used for agricultural purposes. The storage period should be at least half a year, since this is an appropriate time for collection and part of the eventual medical residues can be destroyed during this time period. These substances are always of concern, but fast emissions to surface waters where drinking water is produced in many cases may be the worse of two bad options. Production of pharmaceutical products does increasingly consider the fate of residues after use.

The brownwater (faeces) is flushed with an appropriate amount of water (e.g. 4 or 6 litres) and is either collected separately or together with greywater and discharged into one chamber of a two chamber composting tank (with filter-floor or filter bag) (see Figure 1) where the solids are pre-composted. After a one-year collecting, de-watering and composting period, the flow is directed to the second chamber while the first one is not fed for one year. This allows further de-watering and composting and makes removal from the tank safer.

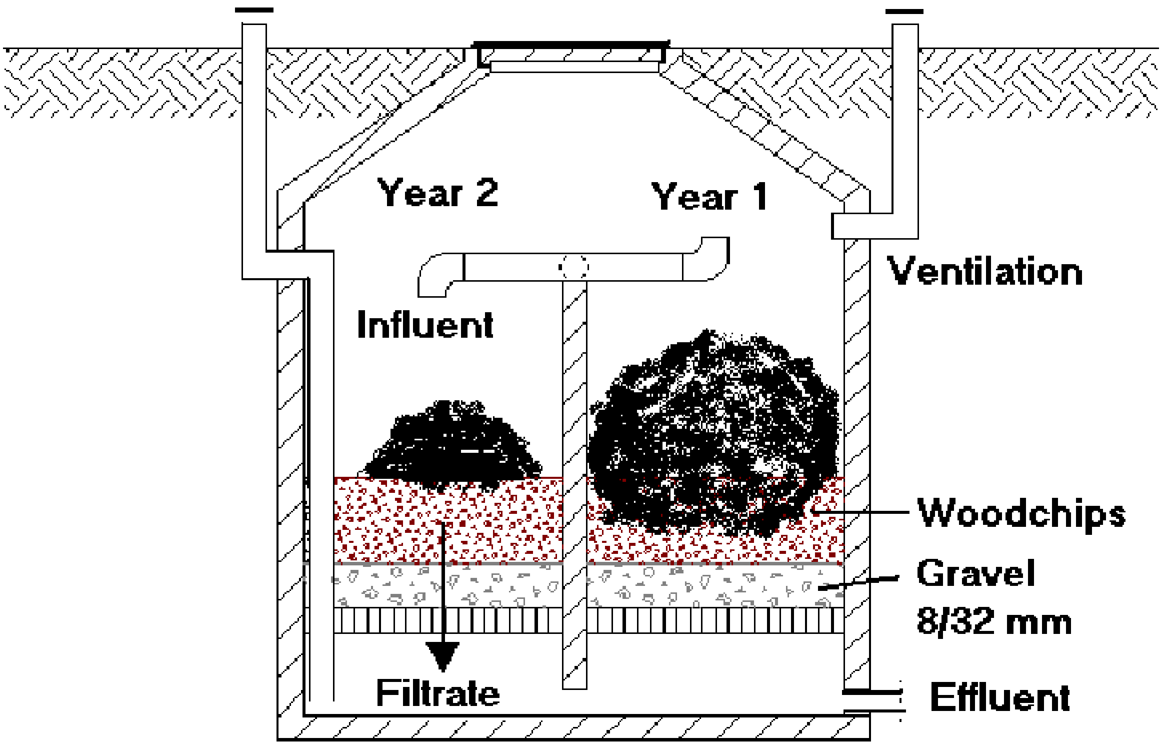

Figure 1: Two chamber composting tank

The products are removed from the composting tank and either used as soil improver in brown land or brought to further full composting - they could be mixed with kitchen- and gardening waste to decompose completely and allow further hygienisation e.g. by composting. The ripe compost is used for soil conditioning and is able to keep or improve soil fertility. The filtrate from the composting tank will be low in nutrients due to the previous separation of urine - the dissolved nutrients are mainly found in urine. Therefore, the filtrate can be treated together with the greywater (except if high quality reuse is planned).

The greywater is pre-treated either in the composting tank with the brownwater (avoiding 3rd pipe inside and from the house to the tank) or treated completely separate for quality reuse. The next step of efficient treatment can either be a bio-sandfilter (constructed wetland with a vertical intermittent flow) or in a combined activated sludge reactor with micro- or nano-filtration. These two technologies form an efficient barrier against pathogens and can achieve high quality effluents with little mainte-nance. The purified water is discharged to a local receiving water, infiltrated into the ground or col-lected for reuse. The constructed wetland requires very little energy but requires some space of about 1 to 2 m² per inhabitant. The different elements of the concept are shown in figure 2.

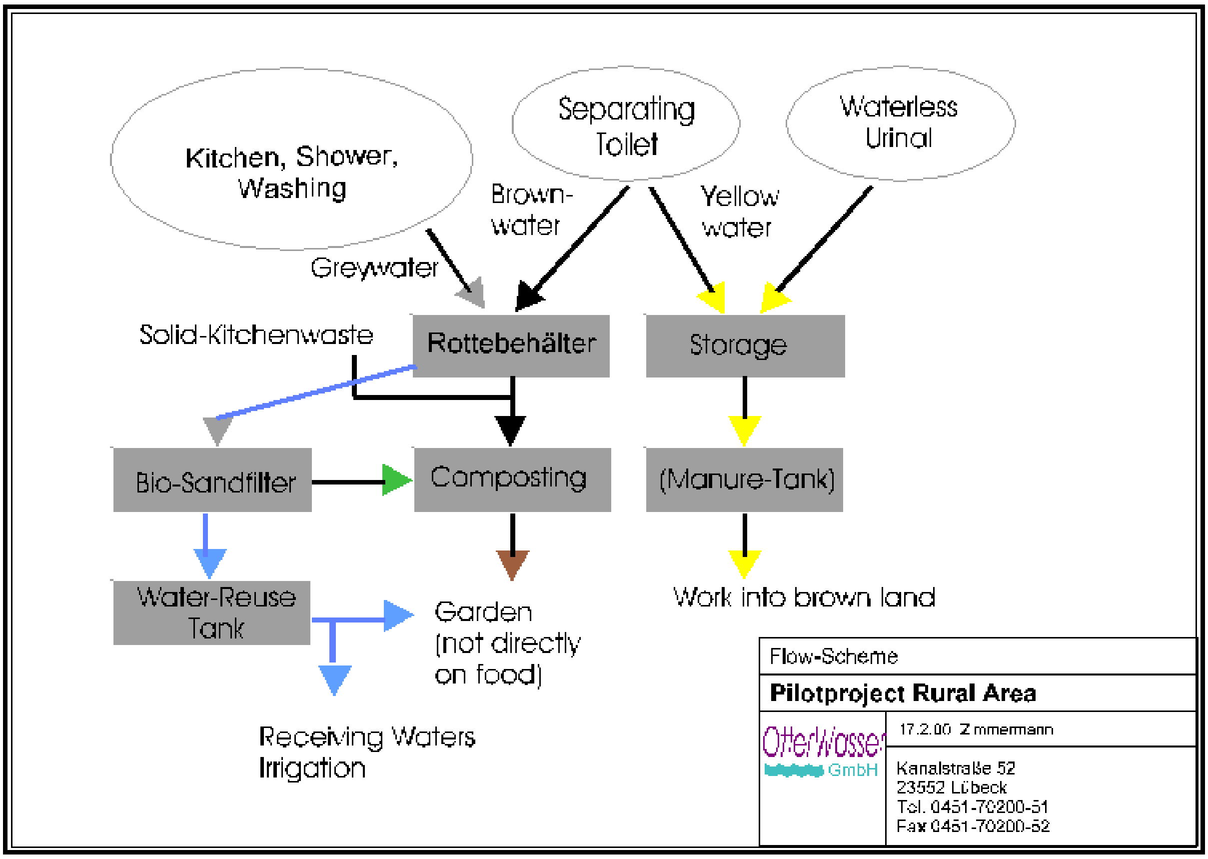

Figure 2: Elements of a rural source control sanitation system with a composting chamber (=Rottebehälter)

The design parameters for the elements of the components of this system can be derived from advanced decentral technology with consideration of changes in loads. Greywater alone will typically have around half the COD load at 2/3rd of the flow. Filtrate from composting chambers will probably not have a big influence except for potential additional pathogens loads. Collection and storage of urine can be designed straight forward, urine contributes a maximum of 1,5 litres per person and day. Waterless collection will be the goal though it is not fully developed jet. Flush water must be a small flow, otherwise storage, transport and usage are getting difficult. Waterless collection seems to avoid problems of scaling (solids growth on pipe surface), too. The calcium from water can add to formation of minerals. Storage tanks must be resistant against chemi-cals, pipes and tank must be very watertight - small but steady infiltration rates can result in high dilution and more frequent transport requirements. Further experience can be drawn from the pilot projects that are realised now.

The concept presented here, depending on the boundary conditions, can also be build differently. Especially interesting is to include the concepts into regional planning. With the instrument of least-cost-planning a very cost-effective solution for a whole area may be found as well as a gradual introduction. In any case, the understanding of background and motivation must be well explained so that inhabitants are motivated to co-operate.

Practical experiences with urine sorting toilets exist mainly in Sweden with more than 3000 installations. It has been clearly demonstrated that this technology is feasible. Drawbacks are observed from too small diameters of urine pipes that clog from scaling. The step to waterless collection has not been done yet in Sweden. A German company is working on a well designed toilet with waterless urine collection. But even with waterless separating toilets one major prob-lem is left. Men are often reluctant to sit down for urinating, despite the unavoidable spreading of urine in the bathroom. This would cause a loss of urine to the brownwater. Younger people seem to accept sitting more easily and understanding the strong effect on the personal local water protection could help adapting. The luxury solution is the private urinal, that should be a well developed waterless model. The business of waterless urinals had severe problems with the wrong type of cleaning chemicals and faults in construction. New models are available in ceramic material, combination with hydrophobic nano-coating is technically feasible and will come soon, hopefully. This type of surface will also be a big progress for sorting toilets. Another problem with sorting toilets is the disposal of paper that is used after urinating by most women and some men. There could be a paper bin for this paper, otherwise it can be disposed into the faecal bowl. If not flushed there would not be additional water consumption. New ideas for this problem would be helpful.

A lot of composting chambers are in successful operation mainly in Austria and Germany. Constructed wetlands with vertical percolation and step feed are becoming the standard solution with space requirements of less than 3 m²/PE. These can be smaller for greywater. Small activated sludge plants with membranes as phase separation are becoming increasingly popular and would reach even better performance with greywater.

The Technical University Hamburg (TUHH) and Otterwasser GmbH, Lübeck have developed the system described above for Wupperverband, Wuppertal for the on-site treatment on a historic water mill near Burscheid (area of Cologne). The system is currently (May 2000) under construction by the Lambertsmühle e.V. (private initiative for the restoration of the water mill). This mill is becoming a museum on the pathway from grain to bread. In the first meeting the idea was to add with some distance the explanation of the pathway ’from bread to grain’.

6. Development Line 2: Vacuum-Toilets and Vacuum Transport to a Biogas Plant

An integrated sanitation concept with vacuum toilets, vacuum sewers and a biogas plant for blackwater is implemented for the new settlement ‘Flintenbreite’ within the city of Lübeck (Baltic Sea, Germany, NN 2000). The area with a total of 3.5 ha is not connected to the central sewerage system. The settlement will finally be inhabited by about 350 inhabitants and is meant as a pilot project to demonstrate the concept in practice. However, all components of the project are in use in different fields of application since many years and therefore well developed. Vacuum toilets are used in ships, airoplanes and trains. There are already some implementations in flat buildings for saving water. Conventional vacuum sewerage systems serve hundreds of com-munities. Anaerobic treatment is in use in agriculture, in industrial wastewater treatment, biowaste treatment, on many farms and for faeces in ten-thousands of applications in South East Asia and elsewhere. The system that is built in Lübeck consists mainly of the following components (Fig. 3):

- vacuum closets (VC) with collection and anaerobic treatment with co-treatment of organic household waste in a semi-centralized biogas-plants, recycling of digested anaerobic sludge to agriculture with further storage for growth periods. Use of biogas in a heat and power generator (heat for houses and digestor plus electricity) in addition to natural gas.

- decentralised treatment of grey wastewater in vertical constructed wetlands with interval feeding (very energy efficient)
- rainwater retention and infiltration in a swale system

The heat for the settlement is produced by a combined heat and power generating engine which is switched to use biogas when the storage is filled. Heat is also used to heat the biogas plant. In addition there is a passive solar system to support heating of the houses and an active solar system for warm water production. Figure 3 is not meant for showing all the details but shall give an idea of the concept with collection and treatment of faeces.

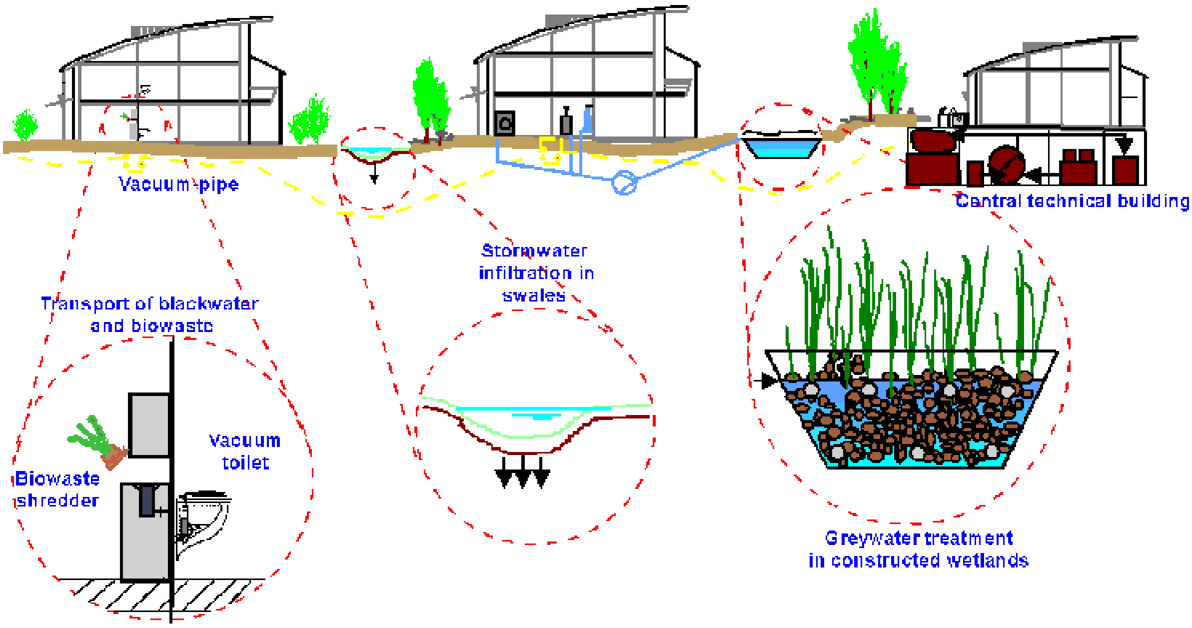

Figure 3: Vacuum - biogas system, greywater bio-filter and rainwater infiltration

At the digestor a vacuum pumping station will be installed. The pumps have an extra unit for the case of failure. Pressure in the system is 0,5 bar operating both the vacuum toilets and the vacuum pipes. Pipes are dimensioned 50 mm to allow good transport by the air. They have to lie deep enough to be protected against freezing and must be installed with an up- and down-gradient around 20 cm every 15 meters to create plugs of the transported matter. Noise is a concern with vacuum toilets but mod-ern units are not louder than flushing toilets and give only a short noise. However, people have to get used to it.

Faeces mixed with the shredded biowaste (only blackwater for mixing) are hygienised by heating the feed to 55°C for 10 hours. The energy is further used by the digestor that is operated mesophilic at around 37°C with a capacity of 50 m^3. Another concern is the amount of sulphur in the biogas. This can be minimised by controlled input of oxygen into the digestor or into the gas flow. The biogas plant is meant to be a production unit for liquid fertiliser as well. It is important to consider pathways of pollutants from the beginning. One important source for heavy metals are copper or zinc-plated pipes for drinking water. These materials will be avoided and polyethylene pipes will be used. The sludge will not be de-watered for having a good composition of the fertiliser and for not having to treat the sludge-water. The relatively small amount of water added to the blackwater keeps the volumes small enough for transportation. There will be a 2 weeks storage tank for the collection of the digestor effluent. Biogas will be stored in the same tank within a balloon that gives more flexibility in operation. The fertiliser will be pumped off by a truck and transported to a farm that has a seasonal storage tank for 8 month. These tanks are often available anyway or can be built with little investment. Figure 4 shows the technical building where the vacuum-pumping station, digestor, heat- and power generator and other devices are installed, besides this there is a convention room, an office and 4 flats.

Figure 4: Community building of settlement 'Flintenbreite' for 350 people containing vacuum pumping station, biogas plant and combined heat and power generation, detail: vacuum toilet flushing with around 1 litre of water.

Decentralised treatment of grey wastewater should be done by biofilm processes. Appropriate technologies would be membrane-bio-reactors or constructed wetlands. These systems form both a barrier against eventual pathogens. Water can be reused in watering the gardens or with infiltration to the rainwater system. Greywater is relatively easy to treat because it has low contents of nutrients. Several projects on technical scale have demonstrated the feasibility and good to excellent performance of decentralised greywater treatment (NN 1999). These plants allow reuse of the water in toilet flushing, what is not economically feasible in the Lübeck project because of the low wa-ter consumption of the vacuum toilets. For Flintenbreite vertically fed constructed wetlands with sizes of 2 m^2 per inhabitant are constructed (could be smaller, too). These are relatively cheap in construction and especially in operation. There is a primary clarifier as a grit chamber, for solids and for grease control. First measurements in the effluent have shown very low nitrogen concen-trations of 0.3 for ammonia- and 0.4 for nitrate-N.

The infrastructure for Flintenbreite including the integrated sanitation concept is pre-financed by a bank and operated by the private company infranova GmbH, where participating companies, planners and the house- and flat-owners are financially integrated and will have the right to vote on decisions. Parts of the investments are covered by a connection fee, just like in the traditional systems. Money saved by not having to construct a flushing sewerage system, by smaller freshwater consumption and by co-ordinated construction of all pipes and lines (vacuum sewers, local heat and power distribution, water supply, communication-lines) are essential for the economical feasibility of this concept. The fees for wastewater and biowaste charged cover operation, interest rates on additional investment and rehabilitation of the system. A part of the operation costs has to be paid for a part-time operator: this also offers local employment. The company cares for operation of the whole technical structures including heat and power generation and distribution, active solar systems and an advanced communication system that is available for the inhabitants.

The material and energy intensity of the structure has been studied by the MIPS-method in comparison to a traditional system at the Wuppertal Institute in Germany (Reckerzügl and Bringezu, 1998). Mate-rial and energy intensity is less than half for the decentralised system as for a conventional central system serving a medium densely populated area (see Table 2). For the central system most of the material intensity results from the construction of the sewerage system. The predicted effluent values are based on averages of measurements of greywater. Effluent qualities are presented in comparison to average values of a modern treatment plant with an advanced nutrient removal and good performance.

Table 2 indicates some major advantages for the new system which justify further research. The cumulated savings of emissions to the seas and of energy- and material usage for an average lifetime of 70 years for 350 persons would be: about 250.000 m^3 of freshwater, 70.000 kg of COD, 1500 kg of P, 13.000 kg N, 30.000 kg of K, 5.250.000 KWh of energy and about 56.000 tons of material usage. The saved emissions can replace fertiliser production from fossil resources and synthesis of nitrogen, too. This can be calculated as another 2.450.000 KWh of energy saved (Boisen, 1996). These numbers are important with respect to a large world population and decreasing fossil resources.

The interest in the integrated concept described above has dramatically increased since the first publication (Otterpohl and Naumann, 1993) and the construction of the project in Lübeck. There are other projects where this type of concept shall be built. The system in general can well be cheaper all in all than the traditional system. This depends on the possibility to infiltrate rainwater locally what is just becoming the standard approach. It also depends on the size of the area that is served and on the number of inhabitants. An optimum size may be an urban area with around 500 to 2000 inhabitants. Smaller units are feasible if the blackwater and biowaste mixture is only collected and transported to a larger biogas plant that would preferably be situated on a farm. The treatment of greywater can be done in an existing wastewater treatment plant if the sewerage system is nearby. In some cases this is the most economical way. Nutrient removal can be improved if a certain percentage of the population is served by a separate blackwater treatment. At a certain proportion nitrification would be obsolete.

Table 2: Estimated Emissions, energy consumption and material intensity of the proposed system compared to a traditional system

Advanced traditional sanitation (WC-S-WWTP) concept			New sanitation system		
Emissions			**Emissions*)**		
COD	3,6	kg/(P*a)	COD	0,8	kg/(P*a)
BOD_5	0,4	kg/(P*a)	BOD_5	0,1	kg/(P*a)
Total N	0,73	kg/(P*a)	Total N	0,2	kg/(P*a)
Total P	0,07	kg/(P*a)	Total P	0,01	kg/(P*a)
Total K**)	(>1,7	kg/(P*a))	Total K**)	(< 0,6	kg/(P*a))
Energy			**Energy**		
water supply (wide variation)	-25	kWh/(P*a)	water supply (20 % water savings)	-20	kWh(P*a)
Wastewater treatment (typical demand)	-85	kWh/(P*a)	Vacuum system	-25	kWh/(P*a)
Consumption			Greywater treatment	- 2	kWh/(P*a)
			Transport of sludge (2/month, 50 return)	-20	kWh/(P*a)
Consumption	*-110*	*kWh/P*a)*	*Consumption*	*-67*	*kWh/(P*a)*
			Biogas	110	kWh/(P*a)
			Substition of fertilizer	60	kWh/(P*a)
			Win	*170*	*kWh/(P*a)*
Total	**-110**	**kWh/(P*a)**	**Total**	**103**	**kWh/(P*a)**
Material intensity***)	3,6	t/(P*a)	Material intensity***)	1,3	t/(P*a)

*) measurements of greywater, NN 1999
**) assumption, no data
***) MIPS-Study (Reckerzügl and Bringezu, 1998)

Source control systems can be considered high efficiency technology. Research on pilot projects will bring far more development and show new ways for all the different social and geografical situations of our crowded planet.

7. Development Line 3: Low Cost Low Maintainance On-Site Systems

There are many ideas and traditional technologies for sustainable sanitation with real source control of human waste (Winblad 1998, Otterpohl et al. 1999). Some are more for rural areas, but there are options for downtown metropolis as well. The basic techniques of low-tech collec-tion and treatment (with or without kitchen waste) are:

- desiccation (with solar heating, double vault systems), difficult for areas with wet anal cleaning (instead of paper), good with urine collection and reuse
- composting (often difficult to operate)
- low-diluting toilets with biogas systems

- urine collection combined with biogas systems for faeces

The main problem is a toilet system that is comfortable, low-diluting and capable to do the transportation job. A promising technique is the NoMix-toilet, that was developed in Sweden. As most visits of the toilet are for urinating, these systems collect urine with very little water. This allows for simple urine collection (stabilise with vinegar-concentrate) or treatment (e.g. drying over a loam wall in hot climates, solar systems to be developed). Urine can be used as a fertiliser directly on brown land or after dilution with 5 to 10 parts of water on plants, not directly on vegetables. Before more research is done urine should be stored around half a year. The faeces from the No-Mix-toilet can be put to biogas plants together with kitchen waste. A source control sanitation system can lead to proper reuse of fertiliser. At the same time purified greywater will be able to substitute freshwater in case of water scarcity. This way systems can be very economic. The sys-tem shown above under 5.) could be used in the upper level of low-tech systems in many coun-tries and replace the disadvantageous spread-out of septic tanks with conventional flush toilets.

8. Development Line 4: Upgrade existing wastewater infrastructure

Urine collection can convert a conventional sewerage system to one with a very high rate of nutrient reuse and very low nutrient emissions. When most of the urine is kept out of the wastewater treatment plant, nutrient removal becomes obsolete (Larsen and Udert, 1999). There are two basic approaches: Central or decentral (semi-central) collection. The central approach would be to store urine in small tanks and to open them at late night times when the sewerage system is nearly empty. A remote control system would empty the tanks at the respective correct time to create a concentrated flow that can be caught at the influent of the treatment plant (Larsen and Gujer, 1996). This method is limited to sewerage systems with a good gradient and appropriate retention times, however it could be applied to branches of the sewerage system, too. Decentral storage and collection is the other possibility.

If all the blackwater is collected and treated separately, a conventional sewage system can become a greywater recycling plant and produce secondary water. Conversion could be done over dec-ades if necessary. Economics have to be considered well, because except in very densely popu-lated areas rehabilitaton of sewerage systems requires high specific investment.

9. Risks, Obstacles and Restrictions

The first objective for sanitation must be minimising hygienic risks. New systems should be better than the conventional sanitation systems, that have a good hygienic standard for inside the houses but in most cases not for the receiving waters.

Sanitation is a very sensitive matter with respect to the strong wish for clean bathrooms and to the taboos around the issue. Failure can be the consequence (and has been in many cases) if this is not considered and included in project development. The issues around new sanitation systems is somehow complex, but they cover an area of basic needs of humans. Not mixing of food and water cycles, returning matter from the land to the land and zero emissions to the waters can be explained to prospective users of new sanitation systems.

Wastewater infrastructure is usually built to be extreamly long lasting. This restriction of change seems so overpowering for many people that they can not even imagine different solutions for the future. We have to consider the lifetime of existing house installations, sewerage systems and treatment facilities in order to avoid financial problems. Change is easier for newly constructed settlements or rehabilitation of complete houses. The lifetime of house installation is far shorter than that of sewerage systems. Components of source control sanitation could be installed in each renovated flat and be connected to the conventional systems first. This can be economic with the water saving from the beginning, later after conversion of a group of houses separate treatment can be implemented.

10. Welcome the Future!

It is quite a challenge to participate in the development of emerging new technology. Professional skills and open-minded search for solutions are needed to find better ways for future sanitation. Open dialogue and exchange of experiences are essential in order to bring the matter forward. There are so many possibilities, that all social and economic conditions can be met. Creativity is needed to find the appropriate technology and the best way of implementing, operating and financing it. There is an extreamly strong need for new solutions whether media, politicians and the public notice or ignore it. Even though many industrialised countries will need decades for conversion due to the long lasting existing infrastructure, these countries are the ones with good resources for research and pilot installations.

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