

# Session G

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*Christine Werner* (GTZ, Germany)

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*Shinji Miura, Masaya Kobayashi, Katsuyoshi Ishizaki* (Nagasaki University, Japan), *Naoko Nakagawa, Zhen Liu*

\*This paper has been peer reviewed by the symposium scientific committee



## Sanitation concepts for separate treatment of urine, faeces and greywater

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### Keywords

Decentralised wastewater systems, faeces, greywater, separation toilet, urine, vacuum separation toilet.

### Abstract

In order to define the experiments for testing new, sustainable sanitation concepts a pre-study has been done. This study includes a cost comparison between two new sanitation concepts with gravity and vacuum separation toilets and the conventional system. It could be demonstrated that the new sanitation concepts may have cost advantages depending on the situation. This was a further motivation starting a pilot project in Berlin/Brandenburg testing the above mentioned toilet systems under realistic conditions. The operation of the gravity separation toilets concept will start in the summer 2003.

### Introduction

World-wide serious problems with water in relation to quantity and quality are recognized as a challenge for the next decades. These problems can not only be solved by maintaining the existing drinking and wastewater techniques and concepts which are in use in industrialised countries.

Thus new techniques and concepts for drinking water preparation and supply and wastewater discharge and treatment should be additionally developed. This more sustainable approach should consider the reuse of treated water as well as the recycling of the nutrients if possible. Furthermore the energy consumption for wastewater discharge and treatment should be minimised. Such techniques and concepts are already available and in use, but further developments and validations are still necessary.

These are the reasons why Berliner Wasserbetriebe (BWB) and Vivendi Water (VW) launched this research-project in the framework of the Kompetenzzentrum Wasser Berlin (KWB).

The main goal of this project is the development of new sustainable sanitation concepts which have significant advantages according to ecological as well as to economical aspects compared

to the conventional systems (end-of-pipe-system), which are mainly used in industrialised countries.

The new sanitation concepts should represent a relevant solution for:

- remote areas, where the connection to a central system (e.g. big pipe networks) wouldn't be technically or economically feasible,
- rapidly growing suburbs in developing countries,
- countries with scarce water resources and
- it should be a contribution to the sustainable development with the recycling of nutrients and water.

## Methods

The project is divided into two phases (**Phase I**, pre-study and **Phase II**, pilot project). **Phase I**, a theoretical approach, has been finished at the end of 2001.

- **A literature based project review**, patent reviews and a collection of informations about the various projects were made. Furthermore existing projects with separate treatment in Germany, Denmark and Sweden have been visited. These informations and detailed economic investigations have been the prerequisite for continuing the project.
- **Cost comparisons between a conventional and two new sanitation concepts** for an intended new housing estate in the federal state Brandenburg near Berlin have been made. The housing estate should be realised stepwise from 672 up to 5,000 inhabitants within the next 10 years. For the economic calculation three different sanitation concepts have been compared for different cost levels:
  - **Conventional sanitation concept:** Conventional flush-water toilets with stop bottom, one sewer system, normal gravity sewer system for the area, pumping station with transport sewer to the existing sewer network, system operated by the public supplier.
  - **Separation sanitation concept (gravity, composting of faeces):** Gravity separation toilets, collection and storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a gravity sewer system, aerobic treatment in a compost separator, utilisation of the compost in the horticulture on the area, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.
  - **Separation sanitation concept (vacuum, digestion of faeces):** Vacuum separation toilets, gravity urine transport, storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a vacuum sewer system, common treatment with bio waste in a biogas plant, biogas utilisation by the equipment of the energy concept, transport of the digested sludge to the farmer nearby and utilisation in the agriculture, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.

The comparison of these three sanitation concepts has been considered for four scenarios which are shown in table 1.

	Inhabitants	Water Operator *
Scenario 1	672	Local company
Scenario 2	5,000	Local company
Scenario 3	672	Berliner Wasserbetriebe
Scenario 4	5,000	Berliner Wasserbetriebe

\* This determines the costs of the "conventional" system and the costs for drinking water in all scenarios

**Table 1:** Scenarios for the cost comparison of the three different sanitation concepts

A decision based on an economic point of view should consider three aspects:

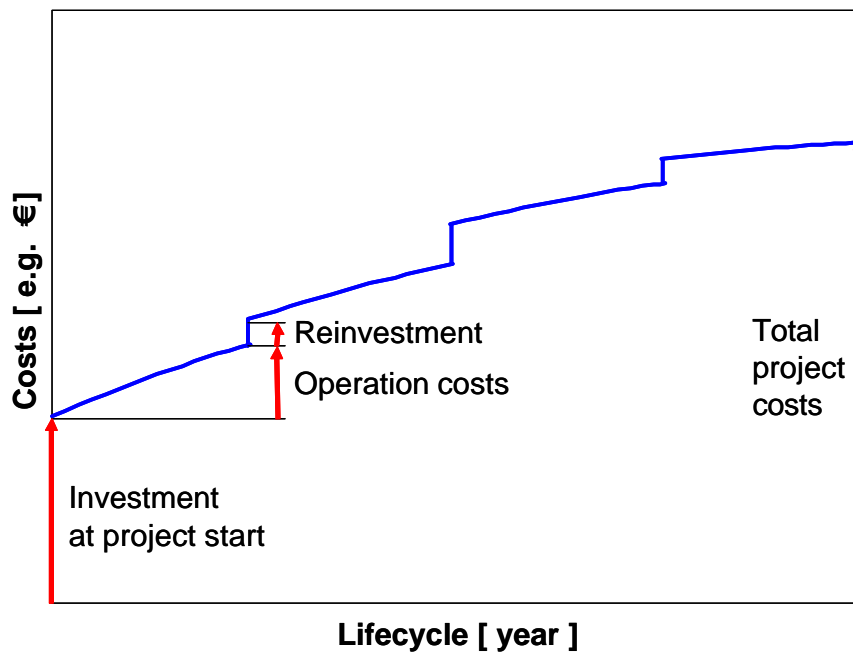
- Costs of the investment
- Costs of the reinvestment
- Operation costs

The cost calculations are made under the following assumptions:

- Lifetime of the project: 50 years
- Duration of the components depending on their lifetime. Reinvestment after the end of the lifetime.
- Real interest rate: 3.5% per year
- Maintenance costs are calculated as a percentage rate of investment. Personal costs are taken in consideration separately.
- Operation costs divided into costs for
  - personal equipment
  - maintenance
  - water and wastewater
  - electricity
  - others equipment

The specific costs for water, wastewater, connection fees, energy and other costs are based on the informations of the local company or of the Berliner Wasserbetriebe. With these assumptions and informations the costs for the whole project period are calculated as total project costs. The total project costs (Projektkostenbarwert) are the sum of money which is necessary for financing the whole project (investment, operation, reinvestment; see figure 1) for the assumed lifetime based on today's cost level.

The calculations have been realised with the German guideline "Dynamische Kostenvergleichsrechnung" (dynamic cost comparison calculation) published by the "Länderarbeitskreis Wasser LAWA", a working group of all federal countries in Germany concerning water management) (LAWA, 1998). This method can also named as a lifecycle analysis.



**Figure 1:** Demonstration of the total project costs (Projektkostenbarwert)

## Results

### a) Literature survey and visits

The main results from the pre-study are:

- 17 new sanitation projects already exist in Western Europe (Table 2).
- The activities in relation to new sanitation concepts are increasing all over the world.
- The separation of urine, faeces and greywater based on the use of new toilet bowls, has proven to be feasible and accepted by the users (Johansson, 2001; Hellström and Thurdin, 1998; Swedenviro, 2001).
- Once urine is separated from the faeces, several configurations exist, differing between them by the collection and transport system chosen and the treatment of the three effluents (faeces, urine, greywater) (Otterpohl *et al.*, 1999).

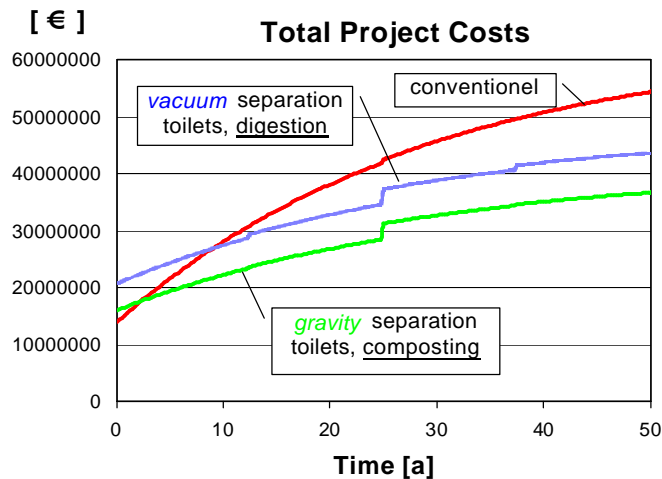
No.	Project Name	Country	City	Project Start (year)	Toilet Installation	URL Project	Responsible Organisation
1	Hamburg-Allermöhe	Germany	Hamburg	1990	Composting toilet		
2	Hamburg-Braamwisch	Germany	Hamburg	1992	Composting toilet	<a href="http://www.oekologische-siedlung-braamwisch.de">www.oekologische-siedlung-braamwisch.de</a>	Ökologische Siedlung Braamwisch e.V.
3	Kiel-Hassee	Germany	Kiel	1992	Composting toilet		Ökologische Siedlung Hassee
4	Öko-Technik-Park Högewiesen	Germany	Hannover	1992	Solitar vacuum toilet	<a href="http://www.oeko-technik-park.de">www.oeko-technik-park.de</a>	BauBeCon AG mit Stadtwerke Hannover AG
5	As	Norway	As	1992	Drying toilet		
6	Ecological Village Björnsbyn	Sweden	Björnsby near Lulea	1994	Separation toilet		NLH (Norrbottnens Läns Hushållningssällskap - the Agricultural Society of Norrbotten County)
7	Bielefeld Waldquelle	Germany	Bielefeld	1995	Composting toilet		
8	Palsternackan	Sweden	Stockholm	1995	Separation toilet		
9	Understenshöjden	Sweden	Stockholm	1995	Separation toilet		
10	Freiburg Vauban	Germany	Freiburg	1998	Vacuum toilet	<a href="http://www.vauban.de">www.vauban.de</a>	
11	Gebers	Sweden	Skarpnäck	1998	Separation toilet (Drying toilet)	<a href="http://www.iees.ch/cs/cs_4.html">www.iees.ch/cs/cs_4.html</a>	Fastighetsägare, BRF Konditor, Gebersvägen 24, 128 65 Sköndal
12	Kiel-Vieburg	Germany	Kiel	1998	Composting toilet		
13	Hyldepäldet	Denmark	Kopenhagen	1999	Separation toilet		
14	Mön Museum	Denmark	Mön	1999	Separation toilet		
15	Wohnsiedlung Flintenbreite	Germany	Lübeck	1999	Vacuum toilet	<a href="http://www.flintenbreite.de">www.flintenbreite.de</a>	infranova GmbH & Co. KG, Flintenbreite 4, 23554 Lübeck
16	Lambertsmühle	Germany	Burscheid	2000	Separation toilet		Wupperverband
17	SolarCity Linz-Pichling	Austria	Linz	2001	Separation toilet		SBL Stadtbetriebe Linz

**Table 2:** Existing new sanitation projects in Western Europe

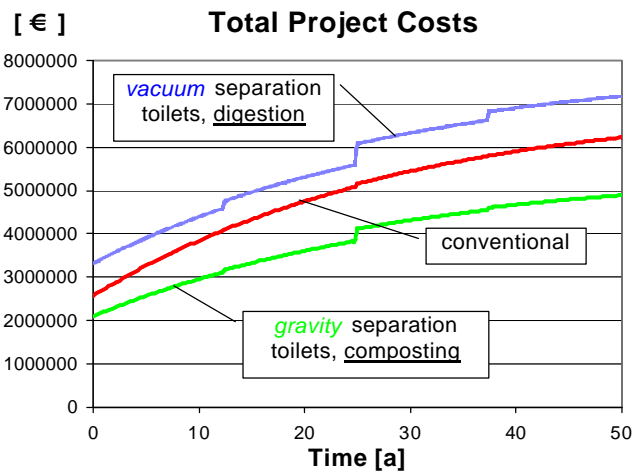
#### b) Cost comparison

The cost comparison between the conventional and new sanitation concepts shows that the new sanitation concepts have not only ecological advantages but can also have economical advantages (see below). The cost advantage is very depending on the specific conditions of the housing-estate. For the chosen example (see methods) cost advantages occur in the most cases of the new sanitation concepts. For the demonstration, the results only from the best and the worst scenario (*Scenario 2* and *Scenario 3*) are shown in figure 2 and figure 3, respectively.

*Scenario 2* (figure 2) shows, that both new sanitation concepts are cheaper compared to the conventional system after 3 and 9 years, respectively. The results from *Scenario 3* (figure 3) demonstrate only the benefit of the new sanitation concept with gravity separation toilets compared to the conventional system right from the project start.



**Figure 2:** Total project costs for the conventional and the new sanitation concepts (5,000 inhabitants); cost basis: *local company*



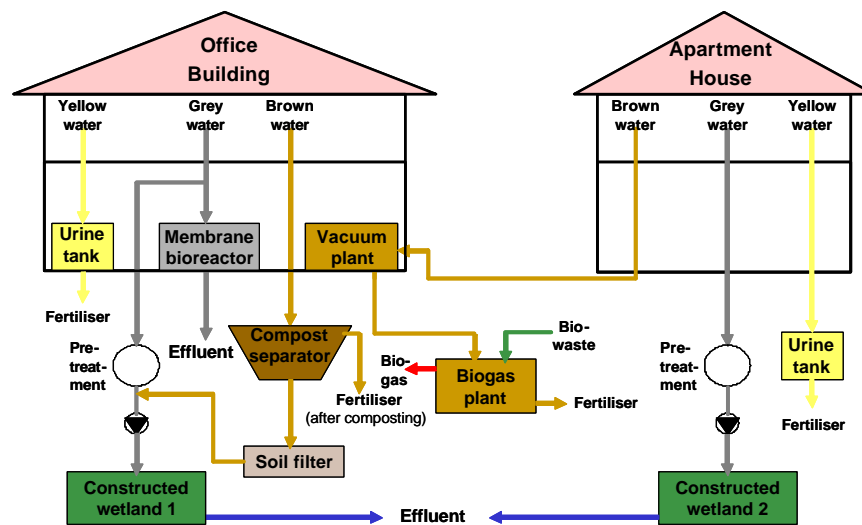
**Figure 3:** Total project costs for the conventional and the new sanitation concepts (672 inhabitants); cost basis: *Berliner Wasserbetriebe*

The results from this cost comparison were an additional motivation for the start of a pilot project testing

- gravity separation toilets and
- vacuum separation toilets

in conjunction with different treatment configurations. The pilot project started in the year 2002 (**Phase II**). The new sanitation concepts will be tested in existing buildings (office building and apartment house) of the Stahnsdorf WWTP owned and operated by the Berliner Wasserbetriebe. The realisation of the new sanitation concept in the office building takes place in the frame of a general restoration of this building. For the apartment house a stepwise realisation of a new sanitation concept is intended.

The general process scheme for the new sanitation concepts in the office building and in the apartment house can be seen in Figure 4.



**Figure 4:** New sanitation concepts with *gravity* separation toilets in the office building and with *vacuum* separation toilets in the apartment house of the WWTP Stahnsdorf

In the new sanitation concept for the office building gravity separation toilets (10 toilets) will be used. Five waterless urinals are additionally provided in the men toilets. The faeces will be drained and composted. The filtrate from the compost separator will be treated with a soil filter before mixing it with greywater. The greywater passes a septic tank before the treatment in a constructed wetland. In parallel to the constructed wetland a membrane bioreactor will also be tested for the greywater treatment. The urine will be stored in tanks. Different methods will be tested for the handling and treatment of the urine before using it as fertiliser. The methods will be adjusting different pH-values during the storage of the urine, extraction of the nutrients etc.

For the new sanitation concept for the apartment house (15 flats) vacuum separation toilets are taken into consideration. This type of toilet is under development. In this concept the urine and the greywater are discharged transported by gravity and the faeces by a vacuum system. Each flow is also treated separately. The urine will be treated as mentioned above. The faeces will be digested together with ground bio waste. The digested sludge is also a fertiliser, e.g. for farmlands. The biogas can be used either in gas cookers or in a combined heat and power unit (CHPU). This topic will not be tested in this project. The greywater passes like in one case of the office building a septic tank before the treatment in a constructed wetland.

Since the dish washing powders has a high content of phosphate (often more than 30 %) and dishwashing machines are more and more common, for both concepts, a phosphate precipitation could also be necessary for the greywater treatment.

The treated greywater can be used e.g. for irrigation in general. In this project the effluent of the membrane bioreactor will be investigated for the different options of utilization as water on a lower quality level than drinking water.

These two sanitation concepts are technical options belonging to the new approach, others are possible, e.g. composting of the faeces together with bio waste in cases if production of biogas is not wished.

The kind of greywater treatment for both new sanitation concepts will differ depending from the special situation. For large settlements an activated sludge tank etc. could be a more appropriate solution than a constructed wetland. But the size of an activated sludge tank for

greywater treatment can be much smaller as for municipal wastewater treatment due to the far lower load of COD, Nitrogen etc. (Otterpohl, 2001).

## Conclusion

The results from the pre-study of this project enhanced the motivation for realising a pilot project testing gravity and vacuum separation toilets.

Although the cost comparison showed higher costs for the new vacuum sanitation concept compared to the gravity sanitation concept and although the operation is likely to be less simple, it may be an appropriate solution especially in cases with water shortages. The flush water consumption will be about 6 l/(p•d) compared to about 15 l/(p•d) for the gravity separation toilet or about 25 – 40 l/(p•d) for the conventional toilet with stop bottom.

Important objects of this pilot project (**Phase II**) are:

- Increasing of the knowledge of design and installation of new sanitation techniques based on separation technologies
- Experience of the operation of new sanitation concepts by investigation of the various modules of the separation concept in different conditions

In accordance to the schedule of this pilot project the start of the operation of the gravity concept in the office building is planned for summer this year (2003).

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## Ecosan modules - adapted solutions for a medium sized city in Mali<sup>1</sup>

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### Keywords

Desiccation of faeces, urine separation, composting with urine, "grey water gardens", agricultural use of human excreta

### Abstract

Based on the specific situation in Koulikoro, Mali, a sanitation system was developed that did not require inhabitants to make essential changes in their customs. It has the following components:

- Separate collection of faeces
- Separate collection of urine
- Separate grey water treatment
- Agricultural field trials

The investment costs for the proposed alternative decentralised waste water disposal system are estimated to about € 1.8 million for the city of Koulikoro. Operating costs can be disregarded since the decentralised sanitation facilities could be maintained by the inhabitants themselves.

The construction of a centralised underground sewage network with waste treatment ponds would add up to € 32 million because of the difficulty presented by regional rock layers. Annual operating costs would amount to about € 140,000. Koulikoro's annual communal budget is only € 200,000 and the average monthly income of a family is €100.

The practical experiences made in Mali with different ecosan modules show clearly that practical solutions are available and that the economic advantages of the ecosan concept are obvious. Next to ecological, agricultural and hygienic advantages, the substantially reduced need for capital investment plays an important role.

### Introduction - specific conditions in Koulikoro, Mali

Koulikoro, the capital of the second region of Mali, was equipped with a central water supply system in the 1970s which was then extended about 20 years later, with financing by the German financial aid agency (KfW). Providing assistance to drinking water supply projects was and still is one of the priorities of international development assistance. In order to achieve sustainability the water tariff system should be able to meet costs. But in reality most central water supply systems in developing countries are not able to cover even operation and maintenance costs. This burdens already weak public budgets. Consequently the question of

<sup>1</sup> Initiated and technically / financially supported by the GTZ ecosan project, Eschborn

waste water treatment, which should be an integral part of any water supply system is not even considered. Central water supply systems result in increased water consumption and consequently in increased waste water as well. The overall aim of drinking water supply projects is to reduce water borne diseases; However, the opposite occurs because the increased waste water is not treated. This subverts the intention to satisfy the basic needs of the population by even increasing the risk to water borne diseases.

As in many places, this happened also in Koulikoro, leading to open waste water flows / run outs throughout the city, exposing everyone to potential diseases and especially children. The Koulikoro municipality cannot afford to construct and maintain a central waste water collection and treatment system. A low cost approach to waste water treatment is seen as the only possibility for improving the current situation. To resolve this problem the approach ecosan was seen as the most appropriate solution by GTZ (German Agency for Technical Cooperation).

As a first step, the initial situation in Koulikoro was researched, and revealed the following: non existence of a central collection / treatment system for waste water; only about 3% of the households have water flush toilets and septic tanks which means that the reminder have traditional latrines; about 25% of the households are equipped with functioning soak pits or so called "puisards" (collection and infiltration pits for waste water).

Most (67%) of the 26.000 inhabitants live in spacious (300 to 400m<sup>2</sup>) compounds. The average household size is 10 persons, who are normally sharing one sanitation facility - used as shower and latrine.

Most of the inhabitants of Koulikoro are Moslems, which means that anal cleaning is done with water. In the case of traditional latrines this water is drained into the pit together with the faeces and urine. The water from showering and urinating drains into soak pits outside the shower area or drainage pipes that lead into the rain water canals. A study has shown that most of the soak pits in Koulikoro are poorly designed and managed as they are simply open holes outside the compound.

Agriculture in and around Koulikoro is an important economic activity but is made difficult as the soil is sandy and poor in nutrients (typical Sahel condition).

### Methods and solutions to solve the existing problems

In order to identify the best solutions for the specific problems of Koulikoro, qualitative studies have been carried out and the results have been discussed with local decision makers, the local administration and the population. As a result the following technical solutions have been elaborated and carried out:

1. Separate collection of **faeces** through two-chamber desiccation latrines including an integrated drainage system for anal washing water => dried faeces are used as fertilizer and for soil improvement in agriculture
2. Separate collection of **urine** (in single households and central facilities):
  - as liquid fertilizer for food crops
  - as dried fertilizer
  - for "watering" of organic material (either from solid waste or agricultural residues ) in order to enrich the compost and to enhance the composting process
3. Separate **grey water** treatment for single or neighbouring households in order to:
  - use it for watering of plants and moisturizing of yards
  - directly irrigate household vegetable gardens within the compounds
4. **Agricultural field trials** for sorghum and cotton to study the fertilizing capacities of the different kinds of waste and waste water at the Polytechnic Institute for Economic Studies based at Katibougou, Koulikoro.

## 1. Desiccation latrines - practical experiences

In Mali, and therefore in Koulikoro, traditional sanitary installations consist of one outdoor fenced bathing and toilet area with a pit latrine underneath and a drainage system conducting grey water either into a soak pit, a rain water drainage canal or simply into the street. Urine is more often evacuated with grey water than with faeces due to urination in the shower area. Traditionally, latrines have one pit. When these pits are full, they are covered with soil. The family, then, constructs a new latrine on another site within the compound.

This strategy is no longer viable due to two reasons: Compounds are continually divided to accommodate expanding families and the municipality is providing smaller plots in the new development areas.

More and more families are obliged to empty their latrines instead of closing them and moving to a new site. To make the situation worse the municipality cannot provide appropriate treatment and the private sector is not equipped to do this type of work. In general latrines are emptied manually and the untreated contents left on the streets or behind the yard for days or even weeks. This potentially spreads pathogenic germs through direct contact or through vectors such as animals and insects.

Under the local climatic conditions (high average temperatures, long dry and short rainy seasons), the two-chamber desiccation latrine is the most simple and most appropriate solution. The two chambers are used on an annual rotational basis. However since the Moslem population uses water for anal cleaning, a considerable amount of water drains into the latrine chamber and prevents the proper desiccation of the faeces. This problem was solved by two measures:

- a) Introduction of a drainage system in the desiccation chambers. The bottom of the chambers is sloped and covered with a gravel layer. All liquids are drained directly into the bottom of a basin (which is filled with gravel and earth) located outside the chambers in order to avoid all direct contact with the contaminated water. In addition the basin is planted in order to facilitate evapo-transpiration of the liquid.
- b) Desiccation is further enhanced by use of aeration pipes and the use of black iron lids that increase the drying process and make it easy to empty the chamber.

Sanitation tests (on nematode eggs and coliformes) have shown, that the hygienisation of faeces through drying is satisfactory after six months. To avoid any risk the chamber size is designed to be used for one year. This guarantees that dried faeces can be handled safely and easily. In addition the one year treatment period conforms to the agricultural production cycle in Mali.



**Figure 1:** Model ecosan installation



**Figure 2:** Emptying of a ecosan latrine

## 2 a. Drying of urine - practical experiences

The separate collection of urine in single households and in public buildings has been tested and proven satisfactory. Under semi-urban conditions, not all households are engaged in agriculture and therefore don't see any need for urine as fertilizer. However, once enough households are equipped with urine separation latrines, the collection and use of urine on a large scale could become economically attractive for small private enterprises. With regard to public buildings the latrines of a catholic priest seminary were adjusted to collect large quantities of urine in one place. Drainage pipes were installed to divert urine from latrines pits into a barrel. This case of the catholic priest seminary was a real 'success story' (Christian culture – dry anal hygiene).

A problem in promoting urine for crop cultivation is that the use of any liquid as fertilizer is not known in Malian agriculture. To promote its use would require considerable awareness raising efforts and the acquisition of new equipment by farmers.

In order to simplify the handling, storage and application of urine as fertilizer, tests were carried out by sun-dried urine. Within two days each litre of liquid can be transformed into around 9 grams of powder. However this method must be improved upon in order to be economically viable.



**Figure 3:** Low-tech urine desiccation - tests



**Figure 4:** The product - fertilizing urine powder

## 2 b. Enriched composting with urine- practical experiences

The best way to use urine presently in Mali is for enrichment of compost of urban solid waste. Most household solid waste in Koulikoro is very poor in nutrients. What little organic material is in it is eaten by ruminants. Household waste mainly consists of sand and dust from sweeping.

The poor household waste can be transformed into valuable compost with the application of urine. The application of urine has three advantages: it saves water, it provides missing nutrients to compost and it enhances the composting process. Urine enriched compost proved to be a good fertilizer and soil conditions in agricultural tests carried out by the local university.



**Figure 5:** Urine collection in a public facility



**Figure 6:** Urine composting

### 3. 'Grey water gardens' - practical experiences

70% of Koulikoro households do not have appropriate facilities to treat and evacuate grey water, therefore, this issue was addressed by the implementation two different technical solutions: a gravel filter at the household level and a "grey water garden".

The treatment of the grey water / urine mix through gravel filters (gravel and sand are locally available) is functioning. Its efficiency depends on the filter size. However, the construction of a gravel filter is more expensive than the construction of a "grey water garden" and therefore it is only justified with a pronounced need for treated grey water for watering purposes at the household level.

The second solution which has been implemented, is the "grey water garden". Its immediate benefit to improve the nutritional situation of the household members was most appreciated by many families in Koulikoro. From an ecological point of view, the management of grey water should if possible take advantage of a planted aerobic system; this should preferably be a plant-based utilization system. The idea behind is: "grow it away, don't throw it away" (Del Porto). Therefore the grey water garden design should encourage high-rate aerobic processes and the reuse of the nutrients in grey water to feed the micro organisms living in the soil. During this process the nutrients are transformed in such a way that the plants can use them easily. As a result pollutants are transformed into plant nutrients.

Grey water from showers presents its challenges from the soap and fibre used for cleaning the body, because it causes very often problems with clogging. In addition the amount of sand and dust, which is transported through shoes and wind into the system has a heavy burden on the filters and the holes of the distribution pipes and the void spaces in filters and soil of the planted beds.

In order to introduce grey water into the irrigation system it is necessary to remove all particles in it that could clog the perforated pipes.

Therefore grey water is first decanted and filtered to reduce solids like fibre, sand and dust. After that the water is drained into the walled garden by subterranean perforated pipes. "Breezer" pipes are incorporated to create an aeration effect.

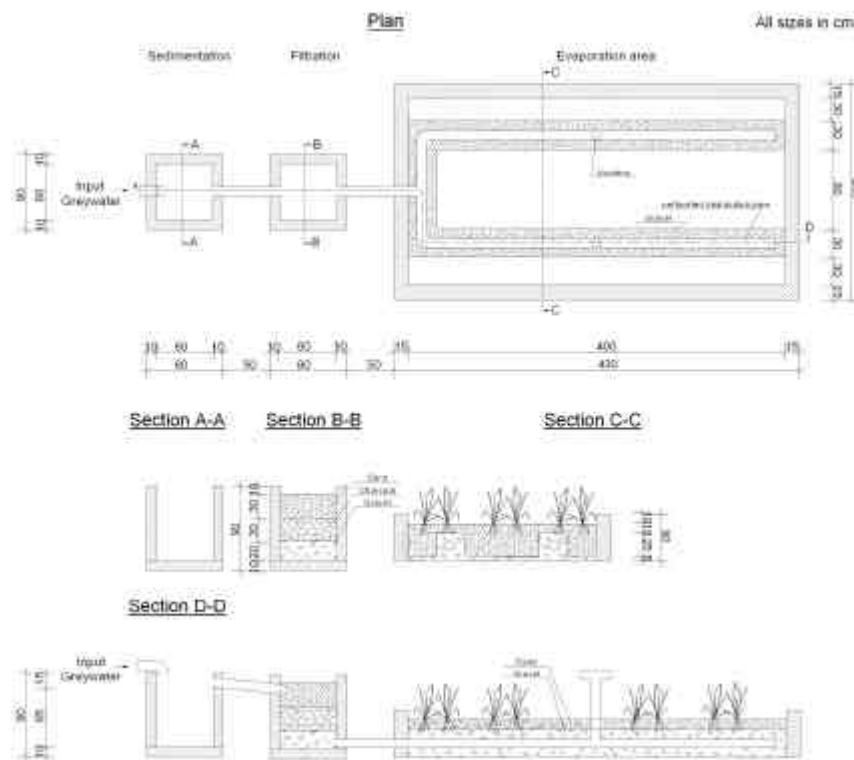
Very good experiences have been made with the cultivation of above ground plants such as okra, bananas, baobab, pepper and papayas. In particular the baobab leaves are rich on vitamin A and C and are very much appreciated by women.



Figure 7: Grey water garden before planting



Figure 8: Planted grey water garden



**Figure 9:** Construction principle of a 'grey water garden'

#### 4. Effects on agriculture - preliminary results

A serious problem in the Sahel region is the degradation of soil, even leading to desertification. The reduction of natural soil fertility has been primarily caused by agricultural overexploitation and the insufficient return of nutrients to the soil. Chemical fertilisers are too expensive for most farmers; in the medium-term, these fertilisers also contribute to even more deterioration of soil quality (acidification).

Existing estimates and calculations show that the treated excreta of one adult in Koulikoro could supply hygienically safe nutrients for about 400 to 500 square meters of arable land. The marketing of nutrients from faeces and urine must be controlled by regular analysis to check nutrient content and to monitor disease-causing agents such as worm eggs and bacteria.

In cooperation with the Institut Polytechnique Rurale, the local agricultural university, the project conducted a series of tests with different groups of nutrients (dried faeces, dried and liquid urine, compost watered with urine, traditional compost, inorganic fertilisers, and varying mixtures of these groups).

Preliminary results are very promising and indicate that the use of urine provides similar results in yield compared to the use of inorganic fertilisers, and that the use of dried faeces has a positive influence on plant growth and soil quality. Urine, as a nutrient-rich fertiliser, can replace inorganic fertilisers. However, introducing its use would need to take the cultural acceptance of human fertiliser into account. The field trials on sorghum and cotton have shown that the combined use of faeces and urine-enriched-compost can lead to an increase in production of more than 100 % not to count the long-term effects on soil improvement.

However, these results need yet to be confirmed through a longer field trial programme. Unfortunately projects are often designed in a way that these longer-term needs of agricultural

research cannot be easily accommodated.

### Conclusion - lessons learned

The lessons learned from these practical experiences can be summarized as follows:

- The use of dried faeces is applicable in Moslem countries. The problem of anal washing water can easily be solved through an appropriate construction, which incorporates a direct drainage system.
- The use of urine as a starter for composting (household waste or agricultural residues) is an ideal approach in countries with water shortage and a promising alternative to the direct use of liquid urine.
- Efficient methods for solar urine water desiccation have still to be developed, especially with regard to the "harvesting" of dried urine.
- The method "grey water garden" for the treatment and use of grey water is an appropriate solution for families with sufficient space in their compound.

The agricultural field trials have only been carried out for a period of two years. Since concluding results can only be drawn after a minimum of three years of testing only tendencies can be provided.

The combination of sanitation and reuse of human waste in agriculture / gardening is a promising approach for both agricultural development and sanitation.

The Malian experience of the ecosan approach has shown that it is vital to adapt the technical and organizational solutions to the particular agricultural / socio-cultural and economic environment. Some alternative solutions that can be combined in different ways (modular approach) have been tested as pilot projects. The implementation of full-scale ecosan solutions in at least parts of a semi-urban area is still far from being achieved.

A successful implementation of ecosan would need a steady and efficient external support (experienced man power and financial resources) on the spot at least for a certain initiative period of time. This is unfortunately not the case in Koulikoro, which has as consequence a steady deterioration of the first facilities build.

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## Planning of an alternative wastewater concept for two villages in North-Rhine-Westphalia (NRW), Germany\*

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### Keywords

Alternative drainage systems for rural areas, ecosan concepts, source separating systems

### Abstract

In recent years it has become obvious that - under the aspect of sustainability - the structures of our present drainage systems, which consist in the main of combined sewer systems, must be reconsidered - in spite of the undoubted efficiency of these in densely populated areas. Indeed several investigations have shown that - particularly for communities in rural areas - there are more sustainable systems for dealing with wastewater than the combined sewer system. However there is an absence of practical examples. Accordingly the Lippeverband resolved to go into the findings, which have been purely theoretical up to the present time, taking as a basis a concrete situation: For two villages in the rural district of Welver in North Rhine-Westphalia, Germany, a detailed planning - regarding storm- and wastewater separately - with different scenarios is implemented. For the wastewater treatment four scenarios are investigated. The first scenario contains a central, the second a semi-central and the third a decentralized solution. The last scenario will expectedly work with a partial stream separation. All scenarios are compared under economical and ecological aspects. The actually planned stormwater concept implements as one possibility a direct discharge of non polluted stormwater into tributaries. A decentralised storm water management in responsibility of the land- and house-proprietors is also possible. The result of the investigation is that there are indeed realizable alternatives to the systems currently used in villages and other residential areas.

### Introduction

Under the aspect of sustainability our present drainage systems - above all the combined sewer system - need to be reconsidered. The mixing and diluting of wastewaters leads to an immense cleaning effort and to watercourses being polluted to an unnecessary extent while at the same time valuable nutrients such as nitrogen and phosphorus are lost. Storm water, which is polluted to only a low extent, is collected and expensively cleaned, while the renewal of the groundwater is reduced through the storm water being led off in this way. Against this backcloth and within the framework of the AKWA 2100 research project (AKWA 2100 = Alternatives to the municipal water supply and sewage disposal system; Hiessl et al. 2003), the Emschergenossenschaft and the Lippeverband were investigating together with other institutions long-term scenarios for modifying the communal wastewater disposal system in such a way that the above-mentioned weak points of the present system are compensated for. It has been shown that there are indeed systems which are more sustainable than the present method of disposing of wastewater via combined systems. This passes in particular for communities in rural areas which have at their disposal adequately large areas for alternative communal water manage-

\*This paper has been peer reviewed by the symposium scientific committee

ment infrastructures and for which at the same time the wastewater would have to be transported over long distances to bring it to a central wastewater treatment plant. The viability of these theoretical results of the research project is currently being checked with the aid of a concrete plan taking as an example two villages of the community of Welver in Germany's North Rhine-Westphalia. For these two villages an alternative wastewater concept is being prepared. It is based on comparing a number of variants under economic and ecological aspects (see chapter 3). The objective is to obtain a wastewater disposal concept which is practical and acceptable for all involved parties and which satisfies the requirements of sustainable development.

### Catchment area and starting situation

The two villages of Stocklarn and Berwicke, which together form the subject of the investigation, have together 576 inhabitants. Thereof 279 live in Stocklarn and 297 in Berwicke. The catchment area of Berwicke is 12 hectares, that of Stocklarn 13. The levels of sealing are 63 % and 43 % respectively. There is regular agricultural traffic in both villages. The Soestbach, a moderately polluted stream which always carries water, flows through the village of Berwicke. The Dorfbach which can run nearly dry in dry periods flows through the village of Stocklarn. There is still no regulated system for disposing of wastewater in either village. At the present time the storm water is led via surfaces and ditches as well as sewers requiring remediation into the watercourses. The wastewater is cleaned with the aid of mechanical or, as the case may be, mechanical-biological domestic wastewater treatment plants. The effluents therefrom are also led via the sewers to the bodies of water. The present plan for a central sewer system for the two villages with a central wastewater treatment plant drafted in 1996 has been deferred in view of the actual activities of the Lippeverband. Regarding wastewater treatment 85 % (Berwicke) and 72 % (Stocklarn) of the domestic wastewater treatment plants are mechanical ones being in part already excessively old and needing to be remediated. On the other hand the newer biological systems are almost all in a good state. The following table gives an overview of the present state of the wastewater treatment plants in the two villages.

	Stocklarn	Berwicke
<u>Mechanical treatment:</u> multi-compartment tanks	38	50
<u>Biological treatment:</u>		
Technical systems with aeration of the wastewater	7	1
Near-to-nature systems (planted constructed wetland, infiltration)	8	8
Systems no longer capable of being remediated	45 %	42 %
Systems needing to be remediated	34 %	35 %
Systems in a satisfactory state	21 %	23 %
Total number of systems evaluated	53	59

**Table 1:** Evaluation of the state of the existing small wastewater treatment plants

It has to be established that the number of biological treatment systems is very small; moreover the majority of the systems for leading off and treating the wastewater are in a poor state means that at present the existing watercourses - and here in particular the Dorfbach in Stocklarn which is dry in the summer - are subjected to a high level of material pollution.

## Investigation of the possible variants

The separation of storm water and domestic sewage is strived for in all variants. Accordingly the storm water concept described in the following section passes for all the different sanitary sewage variants (see section 3.2).

### Storm water

At the present time the storm water in the villages of Stocklarn and Berwicke is led into the relevant watercourses regardless of the degree to which it is polluted. In order to improve the quality of the watercourses and to bring the elimination of storm water up to the present state of arts, different categories of pollution of the storm water are considered in the new storm water concept.

- Category I : Unpolluted storm water ? no treatment necessary
- Category II : Slightly polluted storm water ? treatment necessary in general, exceptions possible on a case-by-case basis
- Category III : Heavily polluted storm water ? treatment absolutely necessary

Since the soils permit only a low level of infiltration, the targeted infiltration of storm water into the ground via the organic soil zone in a deliberate manner is not possible. The storm water is led into the Soest- or Dorfbach. Therefore a treatment is necessary in the majority of cases for the runoffs from areas assigned to categories II and III before the storm water is led into the Soest- or Dorfbach. Table 2 provides an overview of the classification of the areas via which storm water runs off and which have an effect on the necessary/possible treatment measures for the storm water runoffs.

Category		Areas assigned to category	Treatment or discharge
I	Unpolluted	Roofs and yard areas of residential buildings	No treatment, direct discharge: <ul style="list-style-type: none"> <li>• direct discharge into gravel-filled trenches</li> <li>• discharge into ditches</li> <li>• discharge into pipes</li> </ul>
II	Slightly polluted	Roads with low levels of motorized traffic Farmyards, farm tracks and roads between communities	No treatment necessary  Treatment along the roads by infiltration in trough-type gravel-filled trenches (20 cm build-up of ground)
III	Heavily polluted	Farmyards where animals are kept and where liquid manure is handled Through roads with high levels of traffic	Treatment by infiltration through 20 cm A-horizon  Discharge through drainage system, in particular with chokes (gravel-filled trench bodies)

**Table 2:** Classification of the areas via which storm water runs off and which have an effect on the treatment measures

The storm water should be allowed to run off as natural as possible. For that the following elements are used in accordance with local customs: open ditches, trough-type gravel-filled trenches (with choke device) and pipes (where open ditches are not possible). Where a building has an undamaged system for leading off the storm water from the roof and yard areas this should be retained. This concept fulfils the requirements of the technical and legal sets of regulations applied in Germany for the treatment of storm water and the discharging of this into

watercourses (ATV-DVWK instruction sheet M 153, BWK instruction sheet M 3) (ATV-DVWK 2000, BWK 2001).

### Wastewater

For the preparation of the sanitary sewage concept, a variant with a source separating system (separation of urine) based on AKWA 2100 was investigated in addition to variants with central, decentral and semi-central solutions (see table 3). In all variants the diversion of storm water and the treatment of wastewater were considered separately.

Variant	Classification	Description
1	Central	Central collection and transporting of wastewater to one central wastewater treatment plant per village
2		Central collection and transporting of wastewater to one central wastewater treatment plant for the two villages
3	Decentral	One wastewater treatment plant for each property
4	Semi-central	Appropriate grouping together of properties and connection of these to a central wastewater treatment plant for each group
5	Source separating system	Separate capturing of urine and extensive treatment of the wastewater

**Table 3:** Overview of variants

#### Variant 1: Central variant with one wastewater treatment plant for each village

With variant 1, all the sanitary sewage from each of the two villages is led off and treated in the particular village's own separate wastewater treatment plant. The treatment objective is the targeted elimination of nutrients by nitrification and denitrification. For this purpose an SBR system (sequence batch reactor) constructed of prefabricated parts with chemical phosphate precipitation is provided. The storage and treatment of the sludge is carried out in a sludge draining bed. The systems are constructed in a modular manner to facilitate matching to any changes in loading states in the future.

The sanitary sewage is brought to the wastewater treatment plant via sewers. Since the existing sewers are in need of remediation and their course is unknown in part, the assumption is made that all sewers must be replaced. The sanitary sewage is conveyed in general in gravity lines. However not only in Berwicke but also in Stocklarn the wastewater that has been collected will have to be pumped via a pressure pipe to the respective wastewater treatment plant. The treated wastewater is discharged into the Soestbach in Berwicke and in Stocklarn into the Feldbach, a larger watercourse, into which also the Dorfbach flows. The wastewater treatment plants can be operated by the local authority or by a third party.

An advantage of this variant is the opportunity for central charging so that the principle of solidarity can be applied for the complete village. In addition it can be coped with variations in loadings while the cleaning output remains stable. However all existing small wastewater treatment plants must be given up. Accordingly high investment costs will be necessary for the owners of some of the larger properties for the diversion of the sanitary sewage from their properties. A "let the causer pay" system of distributing costs will hardly be possible. In addition ground would have to be purchased for the lines taken by the sewers.

#### Variant 2: Central variant with common wastewater treatment plant

In technical and organizational terms and also in terms of advantages and disadvantages, variant 2 is the same as variant 1. However with variant 2 the wastewater in Stocklarn is not pumped into the village's own wastewater treatment plant but via a pressure pipe to the

wastewater treatment plant in Berwicke treating the sanitary sewage from both village s. For that it is dimensioned appropriately greater.

#### Variant 3: Decentral wastewater disposal

Variant 3 provides the retention and technical enhancement of the present decentral wastewater treatment system (small wastewater treatment plants). With one exception the existing systems with biological stages are in a good state and can continue to be used. Existing systems will be evaluated and in part integrated into the concept. Where the systems are in a good state, the biological stage can be retrofitted in a cost-favourable manner. The minimum system size is laid down as 4 PEs (population equivalents) independently of the present number of inhabitants. The existing lines for the diversion of the treated wastewater will be in part retained; in part it will be diverted via the elements of the storm water system.

Systems for elimination of nutrients, e.g. SBR systems, fixed bed reactors with feeding back for denitrification or planted constructed wetlands with feeding back to the primary clarifier will be retrofitted. No process will be prescribed. Instead requirements will only be placed in terms of the cleaning performance. The treated wastewater will be discharged into the Soestbach respectively the Dorfbach. Whereas discharging into the Soestbach will be possible without any problem in Berwicke, it is probable that the requirements in respect of the quality of the water in the Dorfbach at Stocklarn could only be maintained when membranes are used to clean the wastewater. This would considerably increase the expense of this variant.

The wastewater treatment plants can be operated by the owners themselves. However this requires that each owner takes on a high degree of responsibility himself. Experience indicates that proper maintenance will only be carried out in practice when the owners are required to conclude a maintenance contract with a sewage disposal service provider. The faecal sludge is removed in accordance with requirements. This matter will also be laid down in a maintenance contract.

The advantages of this variant are that costs are distributed in accordance with the "let the causer pay"-principle and that the inhabitants make their own contribution. Nevertheless this can lead to high cost loadings in individual cases. However there is potential for costs to be saved where a number of properties are connected to one system. Moreover the systems can be matched optimally to the local situation and circumstances. But the maintenance of the systems and the removal of the faecal sludge mean that the running costs increase. In addition, the expenditure for operating the systems increases, e.g. the cleaning performance of small SBR-systems falls if the system is underutilized. Furthermore targeted P-elimination is not possible. However it has to be said that the elimination of nutrients achieved by the decentral systems will be adequate - depending on the receiving watercourse.

#### Variant 4: Semi-central disposal of wastewater

Variant 4 provides the semi-central diversion of the wastewater via new networks of sewers, that will have to be constructed, and a semi-central arrangement of small wastewater treatment plants. It is provided that 4 wastewater treatment plants should be constructed in each village, each with a capacity of between 22 and 143 PEs (population equivalents). The different plants being positioned in each village with the objective of keeping the line lengths low. Here too systems for eliminating nutrients, such as SBR systems, should be applied. The sludge must be stored temporarily, transported away and treated. Possibly each village should have its own sludge draining bed. The sewer network and the wastewater treatment plants should be operated by the local authority or a third party. In an analogous manner to variants 1 and 2, costs will be covered via a system of contributions and charges.

The construction of 4 semi-central plants for each village will reduce the variations in loading so that the plants will run in a more stable manner than decentral plants. In addition, there is potential for costs to be saved relative to variants 1 and 2 through the shorter line lengths.

Moreover further savings in costs are possible since the shorter lengths of the lines mean that they can be laid at lesser depths. Compared with the first two variants operating costs will be higher. Moreover the necessity of transporting away the faecal sludge increases running costs like in variant 3. Similarly targeted P-elimination is not possible.

#### Variant 5: Wastewater concept with further source separating system

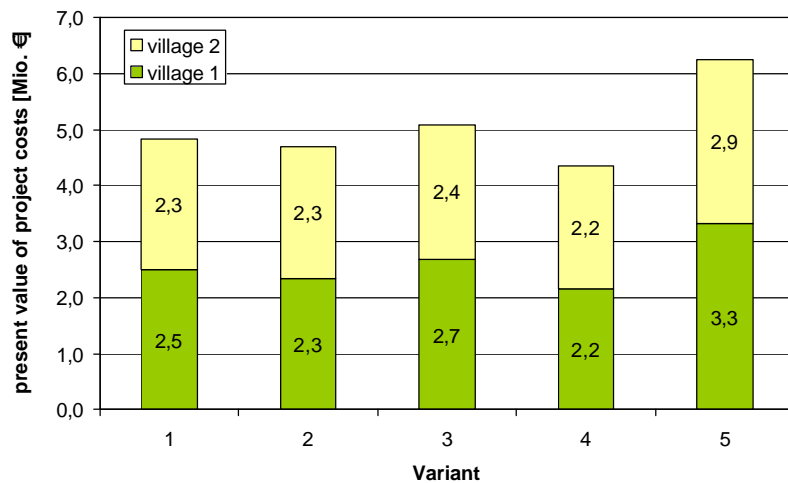
Variant 5 supplements Variant 4 about the consistent separation, collection and use of urine with its content of nutrients. The remaining wastewater, which then contains a low level of nutrients, is treated in biological membrane systems. The use of these membrane systems can only be considered at the present time in semi-central systems as a result of their capital costs. With this variant it is provided that the urine is collected and stored in decentral urine tanks and then utilized in agricultural operations. However the concept for emptying the urine tanks as well as for the further treatment of the urine is still open at the present time. The sludge arising will also be stored, transported away and treated. The semi-central sewer network and the membrane systems can be operated by the local authority or a third party. Refinancing is carried out by contributions and charges.

The obvious advantage of this variant is the reduction of the discharge of nutrients into the receiving waters. The separation of urine diminishes the emissions of nitrogen und phosphates into the streams. In addition the use of the membrane technology reduces the level of germs discharged into the watercourses. With a suitable concept, the nutrients separated off can be used in place of fertilizers. However the effects of endocrinally active substances have still not been adequately clarified. If a decision was made in favour of this variant, conversion of the existing systems could be carried out in stages. However converting of the sanitary systems and the construction of a second line system in the houses would be necessary. Accordingly realization of this variant would depend on its acceptance by the population and would take a relatively long period of time.

### **Comparison of the variants**

#### **Costs**

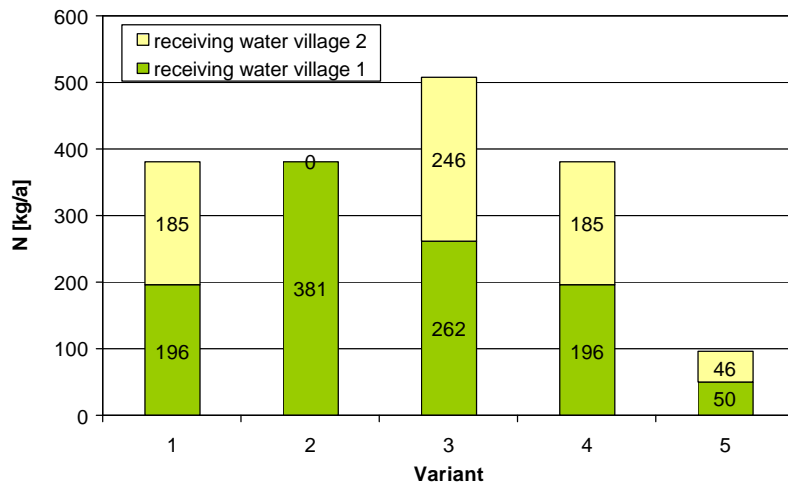
When considering the present value of project costs for the two villages (LAWA 1998), variant 4 with its semi-central wastewater treatment concept demonstrates small advantages over the two central-concept variants 1 and 2 (see Fig. 1). The decentral wastewater treatment concept (variant 3) leads to relatively high present values of project costs as a result of the higher running costs and the lower service lives of the components. Variant 5 is very cost intensive as a result of the additional systems needing to be installed for separating off the urine flow. However, when deciding which variant should be realized for which village, not only the costs but also - in the sense of sustainability - the ecological and social aspects should also be evaluated. Accordingly the results of the comparison of the total emissions for nitrogen are presented in the next section.



**Figure 1:** Present value of project costs for the two villages

### Total emissions

Comparison of the variants under the aspect of the emissions of nitrogen as a significant ecological indicator identifies that variant 5 with its source separating system gives the best result (see Figure 2).



**Figure 2:** Simplified consideration of the emissions of total nitrogen

This can be explained by the fact that the urine contains more than 75 % of the communal nitrogen so that separating off of the urine holds back a large part of the nitrogen. The total nitrogen emissions of variants 1, 2 and 4 are close to each other, there being a difference only in the distribution of emissions. Here the reason is simply that variant 2 provides that all the emissions pass into the Soestbach at Berwicke while with the other two variants the emissions are divided up between the Soestbach and the Dorfbach. The decentral concept, variant 3, shows the worst result in respect of emissions. Here the reason lies in the fact that the small wastewater treatment plants are significantly less efficient at eliminating nutrients than the wastewater treatment plants provided for the central and semi-central variants.

### Preferred variant

Under ecological aspects, variant 5 with its source separating concept shows clear advantages over the others. On the other hand variant 4 must be preferred if solely economic reasons are to be considered. If one considers that variant 5 represents a technical further development of variant 4, then the solution suggests itself of realizing the semi-central concept, variant 4, with the option of introducing urine separation house by house over an appropriately extended period of time. Together with the concept for the storm water, one would then have for the long-term a flexible wastewater disposal system that makes sense in terms of sustainability. However discussions that have been held with the inhabitants of the two villages as well as with the relevant decision-makers indicate that a great deal of persuasion work needs to be carried out if the variant with a source separating system is to be realized.

### Conclusion

The investigation of the feasibility of alternative wastewater concepts for the two villages of Berwicke and Stocklarn of the rural district of Welper has shown that indeed there are realizable alternatives to the systems currently used in villages and other residential areas. However, in regard to economical and ecological aspects, the decentral solution with its small wastewater treatment plants represents the worst alternative to the present system because of its present costs and the technical systems that accordingly come into question. If, on the other hand, the semi-central solution is chosen, one keeps open in addition the urine-separation option, which - if realized in full - would lead to an enormous reduction in the polluting of the watercourses with nutrient and which - at the same time - provides the opportunity of producing an alternative fertilizer.

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## Finding of ecosan-potentials – general aspects of a project example in Yemen

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**Keywords**

Dry toilet systems, faeces, greywater, urine separation

**Abstract**

In the framework of an ongoing water supply and sanitation program for four mid-size towns in Yemen, potentials for the introduction of the EcoSan approach are identified on the basis of visits and discussions with authorities and the population. EcoSan potentials are identified as possible in existing buildings and especially in new areas planned for a university and dwelling areas.

**Introduction**

The Ecological Sanitation (EcoSan) approach can – under certain framework conditions - be regarded as a realistic alternative to conventional sanitation systems from an ecological as well as from an economic perspective. In this context all partners involved in the “Provincial Towns Program II” for the “Water Supply and Sanitation in the towns Al Shehr - Ja’ar - Jiblah and Zinjibar in Yemen”, namely the Yemeni National Water and Sanitation Authority, NWSA, the Kreditanstalt fuer Wiederaufbau, KfW, and the consortium of the consultants MVV-IGIP-ERM-NCO-GHAYTH decided to identify the potentials for incorporating the EcoSan approach in the sanitation components of the program. To this end, a fact finding mission started, in which suitable pilot areas had to be identified in the above mentioned four towns, which would provide potential for the implementation of EcoSan technologies.

In this lecture, the main results of the first fact-finding-mission are presented, for one town in detail and only very briefly for the other towns. It should be stressed, however, that these results are still of preliminary nature and have to be appraised in more detail in the course of the planned follow-up missions. This is particularly the case with regard to economic viability of the different technologies proposed and the acceptance of EcoSan solutions by the target population.

**Methodology**

The scope of work for the first fact-finding-mission included the analysis of the settlement structures with respect to the applicability of EcoSan technologies, of the prevalent socio-cultural situation, the assessment of the potentials for the use of nutrients from waste water and

faeces, including the potentials of agricultural wastewater reuse and particularly the potential acceptance of EcoSan-technologies by the population to be served and the analysis of the potential economic impact as compared to conventional sanitation approaches.

As methodology applied for the analysis of the local situation with respect to EcoSan concepts, all four towns were visited and interviews were conducted with the relevant local stakeholders. On the basis of maps potential town areas were jointly inspected and individual houses were visited and discussions held with the population.

As a result, possible areas for the implementation of EcoSan technologies were identified and considered for the development of EcoSan concept proposals.

## Results

### Present situation and expressed needs

Although the local population often appeared to have a limited knowledge about the importance of cleanliness and (personal) hygiene, people are worried about their sanitary situation.

The main concerns expressed in this regards are:

- Cesspits are insufficiently covered, which can cause death of children, who fall into the hole while playing around;
- Great suffer by sleep disturbances because of the mosquito-bites;
- Great suffer by the constant foul smell and the obligation to live in this contaminated environment;
- Very little maintenance of the sanitation system, which had been designed in the seventies without any further improvement and which is insufficient to cater to the needs of a steadily increasing population.

Water used for anal hygiene is usually pale or tap water. Both men and women use the same method for cleaning themselves over the toilet bowl.

Families asked for their preferences for future toilets and bathrooms in the course of interviews conducted gave different answers: Most of the men wanted full flush toilets, technically well designed and well maintained; furthermore safe drainage systems, wider diameter pipes for the wastewater disposal. Furthermore more spacious toilets and bathrooms, full flush drainage systems and floors with tiles, shower and wash-hand basin are wanted. The wastewater should be disposed through pipes into the main drainage system. No floods of water should be seen in the streets, or near the houses where children play and easily become infected.

However, nowadays the vast majority of all houses have a connection to the water distribution system and have been converted to high standard ceramic full or poor flush toilets. Apart from the rural villages, there is no town zone in any of the four towns visited, in which any significant number of dry toilets would still be in use. The ceramic flush toilets already set the common standard. Any new approach has to meet the indoor standards of tiled bathrooms regarding cleanliness, odour, aesthetic look, etc.

Traditional sanitation methods are no longer considered modern or up-to-date and accordingly, families are aiming at "western standards" as the latest in development, unaware, that in industrialized countries, experts are shifting away from the water consuming full flush toilets and from huge treatment plants to ecologically sound and economically viable technologies.

### General attitudes to the EcoSan approach

Elements of the EcoSan Philosophy are all but new to Yemen. In fact, separation of liquid and solid elements of wastewater have traditionally been elements of domestic waste water management and have heavily influenced typical Yemeni architecture in the past. Dry toilets

and separation of urine and faeces have been found in operation in two of the cities visited and are widespread in rural areas. The use of dried faeces or sludge from cesspits as agricultural fertilizer is common in rural areas. In certain areas, there is a market value for cesspit sludge that is sludge trade is practiced.

It turned out in the interviews conducted with the local population, that people understood and recognized, that EcoSan technologies nowadays are as proper, bright, aesthetic, functioning, non-smelling and clean as the bathroom facilities they had in mind. There was a clearly expressed readiness to switch to the EcoSan system, provided, that this switch is linked to economic benefits like:

- reduced water bills,
- reduced fees for waste water treatment,
- sale of nutrients and soil conditioner.

### Potential of EcoSan-concepts in the visited towns

The town of Jiblah (population 2001: 13.845) is characterized by a strictly confined settlement area of high density. Located on the back of a rock, it is enclosed by two wadis and a mountain slope at its back. Very narrow streets provide only limited access for modern construction equipment and digging a sewer system in the rocky underground of the city seems to be extremely difficult and costly. As a result of the difficult situation, the architecture traditionally provided for dry toilets in which domestic waste water and urine were separated from faeces, which were collected in a storage underneath the toilet, whereas the liquids were led outside the house in the path to infiltrate or dry.

Actually 92 houses still dispose of these traditional system, many of them in poor condition, though. The faeces are collected in the storage, at a few houses together with animal excrements and on a place in front of the house beside the street. This storages are emptied either from outside or from inside the house. Typically the storages are closed with stones. However, important to notice is the fact, that there is no general objection against these traditional elements of EcoSan like urine/faeces separation and that at least some of the owners of the houses with the traditional system are willing to upgrade and continue the use of the system, if a hygienically, technically and economically acceptable high standard solution is provided.

This was confirmed by the local authorities, which in general were very open minded with respect to the EcoSan approach. For them it is to a certain extend also an appreciation of their traditional know how and outstanding architecture and engineering of the past.

For an upgraded system in the existing buildings of the densely populated towns, there are several options:

#### a) The dry toilet system

In the bathrooms, the traditional, old facilities should be exchanged to most modern separation facilities, made from white ceramics or fiberglass, easy to clean and in the typical Yemeni design, which integrate the urine separation and lead the urine via a small pipe into a urine holding tank. Solids fall down into a storage, which needs to be modified to meet modern hygienic standards (ventilation, closed but with controlled access for emptying). Application of additional material for supporting the drying process (e.g. ash, sawdust or wood shavings, soil etc.) is recommended to improve the effectiveness of the dehydration process. Also included should be a cleaning place next to the toilet for anal hygiene and body cleaning after use of the toilet. The washing water needs to be collected separately.

The urine storage facility can be either designed as an individual in-house installation or as a joint storage facility for a couple of houses. The storage facility could be a container of a

volume, large enough for intermediate storage. Outside the settlement area, close to agricultural lands, there should be one or several tanks, large enough to store the urine from the participating households for the period between the applications of urine as fertilizer to the fields.

Also for the dried faeces from the participating households, there should be a defined area, on which the faeces will be further treated to improve their value as soil conditioner and to destroy faecal contamination. The greywater will have to be discharged from the premises in smaller sewer pipes, since there is only very limited space for on-site treatment. Free of the main solid fraction, transportation in small pipes is fairly easy and no blockings should occur.

b) Flushing toilet with urine separation

The system is similar to the dry toilet system except for the fact, that a flushing but urine separating toilet bowl will be used. The consequences are: Water from washing, showering, cleaning, body hygiene will be mixed with faeces and discharged via regular sewer pipes. Only urine separation and its use as high value fertilizer remains from the system described above. Except for this, the system is equal to all the components mentioned above.

The remaining advantage here is the saving of flushing water for urine flushing only (that might make up to a saving of 30% or more of the water bill!) and the reduced amount of wastewater generated. At the same time, however, the household is equipped with what is considered most luxury flushing toilet facilities, which is likely to contribute to an increased willingness of households to adapt such a solution. Additional water and cost savings can be realized if the flush water can be replaced in part by rainwater that is collected on the roof and used as flushing water.

c) Flushing toilets with urine separation but without use of urine as fertilizer

Again, the system is similar to b), however, it does not make any use of the separated urine. Urine will be discharged with the other wastewater in the sewer pipe. The only advantage is the saving in water consumption and accordingly in waste water generation (and reduced cost for both).

Main supporting facts for the choice of these houses are the existing traditional facilities and the acceptance, willingness and know how of the house owners/families to operate such a system. The few individual houses may play a key role as model houses for other town areas, documenting the high standard of bathroom furniture for EcoSan systems. It could thus be demonstrated that there does not have to be a difference in standard between the EcoSan and the conventional sewer approach. In addition, savings of recurrent costs for water and waste water bills could be demonstrated on household level. The parallel existence of both approaches within one city area allows for direct comparison of the individual household's recurrent costs for water and sanitation. However, when comparing the economic viability of the alternative systems, investment and maintenance costs and their impact on household budgets will also have to be taken into account.

Obstacles to the EcoSan approach increase with the scope to which it will be implemented. The dry toilet and urine separation (option a) requires some kind of organization for the collection of urine and faeces (regular emptying of the storage facility and distribution of marketable components). A service (best to be carried out by potential users of nutrients and soil conditioner, i.e. farmers or farmers cooperative) needs to be established and its function must be guaranteed to avoid failure of the approach.

Potential for the re-use of urine and/or faeces sludge as fertilizer seems promising as agricultural land is located around the city on the right and left banks of the wadi and there are huge cultivated areas in the terraces located alongside the right and left banks of the Wadi.

However, due to the few individual houses, which could possibly be transferred to modern EcoSan model houses, the amounts of collectable waste might be too small to establish collection facilities and an organization for its agricultural use. The quantities need to be determined in detail to make a decision on its feasibility in the next phase of the project.

It's slightly easier, if only urine is collected separately (option b)), but nevertheless, more or less the same difficulties apply as for option a).

Only option c) does not require any additional operation or services and as such should not cause any problems in operation and sustainability. However, this is the option with the smallest ecological impact, since only water consumption and waste water generation can be reduced (no separation and direct reuse of any nutrients or soil conditioner, no effects on the load for the treatment plant, no major effect on costly investment for sewer lines). The reduction in water consumption and wastewater generation, however, might be significant.

The EcoSan-Potentials of the choice a) and b) are summarized in the table:

Potentials	Toilets with urine separation (Type can be chosen by the house owner)	
	Dry	Flush
Water saving	+++	+
Water saving by rainwater harvesting	0	+
Use of faeces	+	0
Use of nutrients	+	+

**Figure 1:** EcoSan-potentials for the two different systems proposed

The houses with the EcoSan elements could eventually function as multipliers, not only for Jiblah, but also for other similar areas in Yemen – and there are a lot.

Additional areas for the introduction of EcoSan installations are identified in two other towns:

The town of Zinjibar (population 2001: 19.851) is in the coastal plain area in the south of Yemen. It is expanding rapidly in circles around the town center. The town center is confined and of high density. Wastewater is disposed of by means of rudimentary sewer lines, discharging into wadis and by cesspits, which are supposed to be emptied if overflowing.

However, there is a huge compound earmarked for the construction of a new university complex. This project might be very suitable for a comprehensive EcoSan approach, since it might be possible to plan a system from the scratch and to integrate it in the architectural design and infrastructure planning from the very beginning. It might be possible to design a system, which is independent from any other public system and might be operated by the university on its own. It could include the full range of technologies from individual to public separation toilets, on compound treatment and use of nutrients and organic material.

An integrated EcoSan-concept for this area may contain a full range of sustainable elements like:

- Urine separation and utilization as fertilizer on the surrounding farmlands
- Solid and liquid separation combined with the soilization of the sludge
- Greywater treatment for irrigation use for greenlands on the university area.

This system has to be operated by the university on its own, so the benefits can be demonstrated significantly. Well implemented and operated, it could serve as a model case for future infrastructure planning of new town zones. Linked to a university, it also might be understood as advanced system with a vision in the future and as such reduces reservations of individuals re the new approach. Although there is apparently high potential for realization of a

full fledged EcoSan approach at this location, it needs to be mentioned that the implementation period of the university project is still unclear and that at this stage, no discussions have been held with officials of the university project with respect to their views and acceptance of the idea.

The other town Al Shehr (population 51.889 in 2001) is a booming town and is also located in the flat lands on the coast. A defined, densely populated old core is surrounded by circles of newly settled areas with decreasing density towards the outer zones. The growth of the city seems to be structured and planned.

The community of Al Shehr district is – with reference to the other program towns – comparatively wealthy and a large number of houses are spacious and well furnished. The community is very religious and the houses are clean. Contrary to the other areas the population is fully aware about the importance of cleanliness and hygiene.

The enormous development speed of new zones at Al Shehr opens a new dimension of fully integrating the EcoSan approach into confined areas.

One approach could be to cooperate with a dwelling company or a single investor who plans to develop a specific area and to build a number of similar houses. In contrast to other areas this approach seems fairly realistic, because various companies are planning to settle and to construct dwelling houses for their employees.

In such a case, planning of an EcoSan system can start from scratch and include all necessary infrastructure and management elements to make the most of the approach and to secure its comprehensive functionality. So confined areas can be served independently by an EcoSan concept. The integration of the EcoSan approach into the planning process from its beginning allows for the most possible realization of the economic potential of the approach. The officials of the urban planning section of the baladia have expressed their support in establishing a cooperation between the project and a potential investor.

The conceptual approach can achieve the full range as for the university extension project in Zinjibar.

Rural communities in the periphery of the towns visited already use elements of EcoSan to a large extent. Lower level income households use dry toilets, some of them outdoors in separate buildings or simple structures, some integrated in the architecture of the houses. Higher level income households with brick houses have flush toilets and cesspits. An integral EcoSan concept for a rural area is only possible with an "homogeneous" support of all inhabitants of the village.

Though there is a potential for EcoSan technologies, a successful implementation of EcoSan systems can only be expected, if the high hygiene standards of the individuals are met. However, a change to separation toilets would in almost any case mean a major investment on in-house installations. In urban areas only flushing separation toilets are likely to be accepted. In-house investments would include new toilet facilities in all bathrooms and installation of separate pipes, all at the expenses of the house owner. Therefore private investments will only be made, if economic benefits from water savings materialize for the individual in an adequate span of time and if liquidity of the household is sufficient to finance the necessary in-house investments. In this regard, further information has to be generated in the course of the planned future study phases.

EcoSan can replace conventional systems, but it is very difficult to operate the two different systems in parallel, because this would always mean, that more or less two full systems would have to be implemented and run at the same time --- and at the investment and running costs of two systems. The full advantages and benefits of EcoSan can therefore only be materialized in areas, which do not dispose of any sanitary infrastructure at all and which can be served independently.

In consequence, the next study phases for the EcoSan component of the Provincial Towns Program II will focus on:

1. Development of EcoSan Concepts for the selected pilot areas;
2. Detailed feasibility study for the selected pilot areas and the technologies chosen including a thorough cost-benefit analysis and economic comparison of alternatives.

## Conclusion

Important elements of the EcoSan approach are traditionally established in Yemeni culture. The Yemeni dry toilet is an integral element of historic architecture and goes hand in hand with separation of faeces from urine and water. A significant number of houses in old urban centers continue to use this type of toilet. In certain rural villages, the dry toilets and separation of urine and water is common in almost each household. Also widespread is the use of dried faeces or sludge from wastewater treatment plants in agriculture as soil conditioner and fertilizer.

Accordingly, the officials and persons talked to in the four towns and the surrounding villages were generally open-minded about the EcoSan approach. The philosophy was clear to them and the potential benefits understood.

However, nowadays the vast majority of all houses have been converted to high standard ceramic full or poor flush toilets. Apart from the rural villages, there is no town zone in any of the four towns, in which any significant number of dry toilets would still be in use.

The most important conclusion therefore is:

Though there is a potential for EcoSan technologies, a successful implementation of EcoSan systems can only be expected, if the high hygiene standards of the individuals are met and EcoSan systems are not perceived as being synonymous to a low standard of development.

Secondly:

In urban areas only flushing separation toilets will be accepted.

Today, there are most modern ceramic or fiberglass toilet bowls, which would meet these standards and at the same time, separate the materials.

However, a change to separation toilets would in almost any case mean a major investment in in-house installations. The investment includes new toilet facilities in all bathrooms and installation of separate pipes, all at the expenses of the house owner.

Therefore:

Private investments will only be made, if economic benefits from water savings, reduced wastewater bills and – in some cases – income generation from marketing of urine and organic matter as fertilizer materialize for the individual in an acceptable timespan and if households dispose of sufficient liquidity to finance the necessary in-house installations.

Potentials for economic benefits may be realized by:

- Reduction of water consumption (lower water bill)
- Reduction of wastewater generated (lower waste water bill)
- Utilization of treated greywater for irrigation (lower water bill, higher yields)
- Utilization of high quality nutrients from urine as fertilizer (lower fertilizer bill, higher yield)
- Utilization of organic matter and nutrients from faeces as soil conditioner and fertilizer (higher yield)

Whereas the savings in the water and waste water bill can be achieved immediately through the installation of flushing separation toilets (saving of flushing water for urine), the realization of the other potential benefits requires further installations like urine holding tanks, greywater treatment facilities, treatment for faeces and the implementation of some kind of management structure to operate the system. In addition, marketing of urine and organic matter as fertilizer may need some time to be established on a profitable scale. As such, the EcoSan approach is comparable to conventional wastewater management, which also requires the same, but centralized and in bigger scale.

EcoSan can replace conventional systems, but it is very difficult to operate them in parallel, because this would always mean, that more or less two full systems would have to be implemented at the same time - at the cost of two systems.

This holds particularly true for already settled areas, which already have conventional household installations and possibly a public infrastructure. Since not all houses would switch at the same time – or at all, there needs to be the conventional system to serve these households and at the same time, an EcoSan system would have to be implemented, which also requires a minimum number of households to be connected to make it functional. However, once the conventional system is in place already, it makes only little sense to invest in additional treatment facilities and operations, just to realize some fringe benefits like nutrient values and crop yields on individual basis. Low prices for artificial fertilizer in Yemen emphasize this statement even more.

The full advantages and benefits of EcoSan can therefore only be materialized in areas, which do not have any infrastructure at all and which can be served independently from the conventional sewer system to be established.

These are defined areas, which can be planned and developed from scratch as EcoSan Concept Areas, in which then all elements work hand in hand.

Areas with existing infrastructure can only partially benefit from EcoSan

Rural communities in the periphery of the towns visited already use elements of EcoSan to a large extent. Lower level income households use dry toilets, some of them outdoors in separate buildings or simple structures, some integrated in the architecture of the houses. Higher level income households with brick houses have flush toilets and cesspits. An integral EcoSan concept for a rural area (e.g. Mansura near Jiblah) is only possible with an "homogeneous" support of all inhabitants of the village.

However, for both there is significant potential for improvements with respect to both, the design of the facilities and the use of the valuables.

## Source-oriented sanitation in rural regions

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Source separation, decentralized treatment, demonstration project

### Abstract

Urine and faeces make up over 80% of all nutrients in household waste water, but form only 1 to 2 volume percentage of this waste water flow. In source-oriented sanitation, toilet waste water is collected separately with much less rinse water and treated separately. This keeps the nutrients concentrated, and it becomes possible to recover and reuse them as fertilizer. The purification of household waste water becomes simpler and more robust with this concept. The investment costs for the implementation of source-oriented sanitation in rural regions are estimated at circa 15% higher than those for an IBA class-III system (small waste water treatment plant). However, implementation of source-oriented sanitation in the rural regions as a Dutch demonstration project offers an interesting opportunity, based on a better effluent quality and circa 25% lower operational costs. This would be a first step in a potential future shift of waste water purification towards "resource management".

### Source-oriented sanitation

Our current waste water collection system is characterised by extensive dilution of the waste. Concentrated toilet waste water, circa 1.5 liter per inhabitant per day, is mixed with rinse water of drinking water quality and slightly contaminated waste water (bath, shower, washing machine, etc.) to approximately 125 liter water per inhabitant per day. Together with the same quantity of rainwater, this is transported via the sewer system to the central water purification plants. Despite the small proportion of toilet waste, the costs of the current waste water treatment with its strict effluent standards are determined to a large extent by this small flow.

An alternative, source-oriented approach in which waste water is collected separately at the house level can result in a more efficient sanitation system in which part (or possibly all) of the waste water treatment would be done locally. The main starting point for source-oriented sanitation is the separate collection and treatment of toilet waste water at the house level (figure 1). Urine and faeces make up over 80% of all nutrients in the household waste water, but form only 1 to 2 volume percentage of this waste water flow (figure 2, refs. 3 and 6).

Figure 1: Source-oriented separation and treatment of household waste water flows

Figure 2: Volume and distribution of contaminating components across different household waste water flows

By collecting urine and faeces separately, the remaining waste water flow is almost completely free of nutrients and can be more easily purified, the water quality improved, and the social costs reduced. By keeping urine and faeces concentrated, it also becomes possible to recover nutrients from waste water and re-use them as fertilizer. This will lead to savings of finite natural

resources, like phosphorus and potassium (refs. 1 and 5). Waste water purification changes thereby into “resource management” and can contribute to sustainable economic and ecological development.

In various regions in the Netherlands, grey water is collected separately and treated, as in De Drielanden in Groningen, the borough Lanxmeer in Culemborg and the EcoPark in Emmeloord. In a broadly based research project (EET / STOWA), a varied consortium of Dutch universities and companies is currently conducting research into these concepts, in which technical, constructional and social-economic aspects are being studied. Although research is being done into source-oriented sanitation in the Netherlands, there is still no concrete application of the separate collection and treatment of toilet waste water.

### Source-oriented sanitation in rural areas

In this article, we shall treat the question of whether the implementation of source-oriented sanitation concepts could form an alternative for the connection of lots in rural areas to the sewage system or to IBAs. Currently, there are still about 200,000 lots without a sewage connection in the Netherlands, most of them in rural areas. From 2005 no unpurified discharges are permitted from these lots. It is expected that about 100,000 lots still have to be connected to the sewage system. For the remaining lots, an IBA will be installed.

In the Environmental Management Act it states that local authorities are responsible for the efficient collection and transport of waste water. Local authorities can be granted exemption from this responsibility. A cost comparison between the connection to the sewage system and the deployment of suitable IBAs (individual treatment systems for waste water) can be used to determine the best solution (sewage system or IBAs) for a particular area. In many provinces, agreements have been concluded about so-called assessment sums per sewage connection. If the sewage system in a certain area can be installed for less than the assessment sum, then the area will have a sewage connection. If the costs are higher, then deploying IBAs can form an alternative. The assessment sums vary according to the area between € 7000 and € 11,000.

If a local authority has indicated which discharge outlets will not be considered for sewage connection and if the province has granted exemption from the responsibility for those outlets, then the Act applies to the one doing the discharging. That person must meet the effluent standards set by the WVO household waste water discharge decree, for which the district water board ensures compliance.

### Source-oriented sanitation concepts in rural areas

Developments in toilet systems and transport technology allow toilet waste to be transported without or with very little water (refs. 4 and 7) while maintaining the comfort that we are used to with conventional toilets. The quantity of rinse water in the toilet is thus reduced by more than 85%. In the concepts examined, use is made of these toilet systems in which urine and faeces, whether separated or not, are transported to a storage volume measuring several cubic meters for an individual household. Periodically, the urine and faeces are transported by truck to a central collection point for further treatment. For a demonstration project, processing in an existing sewage water purification plant is being considered.

The remaining (grey) waste water makes up most of the total volume, but contains only a small proportion of the total quantity of nutrients (figure 2). This waste water can be simply and robustly treated on site with a simple purification system (eg a biorotor or helophyte filter). The constant good effluent quality (table 1) can be discharged without problems on site into the surface water.

### Quality of the water to be discharged

According to the effluent quality to be achieved, the IBA systems are divided into three classes, I, II and III. The systems that are considered class III should meet the strictest effluent standards. The current effluent standards for a sewage water purification unit and for the class-III IBA systems are compared in table 1 with the feasible effluent quality for alternatives based on source-oriented sanitation.

	IBA III	SWPU	Source-oriented sanitation
CZV (mg/l):	< 100	< 50	< 50
Total N (mg/l):	< 30	< 10	< 2.2
Total P (mg/l):	< 2	< 1	< 0.15 <sup>*)</sup>

<sup>\*)</sup> to remove P it may be necessary to add a small quantity of FeCl<sub>3</sub>

**Table 1:** The current effluent standards (mixed sample) for a IBA-III system and a sewage water purification unit compared with the feasible effluent quality in concepts based on source-oriented sanitation (refs. 1, 2 and 4)

The separate removal of toilet waste water prevents nutrients, drug remains, hormones and most pathogens from reaching the surface water.

### Costs

An initial estimate of the costs of source-oriented sanitation is reproduced in table 2. The indicative investment costs for the source-oriented sanitation concepts examined are circa 15% (or € 1150) higher than those for the IBA class-III systems. The excess costs are almost entirely determined by the relatively expensive toilet systems.

The indicative operational costs of source-oriented sanitation is substantially lower, by circa 25% or € 95 per year, than those for the IBA class-III system. This is due to the lower energy use and the greater simplicity and robustness of source-oriented sanitation. As the treatment system is relatively simple, we also expect that the necessity for effluent control will be reduced.

	Source-oriented sanitation	IBA III
Investment costs (€):		
Average purchase of IBA class-III (5-6 ve):		4800
Toilets (2x) + vacuum system:	2450	
Total storage system:	1000	
Helophyte filter:	2500	
Installation costs for total system:	3200	3200
Total investment costs:	9150	8000
Operational costs (€/y):		
Energy:	10	65
Collecting + processing (feces/urine or sludge):	150	150
Maintenance:	100	140
Total operational costs:	260	355

(based on references 7)

**Table 2:** Indicative investment and development costs including tax of IBA class-III systems and alternatives based on source-oriented sanitation for a household of six people

## Conclusions and recommendations

The investment costs of source-oriented sanitation concepts in rural areas are circa 15% higher than for IBA class-III systems. The simplicity and robustness result, however, in circa 25% lower operational costs and in a better effluent quality. In addition, it is possible to recover and re-use nutrients and reduce the rinse water use by more than 85%.

Based on the findings described in this article, a demonstration study for the implementation of source-oriented sanitation concepts in rural areas seems to offer an interesting opportunity. An initial step can be taken toward a potential future shift in waste water purification towards resource management and a contribution made to sustainable economic and ecological development. The Rijnland District Water Control Board is currently studying the possibilities of carrying out such a demonstration project in collaboration with the foundation Lettinga Associates, Foundation for Applied Water Management Research (STOWA) and the North Holland District Water Control Board.

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## Energy, water supply and waste water treatment for the Werbellinsee-project (ex “Pioneer Republic Wilhelm Pieck”)

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### Keywords

Decentralized, energy, integrated, rainwater, renewable, re-use, wastewater

### Abstract

In recent years new water management and treatment technologies have been developed and demonstrated in projects. This is true especially for singular concepts using either rainwater management technologies or wastewater treatment in different locations. No experience exists in the operation of integrated decentralised installations including the potential for energy generation. The goal of the research is to gain experience in comprehensive design and implementation of singular technologies aiming at quasi-autark concepts requiring only a minimum of public water, waste and energy management services. These concepts should prove to function in different types of settlements and urban structures as well as various regional conditions and demands.

The aim of the research and development component of this project is to demonstrate the functioning of a comprehensive approach under technical, socio-cultural, economic and legal aspects by integrating individual technologies that reflect the state of art. For wastewater management it is proposed to use anaerobic sewage treatment, membrane technology, natural purification procedures as well as faeces and urine separating technologies. For water conservation, water saving devices as well as rainwater harvesting and wastewater processing and recycling is envisaged. For solid waste management garbage separation, composting it and incineration is considered. The recovered nutrients from wastewater treatment and solid waste management shall be used for landscaping horticulture on site and for agriculture in the vicinity of the project site. For the supply of energy, block heating generation plant technology that uses renewable energy resources shall be adopted. The operation and maintenance of all the above installations would be run by one operating authority.

### The present situation

The Werbellinsee project (see figure1), offers place for about 1.100 visitors in around 30 guesthouses. The project was founded by the former German Democratic Republic in 1952 and was named after its founder and the first president of the German Democratic Republic, “Pioneer Republic Wilhelm Pieck”. Today the project site is used for recreation by the youth (European Meeting Place for Young People), sport, vocational education and international meetings. The area of 200 ha at the marvellous Werbellin lake is covered by 100 ha of forest. The Werbellin lake extends over 10 km in length and 1 km in width. The project site is located within the Uckermark Biosphere Region. The built up area is protected under the monument protection law and comprises of 42.000 m<sup>2</sup> floor area. The project was designed by Richard

Paulik<sup>1</sup>. At present the heating is provided by a contracting company via a heating network. Waste water is pumped through a 30 km long sewer to a waste water treatment plant. Power and water as well as solid waste management are provided externally by public institutions. The reconstruction of parts of the existing technical infrastructure is planned under the framework of the original autarkic concept of water and energy supply as well as management of solid and liquid wastes.

### Aims and objectives

The aim of reconstructing parts of the technical infrastructure is to revive the original autarkic concept of water and energy supply and management.

The research and development project will demonstrate new concepts, technologies and products for minimising wastewater, separation of faeces, urine and water and reusing treated wastewater. Furthermore the potentials of reuse of rainwater can be demonstrated. The decentralised generation of electricity and heat will include the use of organic wastes and leftover wood from logging activities.

The project comprises of the following elements:

1. Drinking water supply by rehabilitating the existing deep ground water wells on the site
2. Minimising wastewater by modern sanitation technologies (separation toilets, dry toilets, separation of urine and faeces, urine will be used for soil improvement)
3. Remaining wastewater being treated at the treatment plant on the project site (anaerobic treatment of sludge, trickling filter, rootzone treatment and membrane technology) for reuse in irrigation and toilets
4. Rainwater run-off collected in cisterns of different dimension for drinking water substitution (baths, toilet flushing, washing machines) and for groundwater recharge
5. Anaerobic treatment of organic waste (especially from the restaurants), use of methane gas and sludge from waste water treatment for energy production
6. Block heating and power generating plant that produces energy from renewable resources (methane gas, chopped wood, wood pellets)

### Wastewater management

Together with the reconstruction of the wastewater treatment plant water saving technologies will be installed. To allow a comparison between different systems the houses will be equipped with different toilet types such as separation toilets and urinals without flushing, Gustavsberg water saving systems, 1 / 2 / 4 litre WC, hybrid toilet systems with water separator connected to a composting facility (for smaller buildings) and Clivus multrum compost toilets. At the project site a separate sanitary and stormwater drainage system already exists and shall be integrated with the proposed infrastructure. Organic wastes from canteens and faeces separated from sewage will be treated in decentralized methane reactors. The urine will be collected and treated separately and used as fertilizer. The wastewater yield of 1.900 population equivalents will be 285m<sup>3</sup>/d and ca. 104.000m<sup>3</sup>/a. About 20.000m<sup>3</sup>/a of purified wastewater will be used for supplying a nearby moor, thus about 76.000m<sup>3</sup>/a will remain for re-use.

<sup>1</sup> Richard Paulick, born 1903, affiliated with BAUHAUS since 1924, founder of Socialist Labour Party in 1933, emigrated to Shanghai, 1942 professor for architecture at the University of Shanghai and 1945 town planning director of Shanghai, 1949 member of Institute for Construction under Hans Sharoun, among other works architect of parts of Karl-Marx-Avenue in former East Berlin

### Rainwater harvesting

Rainwater run-off from roofs amounting to 13.000 to 25.000m<sup>3</sup>/a will be stored in cisterns after being purified. The capacity of the cisterns will vary between 5 to 300 m<sup>3</sup> according to the roof areas to be connected. Each cistern will be equipped with a filter, a pumping device and a drinking water connection for top-ups. Water from the rainwater cisterns will be used for drinking water substitution (baths, toilet flushing, washing machines) and for groundwater recharge. The run-off from pedestrian pathways and roads will be between 25.000 and 50.000m<sup>3</sup>/a will be collected in infiltration trenches. Rainwater run-off will not be discharged into the Werbellin Lake.

### Water supply

The water works at the project site were shut down in 1996. The existing filter tanks will be cleaned, and the pumps, fittings, filter materials (for removing ferric oxide) and backwashing equipment will be renewed.

For irrigation of the intensively used sport fields, for green areas and gardens around 32.000 m<sup>3</sup>/a in a year with average precipitation and around 60.000 m<sup>3</sup>/a in a dry year will be needed. The total demand of 67.000m<sup>3</sup>/a in a wet year can be completely provided for by using purified water from the treatment plant. In a dry year the demand rises to 95.000 m<sup>3</sup>, hence 13.000m<sup>3</sup> of rainwater and 6.000m<sup>3</sup> drinking water will have to be added to purified waste water.

The demand for process water for toilet flushing is estimated to be 35.000m<sup>3</sup>/a. In dry years around 13.000m<sup>3</sup> of drinking water has to be added.

For other purposes (household, small industry) process water from the cisterns is available. In a wet year the demand of around 17.000m<sup>3</sup>/a can be supplied in this way. Surpluses will be used for the recharge of groundwater.

### Solid waste management

Organic waste from canteens and faeces separated from sewage will be treated in decentralised methane reactors. The compost from toilets together with organic waste from the gardens will be composted and used on site for horticultural purposes. The sludge from the purification plant can be used either for energy generation or for composting in order to close the loop within the project site.

### Power generation and heating

Energy has to be supplied for buildings with a total floor area of 42.000m<sup>2</sup>. At present a demand of about 3.500kW is estimated for heating purposes.

For a decentralised heating and electricity supply for the project site, a Block Heating and Power Generating Plant (BHGP) will be setup using methane gas from the wastewater purification plant and the methane reactors. The methane gas will be burnt and converted into heat and electricity. For peak demands, chopped wood will be additionally used as a renewable resource for energy production. Wood exists in sufficient amounts in the region. The use of solar energy is not suitable due to the dense tree canopy on the site.

The BHGP technology consists of a boiler which will be heated by a special burner. The hot combustion gas is used to heat thermo-oil in a heat exchanger. By introducing a new technology, the ORC-process, the heat of the thermo-oil is used to support a low temperature steam circulation, which is driving a condensation turbine for generating electricity. The operating medium for the ORC-generator is silicon oil, which has a boiling temperature of 80°C. This enables a higher degree of efficiency compared to a traditional steam power station. Since

the steam generator is heated indirectly, no supervision of the BGHP is necessary and maintenance required for this system is low. Only one person is needed to run the BGHP.

The annual demand for electricity supply is estimated to be 2.000 MWh/a. By installing a block heating and generating plant (BHGP) the energy costs can be reduced by 60%. By using energy conserving techniques of the building renovation, the maximum energy demand for heating will be reduced to 50%. The annual operating time of the BHGP is estimated to be 5.000 hours. This will be sufficient for the generation of 2,500 MWh/a. The electrical output of the BHGP will be 500kW. Management and regulation of peaks will reduce the power demand peaks to a maximum of 700 kW and contribute to a significant reduction of costs.

### Operating authority concept

Operation and maintenance of the installations for energy production and for water and waste management in the project area of Werbellin lake would be run by one operating authority. This can be done by a corporation founded for this particular purpose or by an institution experienced in operating at least parts of the new technology. Whoever shall operate these installations, will have to be trained, as such technologies and their integrated combination do not exist so far in a project of this scale. The local water authority could participate as well. The options of forming an operating authority (corporation) are studied at present.

### Conclusions

The aim of the research and development component of this project is to demonstrate the functioning of a comprehensive approach under technical, socio-cultural, economical and legal aspects by integrating new technologies reflecting the state of art. The previously existing autark systems for energy and water supply as well as wastewater treatment will be reactivated and technically modernised. It is expected that the integral planning approach will create a synergy, which will result in the enhancement of both environmental and economic benefits.

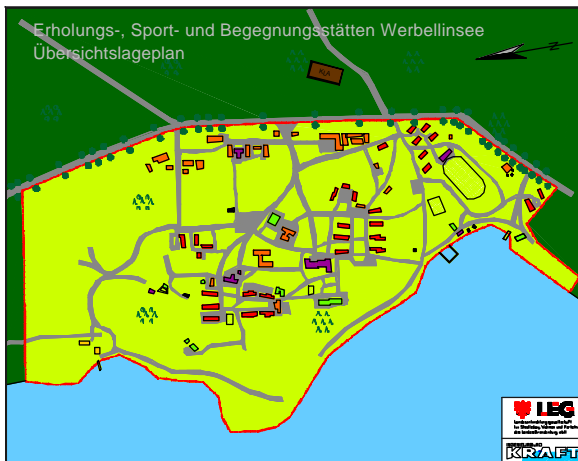


Figure 1: Layout of Werbellinsee Project

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## SWAMP - Sustainable water management and wastewater purification in tourism facilities

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### Keywords

Ecological sanitation, reclamation concepts, water saving, urine separation, irrigation, reed bed treatment systems

### Abstract

A great number of tourism facilities of various types in different locations throughout Europe do not yet have an adequate sewage treatment system solving the related problems, e.g. high seasonal fluctuation of wastewater flow, lack of water, low maintenance capabilities of owners, and natural environment deserving special protection. "SWAMP", a project under the Energy, Environment and Sustainable Development Programme of the 5<sup>th</sup> Framework Programme of the European Community develops sustainable water management concepts and tests them on 13 concrete examples with partners in Austria, Italy, Latvia and Germany. SWAMP means an efficient water use, recycling of nutrients and a cost effective wastewater treatment by constructed wetlands.

### Wastewater and sustainable water management in tourism facilities

Water management in tourism facilities is of particular concern throughout the world. In fact, tourism industry is more and more attracted by isolated virgin locations where neither water supply nor wastewater collection is available. A welcomed development beside these aspects is a growing tendency of tourists to consider the environment quality when choosing an accommodation facility. Sensitivity to environmental matters and relating requirements are increasing in all segments of the conventional tourism market. The main innovation of SWAMP is to consider wastewater as part of the entire water consumption process. Sustainable water and wastewater management means an efficient water use, avoidance of hazardous substances, cost-effective wastewater treatment and reclamation of nutrients by agricultural irrigation.

### Objectives of the SWAMP-project

SWAMP aims at developing economically feasible and technically satisfying wastewater management systems for tourism facilities with high fluctuations of wastewater quantities. Sustainable water management concepts will be developed and tested. This will be achieved by the following work packages:

- WP 1: Audit of each participating facility and development of sustainable wastewater concepts for 13 typical tourism sites with capacities from 50 to 1.200 p.e. in various climates of Europe
- WP 2: Realisation of one practicable variant at each location
- WP 3: Monitoring of pilot plants focusing on operation, social acceptance, economical advantages and of innovative sanitation appliances and treatment efficiency of constructed wetlands

WP 4: Contributions to common European guidelines and elaboration of national proposals focusing on technical rule, cost-effectiveness and ecological benefits

WP 5: Promotion and publication of the applied technology by marketing agencies in each partner country


 SWAMP - Sustainable Water Management and Wastewater Purification in Touris Facilities		Save Water			Reclaim Nutrients			Reuse
		Water saving technologies	Waterless urinals	Vacuum toilets	Separate grey- and blackwater	Use of sludge in agriculture	Urine separation	Natural treatment plants
Austria	Klug-Weid						X	
	Weissmann	X	X				X	
	Pleschwirt						X	
Italy	Fattoria Baggidino	X					X	X
	Parco del gigante						X	
	La Cava	X			X		X	X
	Relais Certosa						X	X
Germany	Park Moränasee	X				X	X	X
	Burg Lenzen	X	X	X			X	
	Stranddorf Augustenhof	X					X	
	Kulturraum Sammatz	X				X	X	
Latvia	Art museum Pedvāle	X				X	X	
	Mazais Krogs	X				X	X	
	Mežezers	X				X	X	

Figure 1: Components of Sustainable Techniques in SWAMP -Projects

### Innovative approaches

The project will advance the state of the art of wastewater treatment in combination with constructed wetland technology by following three innovative approaches:

**Least-Cost Planning:** An audit of the water flow optimises the layout of a treatment facility. An integrated view of used and treated water will lead to technically adapted and cost-effective solutions. Less water consumption will reduce costs for water supply and wastewater treatment. A decrease of wastewater discharge will minimise pollution of wastewater effluents and expenditures for water protection.

**Treating Wastewater as a Resource:** Normally wastewater is considered as a substance to be disposed of as soon as possible. In this part this attitude has led to expensive and energy intensive treatment plants with a negligible reuse of nutrients. Separation of sewage into its components black water, urine and grey water offers new possibilities for treatment and reclamation of wastewater. Natural treatment plants, e.g. ponds, reed beds, constructed wetlands as an efficient method for wastewater purification have to be adapted to these new challenges. One innovative approach of SWAMP is to implement these techniques and to test them in routine operation.

### Wastewater pond-reed bed treatment system at Park Moränasee – one of the German SWAMP - Projects

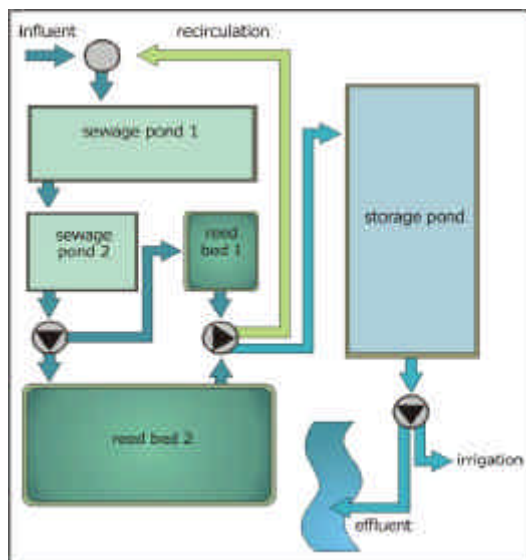
„Park Moränasee“ is a camping site mainly used in summer and at weekends. According to economic advantages instead of connecting the park to a public sewer system the sewage is purified in a private treatment plant on site. Rainwater was consequently separated from wastewater and percolated into the ground on the parks area. Depending on season wastewater quantities vary between 20 - 250 m<sup>3</sup>/d. Due to these high fluctuations the treatment plant is designed as a combination of wastewater ponds and planted soil filters.

**Wastewater pond-reed bed treatment  
Park Moränasee, Dittmern, Germany**

Construction year:	2002
Scale:	900 p.e.
Wastewater quantity:	20 - 250 m <sup>3</sup> /d
Wastewater ponds:	2.800 m <sup>2</sup>
Soil filter:	2.600 m <sup>2</sup>
Storage pond:	5.000 m <sup>3</sup>

**Figure 2:** Wastewater pond-reed bed treatment system “Park Moränasee”

The ponds serve for pre-treatment and storage of the sewage. The reed bed treatment system where aerobic treatment takes place is continuously fed with sewage. First desludging of pond 1 is scheduled after 20 years of operation. During the main season purified wastewater is stored in a detention pond for agricultural irrigation, the effluent is released into the receiving water by a discharge control. Purification requirements are very strict in order to protect the good river quality.



In sense of a sustainable wastewater management advantages of the natural treatment system at Park Moränasee are a simple structure with easy obtainable construction materials, construction by local firms, high hydraulic buffer capacity, high treatment efficiency, especially concerning hygienic parameters, low energy consumption and operation costs, long term desludging of ponds and agricultural utilisation of sludge and a good integration into natural environments.

**Figure 3:** Flow scheme of the wastewater pond–reed bed treatment system “Park Moränasee”

**New Sanitation Appliances:** Nowadays some special sanitation appliances are available on the market. Water saving and wastewater avoidance by water saving armatures, water flow-restriction, limitation devices for toilet flushing, waterless urinals, vacuum toilets and separation toilets decrease the drinking water consumption. Reduced wastewater quantities lower investment costs and increase the effectiveness of treatment plants. Vacuum systems in combination with no-mix toilets allow the separation of faeces (black water) and urine. Urine contains nutrients as N, P, K that can be utilised as fertiliser in agriculture. There is a need to gather experiences of a broader use of such appliances, with respect to cultural particularities, as water- and sanitation-related hygiene practices are very individual and related to education. A further innovative approach of the SWAMP-project will be to start cautiously but seriously a public discussion on sustainable wastewater management.

### Guidelines and scientific objectives

Recommendations for European and national guidelines concerning sustainable water and wastewater management and reed bed treatment systems in tourism facilities in partner countries are prepared. The overall objective of preparing guidelines implies several other scientific and technological subordinate objectives, as the development of a cost-effective water management, reclamation concepts for treated wastewater, separation technologies in sanitation, reed bed treatment systems for wastewater treatment with respect to tourism facilities in remote areas. The work will be accompanied and completed by marketing agencies involved in the project promoting and disseminating the new technologies.

### SWAMP-partners

**AEE Intec**  
Gleisdorf, Austria

**IRIDRA Srl**  
Firenze, Italy

**Ambiente Italia s.r.l.**  
Milano, Italy

**Ökologisches Projekt**  
Graz, Austria

**Carl Bro Latvia**  
Riga, Latvia

**Sia Aprite**  
Cesis, Latvia

**Ingenieurbüro AWA**  
Uelzen, Germany

**Target GmbH**  
Hannover, Germany



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Overview of the Fifth RTD Framework Programme

[www.swamp-eu.org](http://www.swamp-eu.org)

Web site of the SWAMP-project

[www.baltic-soilfilters.de](http://www.baltic-soilfilters.de)

Information on constructed wetlands in rural areas of the Baltic States

## Sanitary systems in Ouagadougou, Burkina Faso: Current practices and future potential

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### Keywords

Domestic sanitation, sanitation providers, urban agriculture, pilot project

### Abstract

This paper aims to establish the current sanitary situation within the formally settled quarters of Ouagadougou. The current sanitary trends will be presented and analysed and a very brief overview of some of the measures considered necessary for the introduction of a closed-loop oriented system of domestic wastewater management in this context will be given.

### Introduction

Ouagadougou is the capital of the land-locked West African Sahel nation of Burkina Faso. The city currently has a population of 1.2 million, with an estimated growth rate of 9.8%. Average temperatures are around 30°C (max. 40° from May – June, min. 19°C from December – January). The city's water supply is reliant on surface water resources, with the major source being the reservoir at Loumbila (30km west of the city), supplemented by three drinking water reservoirs within the city limits. In recent years the national water supplier ONEA (l'Office National de l'Eau et de l'Assainissement) has been unable to ensure a continuous water supply in the dry months of May, June and July, and there is an urgent need for the new drinking water reservoir at Ziga (50km west of the city) to come into service (planned for 2007). Groundwater resources represent a relatively small percentage of the public water supply (10%), due to the hydrogeology of the region. This small percentage is however not unimportant as it represents a relatively reliable fresh water reserve in dry seasons.

At the start of the 1990's a quarter of all illnesses in Ouagadougou were attributable to poor sanitation. The poor sanitary situation was aggravated by the wide range of institutions implicated in the provision of sanitary services and their lack of coordination. Since 1992 a concerted effort has been made by ONEA to improve the city's sanitary situation with the development and implementation of a strategic plan for the "classical" sanitary disposal of wastewater (a central wastewater treatment lagoon for industrial and medical wastewater; VIP latrines and closed greywater soakaway pits for decentralised domestic sanitation; latrine blocks in schools). The original strategic plan for decentralised domestic sanitation was tested during a 3 year pilot phase in two sectors of Ouagadougou, eventually being expanded to the entire population living within the officially recognised city limits (i.e. the sanitation needs of informal settlements are not considered within the plan). Today there remains a huge demand on behalf of the population that sanitary facilities be improved.

During a three-month period, from August to November 2002, the sanitary installations in Ouagadougou were visited with sanitary extension agents of ONEA. These included new or rehabilitated domestic installations as well as older, more traditional means of sanitation. The latest reports on the sanitary situation were collected and analysed and compared to the

findings of the field visits. In addition to establishing the local sanitary situation, the legislative, social and agricultural conditions were examined in order to assess the ease with which ecosan systems would fit into the local context.

Additionally, a very successful ecosan advocacy workshop was organised with decision makers from governmental and non-governmental agencies, and from the fields of sanitation, agriculture, education, research, population participation, women's groups etc. being invited. The aim of the workshop was both to provide information on the possibilities to implement ecological sanitation and to establish the level of interest and opinion of the participants.

## Results

### 1. The domestic sanitary situation

In Ouagadougou, decentralised domestic sanitary installations dominate. The present construction of a sewage network and centralised wastewater treatment lagoon is planned only to serve the city centre, the hospital, the main hotels, and the industrial park. Each individual household is responsible for its own "waste"water management, which is chosen according to the household needs and financial means.

Greywater from domestic use is for the most part disposed of either by allowing it to flow freely across the ground surface, or channelled toward an open soakaway pit. These also serve as depositories for domestic waste and as breeding grounds for disease.



Traditional pit latrines (often doubling as showers) represent around 80% of all toilet facilities, compared to an estimated 70% in 1991 before the strategic plan was introduced. Improved Ventilated Pits, which have been extensively promoted over the last 10 years only represent around 5%. This is due in part to the high construction costs for such a latrine as prescribed by ONEA (approx. 450 Euro, excluding a subvention for the floor slabs, aeration pipe and doors). An estimated 7% of the urban population remain without access to any form of sanitary installation in their courtyards – unchanged from 1991, before the strategic sanitation plan was introduced – and defecate simply in the surrounding environment.

Most homes (around 75%), if choosing to construct a new sanitary installation, will simply engage a local mason who will charge much less than those trained by ONEA to dig an unlined single pit and build the superstructure. These installations, while all being similar, are not constructed

**Figure 1:** A "traditional" pit latrine

according to a particular plan. Pits normally average 4m depth, with exceptions in the area of the drinking water reservoirs, where the high groundwater level has limited this depth to around 2m. Fig. 1 shows a well maintained latrine in a courtyard with 7 apartments. In this case the single pit also serves to collect shower water, and pit ventilation is provided by means of a PVC pipe.

The emptying of latrine pits is most often performed by hand when the pit is almost full, although several firms do also offer a vacuum service (cost around 22 Euros). The contents are either left in a public place to dry completely, after which they are used for gardening/agricultural purposes, or they are taken by the vacuum tankers to the outskirts of town where they are freely dumped or sold to farmers.

No particular anal cleansing method was found to be particularly dominant. Users were equally likely to use water as they were to use paper, pieces of wood, or other material. Along with

receiving the blackwater, the pits are also used to dispose of greywater (from showering), and domestic solid waste, such as plastic bags, broken bottles, used batteries etc. This leads to a rapid filling of the pits with various materials and a highly heterogeneous content.

## 2. Organisational responsibility and legislation

Today, as in 1990, a wide range of both national and communal bodies have a responsibility for sanitation provision, however only ONEA, who charge around 1.5 Euro cent per m<sup>3</sup> of drinking water sold for the collection and treatment of wastewater, appear to have any funds to intervene in the sector. However, while other organisations may not dispose of sufficient funds to finance sanitary measures, they do have responsibilities in this regard. The government ministries involved in sanitation include the Ministries of Water; Health and Social Action; the Environment and Tourism; Basic Education; Secondary and Superior Education and Scientific Research; etc. Added to this are communal authorities that are gaining increased responsibility due to the decentralisation process currently underway, as well as private enterprise and NGOs. No effective coordination between these actors is currently apparent.

This multitude of actors and responsible authorities has contributed to a high degree of uncertainty and intransparency in the provision of sanitation. Often the actors even within government bodies are not aware of the activities / responsibilities of other government bodies.

On a legislative level it is stated that for an individual to obtain a construction permit in Ouagadougou, evidence must be provided that a form of sanitation will be constructed. The type of installation must not be stated, nor are there any formal instructions laid down by the authorities, which could regulate the performance of the sanitary facilities.

## 3. Urban agriculture

Agricultural activity is widespread among the population of Ouagadougou, and can broadly be divided into four different forms:

- a) Officially sanctioned urban agriculture – this is practised for the most part on the land surrounding the drinking water reservoirs within the city limits. 2 main types of cultivation are pursued: Individual gardeners, for the most part women, cultivate vegetables for sale and consumption within the city, while another mainly male group tend tree and ornamental plant nurseries. These groups currently use industrial and medical wastewater collected from the open storm sewers, to irrigate and fertilise their plants.
- b) Inter-domiciliary agriculture – this is practised within neighbourhoods where empty plots of land, sometimes of only a few square metres are planted with a wide range of crops (maize, millet, gumbo, ground-nut etc.) by local people in order to supplement their income/diet. The town council formally forbids the practise.
- c) Agriculture within the confines of a family compound – most families will plant a range of food-crops in their yard to supplement their diet. Crops include maize, possibly millet, peppers etc.
- d) Agriculture on the outskirts of the city – here, agriculture is practiced on a large scale with much of the population having plots where they continue to cultivate, even if they are employed in other sectors.

Due to the scarcity of water resources in and around Ouagadougou, and the expense of mineral fertilisers, many cultivators, in particular those engaged in agriculture as their main source of income, currently use wastewater or the sludge from emptying pit latrines to fertilise their crops.

### **Possibilities to introduce closed-loop sanitation systems in the Ouagadougou context**

The introduction of ecosan principles to the wastewater management in Ouagadougou could play an important role in helping the city's increasing population face the triple threat of poor sanitation, decreasing water quality, and an increasing demand for food. However there are

also several factors that could prevent a successful implementation of the approach. Any intervention should start on a pilot level, identifying potential user who are in need of sanitary facilities and will be able to use the products of an ecosan system (either for their own activities or by identifying a potential market for them). Such groups have already been encountered who have expressed a great deal of interest in closed-loop systems. One proposed model to assist implementation would require action on both a legislative and executive level. Some of the proposed measures are:

**Legislative level:**

- Clearly establish one responsible body that is in a position to oversee sanitary measures and with the political responsibility to carry out its mandate. While not only relevant for the implementation of ecosan systems, this measure is of great importance in order to ensure efficiency of operations.
- Clarify legislation to obtain a construction permit. In order to better control the effects of sanitation on public health, the environment etc. basic guidelines should be given providing the framework of how sanitary systems should perform. Such a framework is envisaged to both regulate the impact of the sanitary system and provide an impetus to private enterprise (who currently provide the majority of installations).

**Executive level:**

- Identify the most suitable sanitary system to serve the needs of the users
- Awareness raising activities to propagate the full range of benefits of a closed-loop system
- Identify markets for the recyclates (whether it is the user or if it could be sold on)
- Investigate the logistical possibilities for transport / distribution of recyclates

Social acceptance for the agricultural use of the recyclates would appear not to pose too great a problem at present, and is in fact preferred by many to the current methods of crop fertilisation. While the environmental benefits of closed-loop systems were welcomed it was the income generating possibilities associated with ecosan systems that provoked a great deal of interest among those questioned (particularly women's groups), and should be considered as a strong motivating factor for participants.

**Conclusion**

Due to an expressed need for improved sanitary facilities, an active agricultural sector requiring low-cost fertiliser, the need to protect surface water resources and the possibility of the creation of income generating activities, a great deal of interest exists in Ouagadougou regarding the implementation of closed-loop sanitation systems.

This interest however faces several problems, such as the costs of introducing new sanitation concepts and systems, unclear institutional responsibility, social practices of using toilets as receptacles for all kinds of waste and a certain resistance to new ideas among those currently promoting other forms of sanitation. A successfully implemented pilot project will help serve to overcome these difficulties.

## Zero emission concept for water and wastewater management, project Rügen, Germany

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### Keywords

Blackwater, case study, decentralized treatment, demonstration project, greywater, reed bed, rural area, source separation, sustainable sanitation, vacuum toilet, water saving, zero emission.

### Abstract

A sustainable sanitation concept will be realized at a visitors centre in the national park JASMUND on the isle of Rügen, Germany. Main idea of the zero-emission concept is source separation of faeces. Blackwater will be collected by vacuum toilets and reused via a biogas plant and agriculture. Greywater will be treated on-site by reed bed technology and recycled for toilet flushing and watering. Rainwater will be throttled on-site and infiltrate in a nearby forest. In comparison to conventional wastewater management (3km duct to public sewer or decentralized treatment of unseparated wastewater) cost reduction of 25 percent are estimated.

### Introduction

The environmental foundation World Wide Found for Nature (WWF) Germany and the city of Sassnitz are realizing the reconstruction of a former military base into a visitors centre. The project is located in the smallest German national park Jasmund on the isle of Rügen in the very north-east of Germany. The visitors centre will consist of ecological exhibition and restaurant. Up to 1.000.000 persons per year and up to 4.000 persons per day are expected to visit the location close to the famous chalk-cliff (figure 1).



**Figure 1:** Crowd puller chalk-cliff



**Figure 2:** Visitors centre

The planned shape of the building 120 m above sea level is shown in figure 2.

### Present situation

After feasibility studies in 1998 the centre is under construction at the moment and will open in 2004. During former use of the area wastewater from public restrooms and restaurant was partly discharged to the Baltic Sea after sedimentation and partly transported to municipal treatment plants by tanker. The public sewer is in a distance of 3km.

Freshwater is taken from a nearby spring. Due to the little flow especially during summer months and for ecological reasons the water consumption has to be reduced to a minimum.

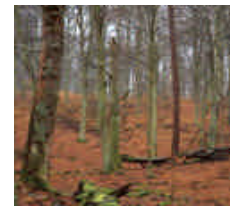
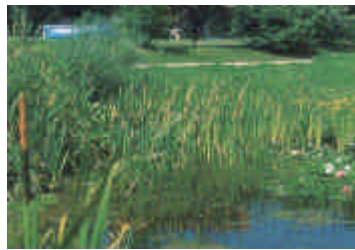
### Zero emission concept

Water supply and wastewater management bases on the idea of source separation and recycling of substances and water. Another goal is to prevent any pollution in the surrounding ecosystems of the national park and the Baltic Sea. Furthermore the change of water balance of the area has to be reduced to a minimum.

Main idea of the concept is the separate drainage and treatment of

- rainwater
- greywater and
- blackwater.

**Rainwater** will be collected in a pond on-site and throttled to the natural flow. It infiltrates in a nearby forest.



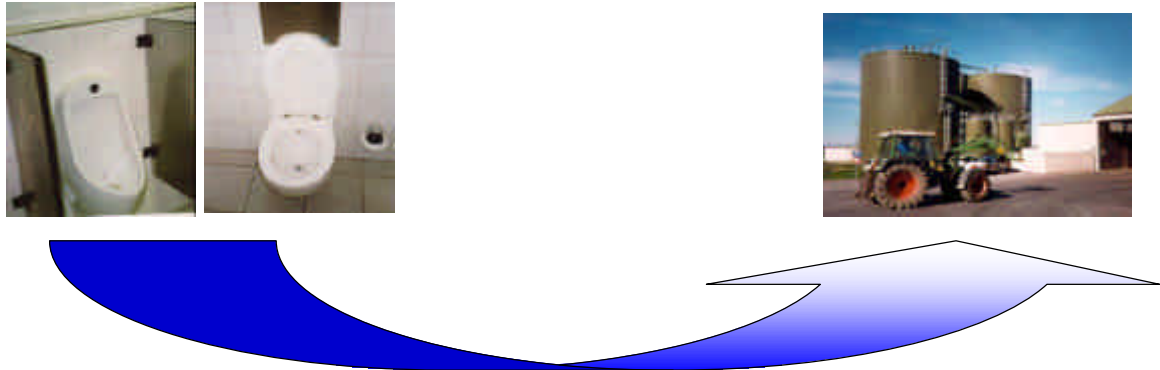
**Greywater**, mainly from washbasin, will be treated by reed bed technology on-site and recycled for toilet flushing and watering.



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**Blackwater** will be collected by vacuum toilets and is stored on-site. Transportation takes place by tanker to a nearby existing biogas-plant. After fermentation the substrate will be used as fertilizer in agriculture.

Rainwater will be mainly drained in shallow trenches and collected on-site in a pond. To reduce erosion and to maintain the natural local water balance from this pond a throttled flow of rainwater will be discharged to infiltration in nearby forest.



Less polluted wastewater without faecal contamination (grey water) will be treated by a reed bed (vertical flow constructed wetland). The soil filter planted with reed was designed on the water and organic load on the basis of experiences gained with treatment of greywater in projects in Berlin and Hanover. The treated greywater is used for toilet-flushing and watering. Surplus water will be discharged together with the rainwater.

High polluted wastewater (dishwater, etc.) and wastewater from vacuum-toilets and urinals (blackwater) will be stored on-site. Transportation takes place by tanker to a nearby existing biogas-plant. After fermentation the substrate will be used as fertilizer in agriculture.

### Conclusions and results

Based on a detailed analysis of the fluxes of water and nutrients, investment and running costs the effects of ecological sanitation compared to conventional solutions were quantified:

- Reduction of demand of drinking water of about 80%:
  - 5 percent by water saving fittings (2.5 litre per min at washing basins)
  - 12 percent by dry urinals
  - 43 percent by vacuum-toilets
  - 21 percent by greywater-recycling
- No emissions to the Baltic sea and the surrounding ecosystem
- Recycling (agricultural use) of 750kg nitrogen and 150 kg phosphorus each year
- Production of 1.900 m<sup>3</sup> biogas each year
- Negligible change of local water balance
- 25 % reduction of costs (investment and running costs)

As shown in this example ecological sanitation is not only advantageous for environment but even cheaper than conventional (end-of-the-pipe) solutions.

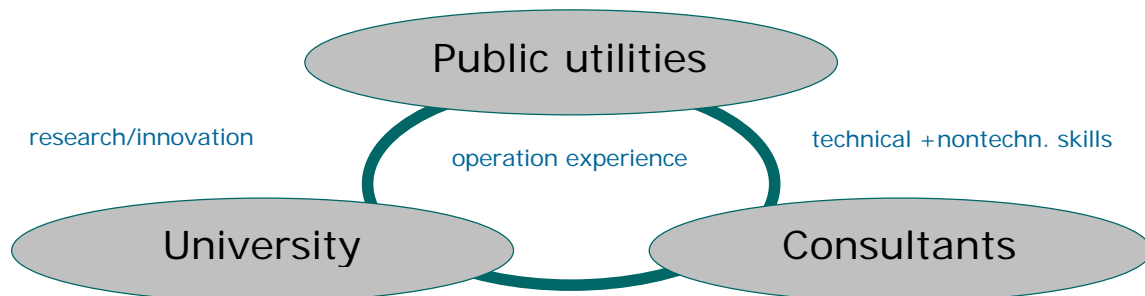
### Other ongoing and future ecosan-projects of "aquaplaner"

Apart the zero-emission-concept Sassnitz the following ecosan-projects of the *aquaplaner* engineering office are in preparation. Depending on the local conditions different combinations of ecosan-techniques will be realized.

Ecological sanitation and water management for:

- Museum in Egypt (7.000 visitors daily)
- Housing estate in Darmstadt (400 inhab.)
- Housing estate in Hannover (750 inhab.)

Future projects will be offered in cooperation with the association „WATER HANNOVER - Centre for sustainable water management“.



WATER HANNOVER is a network of consultants (e.g. engineering offices), Public utilities of water supply and wastewater drainage and university.

The aim of WATER HANNOVER is to offer independent integrated consulting services world wide. In comparison to conventional consulting offices social aspects, operation experience and education of local personal are included. By this holistic approach WATER HANNOVER is the ideal partner for planning of sustainable projects.

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## Possibility of sustainable sanitation in Japan

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### Keywords

Sustainable sanitation, eutrophication, domestic wastewater, dry-toilet

### Abstract

Sustainable sanitation is an approach from the actual sanitation to improve the environmental protection and resources. The flushing toilet, brought by modernization to make our life comfortable, is considered as sanitary by us.

However, nitrogen and phosphorus that are not removed through the conventional sewage disposal plant, pollute highly the water.

It is obvious that the sewage contaminates underground water, river, lakes, marshes. Furthermore, the current sewage disposal plant, which cannot remove those nitrogen and phosphorus, is causing a serious problem of eutrophication in lakes and marshes.

Many kinds of dry-toilets have been developed as reported in the last conference. In this paper, we understand how high and evident is the efficiency of the so-called dry-toilet in water saving and water quality.

### Sustainable sanitation example (Nagasaki city, Japan)

There is a house situated in the city of Nagasaki using separation distributed processing system of domestic wastewater. Human excrement is treated by bio toilet, and gray water is treated by septic tank. This system has been in use now for one and half year. Just one technical problem occurred to the agitator in the bio toilet treatment tank. However, it is working smoothly. In this house, the garbage is also carried into the bio toilet to be treated. We can tell that this system is contributing highly to the reduction of the refuse. We are planning to carry out a quantitative investigation to reveal exactly the rate of nitrogen and phosphorus found through this system.



**Figure 1:** sustainable sanitation example



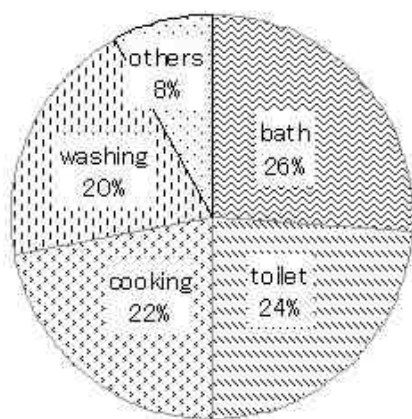
**Figure 2:** bio toilet treatment tank

**Proportion of pollution coming from human excreta in domestic wastewater**

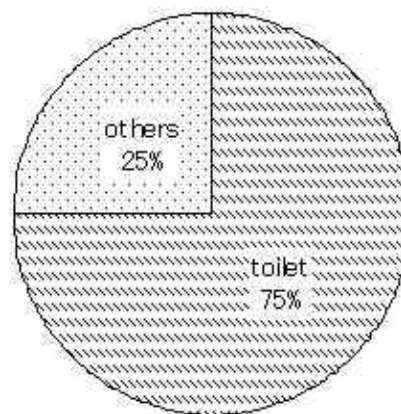
According to an investigation conducted by the Tokyo Water Authority, the amount of the water used of a toilet is 24% of the whole domestic water use (see fig3). But, the proportion of pollution by human excrement in domestic wastewater is 75%. (see fig4) In regards to this high rate of pollution, it is urgent to introduce a system separating the human excrement from the domestic wastewater in order to save the quality of the water.

Through this process, the excreta can be carried out and used in an effective utilization. It will contribute greatly to load off the water area.

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**Figure 3:** Proportion of quantity



**Figure 4:** proportion of quality

### Comparison of the contaminant curtailment effect

The main processing method of human excreta in use in Japan are various: sewage disposal plant, human excreta treatment plant, combined septic tank, individual septic tank, sea dumping, etc.

Then, a comparison study on environmental pollution in public river basin has been conducted. For this study, an advanced wastewater treatment system that includes a bio-toilets has been used.

When considering the environmental load through this treatment-Off-human excreta system, we should take into account all the environmental load items, from the design to the disposal system. However, we evaluated the BOD, T-N and T-P contained in wastewater. The result is shown on table 1.

We used the following fiducially points regarding the design of a human excreta septic tank in the calculation of human excreta and drainage from household.

- a) and b) are widely used in the actual process which does not separate human excreta from the domestic wastewater.
- c) Treat only human excreta.

An individual septic tank has a very loose effluent standard. (BOD90ppm) As the domestic wastewater is discharged without being treated. This is a very serious problem. Therefore, Private Sewerage System Law has been revised and the establishment of an individual septic tank is now forbidden. This law took effect on April 1st, 2001. However, all individual septic tanks have not been put yet out of use. In Nagasaki prefecture, 7.3 % of the whole processing methods of human excreta is an individual septic tank method.

- d) The dipping-up system is used as well. In this case, human excreta is carried to the treatment plant. Like for the individual septic tank, domestic wastewater is discharged without being treated.
- e) System based on the concept of sustainable sanitation.

Human excreta are treated in a merger dry-toilet, and domestic wastewater in a septic tank. By separating human excreta from domestic wastewater, the burden concerning the treatment equipment can be reduced greatly. We estimate that this system can replace the system described in c).

	BOD	T-N	T-P
a) sewage disposal plant	4.0	6.0	0.7
b) combined septic tank	4.0	6.0	0.7
c) individual septic tank	31.5	10.0	1.0
d) human excreta treatment plant	27.5	2.5	0.4
e) sustainable sanitation	3.0	1.4	0.2
f) advanced process in the sewage disposal plant	2.0	2.0	0.2

(Unit:g/person·day)

**Table 1:** comparison of the contaminant curtailment effect

- f) We assumed performing advanced process in the sewage disposal plant. This system is carried out in about 13 disposal plants, such as Lake Biwa, Kasumigaura, etc which discharge drainage to a lake.

As mentioned above, according to the result of the comparison study, in the system using the bio-toilet we propose, it shows that discharged water quality is equivalent to the same than the quality from an advanced wastewater treatment institution, in regards to the BOD T-N, and T-P.

### Conclusion

It cannot be said that in small and medium municipalities where density of houses is low, the cost of the investment will be reasonable. Though the sewerage is a suitable method in large cities with a high density of people, medium and small size cities should examine a method of treatment adapted to the needs of each area.

In the regions where sewage-treatment plant is used, as mentioned in this paper, the water pollution from human excreta is a major problem. It is necessary to consider a new toilet system.

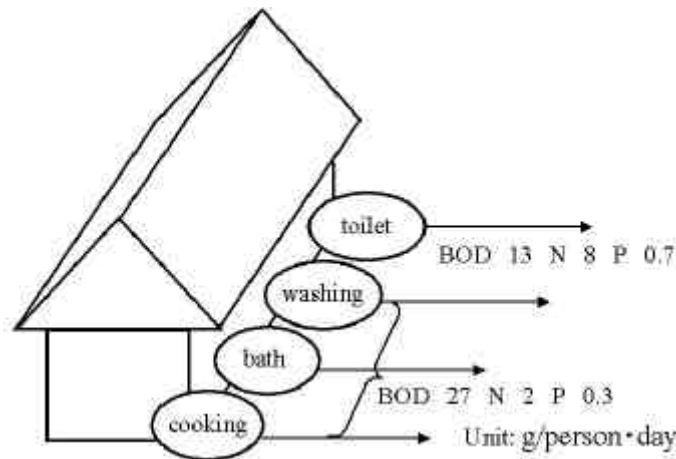


Figure 5: separated treatment for domestic wastewater

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