Project work

Evaluation of ecological sanitation pilot facilities in Senegal and Mali

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SUMMARY

Evaluation of ecological sanitation pilot facilities in Senegal and Mali

In many countries in the world serious problems such as water scarcity and pollution, no or poor sanitation facilities, lack of fertilizer, lack of food and soil degradation are prevailing. Due to these problems many people suffer and with conventional end of the pipe systems these problems can not be solved. One solution for a number of problems is the Ecological sanitation approach where nutrients and water can be reused for agricultural use in a sustainable way and disease spread is prevented .

Background of this study thesis was the evaluation of ecological sanitation plants in urban Senegal and semi-urban Mali. In Yoff (Senegal) the pilot station was built in the year 1999 by an local organisation called APECSY which is trying to create an sustainable urban district. The ecosan toilet which is working on the composting process also diverts the urine from the faeces. Here the urine is lead together with the washing water into a reed bed and finally used for watering a garden area.

In Koulikoro (Mali) seven ecosan stations were built by the GTZ in the years 2000-2001 which base on the dehydration and urine separation process. As special feature the urine is lead together with the washing water into a wastewater garden basin by subsurface irrigation pipes.

The specific concern of this work was the research and evaluation of the constructions in the prevailing region regarding the operation, organisation, user sensation and soco-cultural acceptance. This was done by means of thoroughly inspections of the construction itself, the preparing of questionnairs for the users accompanied with discussions.

Besides the plant specific problems general problems could be observed. These problems start in the very beginning of the project with the wrong planning of the installations, e.g. wrong slope of dessication chamber or unsuitable toilet hole placing. This proceeds to the lacking educational program and ends in the non-existing aftercare of the project resulting in a partial failure of it

In summary it can be stated that the users are very satisfied with the new sanitation concepts which showed a lasting improvement of the living standards.

RESUME

Évaluation des installations pilotes Ecosan au Senegal et Mali

Dans beaucoup des pays dans le monde il y des problemes sérieuse comme la pénurie et la pollution des eaux, non ou mauvaise installations sanitaires, manque au engrais, manque de la nourriture et la degradation des sols . En raison de cettes problèmes beaucoup des personnes souffrent et avec les installations sanitaires conventionnel il y pas de solution pour ca. Une solution pour beaucoup des problèmes c'est l'idee de assainissement écologique où les substances nutritive et l'eau sont recylé pour l'agricoulture dans un moyen durable et avec la destruction des agents pathogènes.

La toile de fond de cette project était l'évaluation des installations sanitaires eocsan au urbain Senegal et semi-urbain Mali. À Yoff (Senegal) l'installation pilote ètait construé l'année 1999 d'un oraganisation locale avec le nom APECSY. L'APECSY essaye de créer un district urbain durable. Le toilette ecosan que travaille avec processus de compostage aussi sépare l'urine et les fécales. L'urine et

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ABBREVIATIONS AND GLOSSARY

APECSY	Association Pour la Promotion Economique Culturelle et Sociale de Yoff (Association for the economic, cultural and social promotion in Yoff)
DALY	Disability Adjusted Life Years
ecosan	Ecologically and economically sustainable wastewater management and sanitation concepts
Sida	Swedish International Development Agency
WHO	World Health Organisation

Black water	water that contains human excreta
Grey water	water generated from food preparation, bathing, washing (household + washing water)
Yellow water	urine or urine with water
Household water	water generated from food preparation and cloth washing
Washing water	water generated from bathing and washing

1. INTRODUCTION

In the world today, 3 billion people are without proper sanitation and over one million tons of human faeces are produced each day, 50% of which remain uncollected. [Peasey, 2000] In many regions of the world problems of water scarcity and water pollution severely lower the living standards, cause diseases and deaths. People in the most parts of the world are dependant on surface or groundwater. These waters often have a poor quality which is steadily deteriorating, due to a lack of proper sanitation and sewerage systems (see figure 1-1) and inefficient solid waste management. Many sewers still end in receiving waters, and treatment plants are either never build or do not function. Raw faecal matter in receiving waters adds to the WHO-estimated death toll from polluted waters, which exceeds five million people a year.

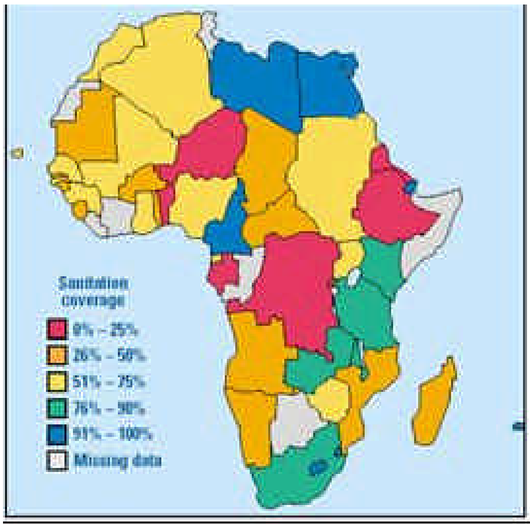


Figure 1-1*: Sanitation coverage in Africa 2000 (WHO, 2000)*

The above desribed scenario often is prevailing in urban and peri-urban areas of developing countries where the supply of clean drinking water and sanitation services are non existing or inadequate. This is often due to several factors which include inadequate fincancial resources, insufficient or polluted water, lack of space, difficult soil conditions and limited institutional capabilities [Esrey et al, 1998]. In future this problem will grow worse because of the constant rural exodus leading to growing mega cities where sustainable, safe and affordable sanitation will be more and more critical to achieve.

One solution for a lot of problems depicted above is the concept of ecological sanitation where human waste and wastewater is recycled in a hygenically sound closed-loop. With the system it is possible for agriculture to recover nutrients from human waste thus enhancing soil fertility, establish a substainable food production and prevent water contamination.

1.1. AIM OF THIS PROJECT

The system of ecological sanitation has been succesfully implemented in a number of countries with modifications to satisfy the economic, religious and social conditions prevailing. From the large number of existing ecosan systems (see Esrey S. et al, 1998) the appropriate one has to be choosen in order to guarantee an adequate and improved situation for the users. This is normally done by the construction of demonstration plants connected with an educational, long-term research and development monitoring program.

For this project an evaluation of pilot plants in Yoff (Dakar, Senegal) and in Koulikoro (Mali) should be conducted which were built in the years 1999-2001. The main interest in the research and evaluation programm was to investigate the type of ecosan installation constructed in the prevailing region regarding the operation, organisation, user sensation and socio-cultural acceptance. This was done by means of thoroughly inspections of the construction itself and the preparation of questionnairs for the users accompanied with discussions.

The aim of this evaluation had been to find out how the systems work after a period of approximately two to three years. This included the discovery of problems resulting of wrong planning or construction (not adequate for the situation, too expensive, not working correctly etc.), bad or missing educational programs or lack of participation.

With the results of the above mentioned problems proposals for the improvement of the systems should be made. Therefore the installations and operation of the system are explained in detail in order to give solutions for the existing problems.

During the evaluation work general problems were discovered connected to the implementation of new technology especially ecosan systems. These general problems are depicted and solutions are provided.

1.2. SANITATION IN WEST AFRICA

It is predicted that Africa will face an increased population growth over the coming decades (65% over the next 25 years), with the greatest increase coming in urban areas. This presents a huge challenge to services in the region. As depicted in table 1-1 and figure 1-2 the situation concerning water supply and sanitation coverage in Senegal and Mali is not satisfying. In order to meet the 2015 international development target for sanitation, an additional 211 million people in urban areas and 194 million people in rural areas will need to be provided with access. This will require that four times as many additional people gain access to improved sanitation between now and 2015, as additionally gained access between 1990–2000. [World Health Organisation and United Nations Children's Fund 2000]

***Table 1-1**: Sanitation coverage in Senegal and Mali 1990 and 2000*

	Year	Total population (x 1000)	Urban population (x 1000)	Rural population (x 1000)	% urban sanitaion coverage	% rural sanitation coverage	% total sanitaion coverage
Senegal	1990	7 327	2 933	4 394	86	38	57
	2000	9481	4 498	4 983	94	48	70
Mali	1990	8 843	2 105	6 738	95	62	70
	2000	11 234	3 375	7 859	93	58	69

[World Health Organisation and United Nations Children's Fund 2000]

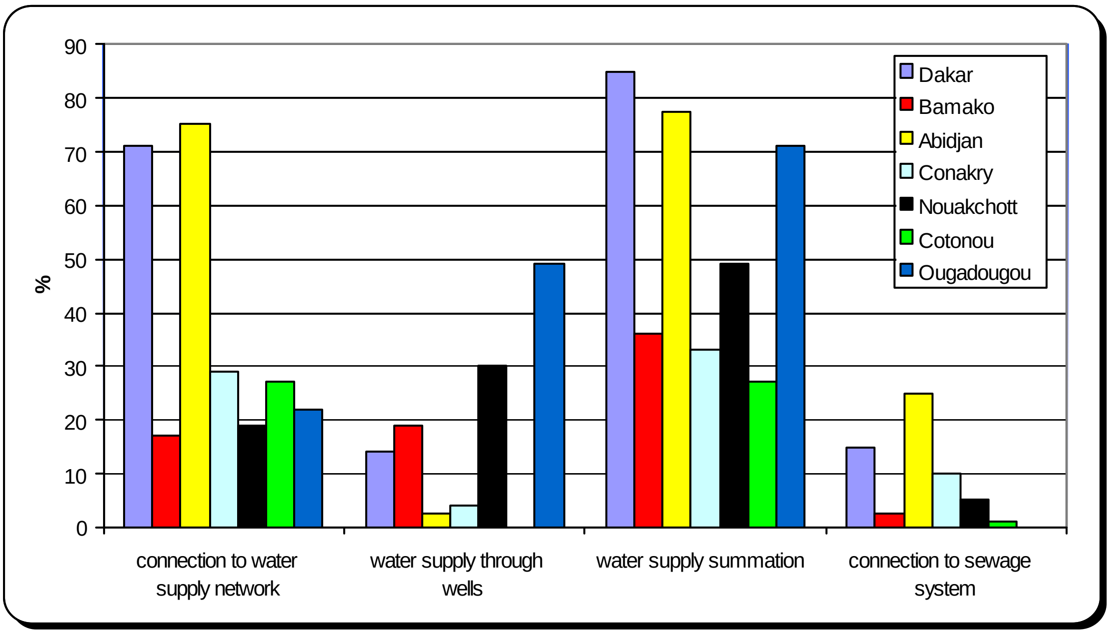


***Figure 1-2**: Percentages of drinking water acces and sewage drainage connection in capital cities in West Africa [Malick et al, 2002]*

In figure 1-3 the distribution of different types of sanitational installations in Africa, Asia and Europe is depicted. It can be seen that in Afrika a large percentage of people have no acces to toiltes (unserved) or use simple pit latr ines which poses a dangerous health risk to the population.

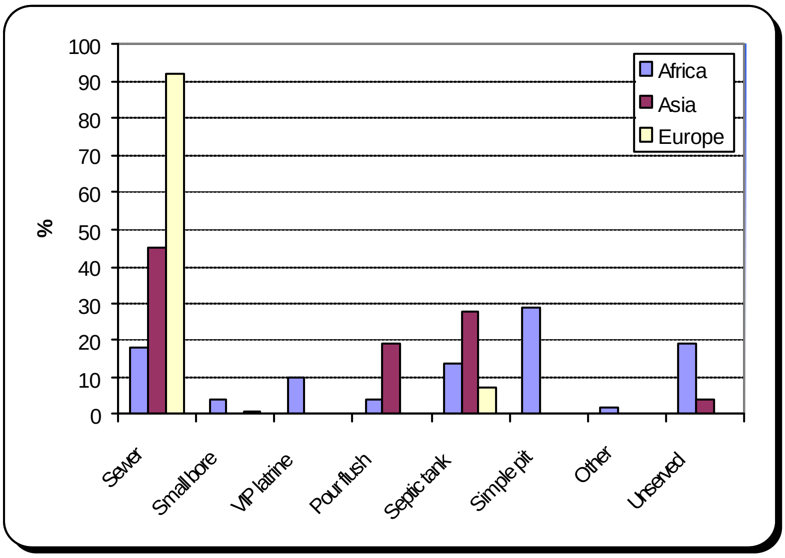


Figure 1-3*: Sanitation in the largest cities: mean percentage with each type of facility, by region [modified from World Health Organisation and United Nations Children's Fund, 2000]*

SENEGAL

Figure 1-4*: Sewage lead into the ocean*

In the table 1-1 above it seems that there are only few problems with the sanitation in urban areas in Senegal and Mali (94 % and 93%) . But even when the sanitation coverage percentage is high there i s a lack of proper sanitation or the eventual disposal of sewage respectively . In Dakar which is a city of nearly 2.5 Million inhabitants the central sewage treatment plant purifies only around 14.000 m^3 per day; most of the sewage is discharged directly i nto the sea by open channels. (see figure 1 -4)

The majority of the houses in urban areas are equipped with on-plot systems like septic tanks (close tanks) which are emptied from time to time. The second alternative are open septic tanks where the liquid p hase is able to seep into the under ground (open tanks) which leads to a prolonged emptying cycle and to a severe groundwater contamination.

For the desludging process of the septic tanks a vehicle pumps out the contents to bring them to the sewage treatme nt plant for purification. This normally not happens but the sewage is lead directly into the sea , a hole is dug at the beach or in the road during the night into which the sewage is emptied (see figure 1-5 and 1-6).

Figure 1-5*: Sewage dump at the beach*

Figure 1-6*: Sewage hole in the road*

Another sanitation problem is connected to the increasing poverty especially in large cities. Growing numbers of people in the cities live without proper housing and thus often no or only simple means of sanitation are provided. These people normally have to defecate in the nature or dig out the content of the pit latrine manually which poses a serious health hazard.

MALI

In rural areas in Mali it is nearly the same situation as in Senegal with the difference that in larger cities like Bamako open drainage channels are common. These drainage channels often are blocked with rubbish and other material leading to standing sewage in the system.

Figure 1-7*: Drainage on the street in rural Mali*

In rural areas pit latrines are common but open defecation also takes place in more poor regions. Household water and overflowing latrines like in figure 1-7 can be seen in all rural areas. These waters pose health risks especially for children playing in them and are leading to the deterioration of living standards for the population.

1.3. DISEASES RELATED TO SANITATION

The human excreta contains germs, eggs and other living organisms; disease causing organisms are called pathogens and parasites. The majority of them are found in faeces. Urine is usually sterile and poses a risk only in special cases [1]. The major pathogens which use urine as significant route of spreading can cause typhoid, paratyphoid and bilharzia. [Jönsson et al., 1999] Urine is a major source for the spread of bilharzia. Faeces are the major source of pathogens for typhoid and paratyphoid even when they are found in urine. Pathogens and parasites found in human excreta can result in a wide variety of illnesses, incluing diarrhoea and malnutrition. Poor growth, iron deficiency, vitamin A deficiency and other micronutrients deficiencies also occur, with the effects sometimes lasting a lifetime. Not all pathogens and parasites result in death but the continual debilitation of disease and malnutrition predisposes people to disease or ill-health and death from other causes.

In fresh faeces there are four main groups of organisms of concern to humans: bacteria, viruses, protozoa and helminths. These organisms once excreted:

- may be immediately infectious;
- may require a period of time outside of the body to become infectious; or
- may require an intermediate host before becoming infectious.

Bacteria and viruses are immediately infectious once excreted. Protozoa are excreted primarily as cysts, and can be immediately infective or require a period of time outside the body. The eggs of helminths, many of which are resistant to environmental conditions, require a period of time outside of the body. Some parasites, such as bilharzia, also require an intermediate host before becoming infectious. [Esrey, S. et al, 1998]

When a person excretes pathogens which are not contained or destroyed, the environment becomes contaminated. Once human excreta gain access to the larger environment (see figure 1-8), they can contaminate fingers (hands, clothes and utensils), fluids (e.g. drinking and cooking water, beverages and other water bodies), fields (e.g. vegetables and household yards) and flies (e.g. houseflies and blowflies, domestic animals and snails).

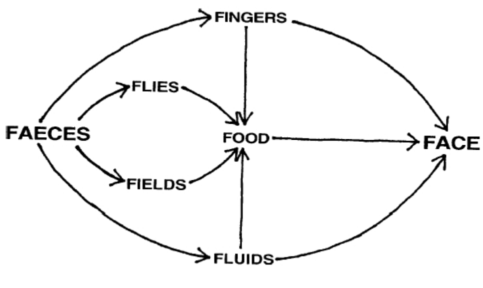


***Figure 1-8**: The f-diagram presents multiple routes of transmission of multiple pathogens* [Esrey, S. et al, 1998]

[1] For a more complete description of each of the above pathogens and diseases see for example Beneson AS (ed) (1995): *Control of communicable diseases manual*. American Public Health Association, Washington DC, USA.

A contaminated environment puts people at risk of exposure to the pathogens, leading to infection and disease. Newly infected people then excrete into the environ ment and there is a repeated cycle of infection, contamination and infection. In table 1-2 the mortality and DALY [2] estimates related to water and sanitation diseases can be seen.

Table 1-2: *Water and sanitation related diseases*

Disease	Mortality estimates for 1999	DALY estimates for 1999
Faecal-oral		
Diarrhoeal disease	2.213.000	72.063.000
Poliomyelitis	2.000	1.725.000
Water-washed		
Trachoma		1.239.000
Water based		
Schistosomiasis	14.000	1.932.000
Water-related vector		
Malaria	1.086.000	44.998.000
Lympahtic filariasis		4.918.000
Dengue	13.000	465.000
Intestinal nematode infections	16.000	2.653.000
Sum	**3.440.000**	**2.020.560.000**

DALY - Disability Adjusted Life Years [Hunt, 2001]

The spread of pathogens can be reduced or stopped by using barriers to prevent them moving from one place, such as the ground, to another (fingers, food and/or water, see figure 1-9). A primary barrier would prevent faeces from reaching fingers, flies, fluids, fields and foods; it would prevent the spread of pat hogens. However, if pathogens gain access to fingers, foods and so on, secondary barriers (e.g. washing hands with soap or ash, cooking food) must be relied upon to prevent exposure.

Once excreta leave the body and before they gain access to the larger environment there are a number of options for preventing the spread of pathogens. The traditional approach is to flush away the excreta (flush-and-discharge) or to store it in a deep pit (drop-and-store). These disposal methods lead us to believe that envir onmental contamination has been prevented. However, this is a false belief as over time the contents of the pit may leak into the groundwater, be washed out by ra in or pose the risk when eventually emptied.

In the flush-and-discharge system the sewage can be treated adequately but in the most cases are discharged totally untreated or only partly treated so that the pollution problems spreads downstream.

[2] The summation of healthy life year s lost due to disability and mortality. Life years lost due to disability are computed by adjusting age-specific life expectancy for loss of healthy life due to disability. The value of a year of life at each age is weighted, as are decrements to health fr om disability from specific diseases and injuries and future life years are discounted [Gold M.R., Siegel J.E., Russel L.B., Weinstein M. (eds). (1996) Cost-effectiveness in health and medicine. New York: Oxford University Press]

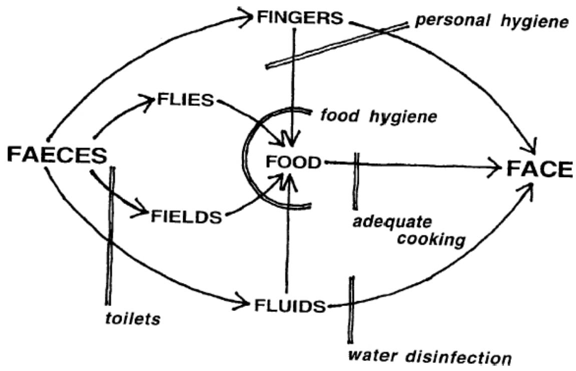


Figure 1-9*: The f-diagram with barriers to prevent spread of pathogens [Esrey, S. et al, 1998]*

1.4. PATHOGENE REDUCTION

Each time many thousands or even millions of pathogens or parasite eggs are excreted in faeces. However, after they are excreted into the environment all pathogens eventually die or become incapable of causing disease. Some organisms remain alive and capable of causing disease longer than other organisms of the same type.

The time it takes for all the organisms of the same type to die is referred to as the die-off rate, which varies for each pathogen. Two exceptions are salmonella and some other bacteria, which may temporarily increase in number outside the body; and the eggs produced from those parasitic worms with developmental stages. Eggs from most worms do not increase in number, but they take a longer time to die than other pathogen types.

A number of environmental conditions (see table 1-3) will speed up or slow down the time it takes a pathogen to die, depending on the characteristic or level of the condition. The major conditions considered to be important for die-off are: temperature, moisture, nutrients, other organisms, sunlight and pH. Each of the conditions can vary naturally or artificially which means that the time it takes a pathogen to die-off can be increased or decreased from the average die-off time. [Esrey, S. et al, 1998]

Table 1-3*: Environmental conditions accelerating the death of pathogens*

Environmental factors	How
temperature	Increase in temperature
moisture	decrease in moisture
nutrients (organic matter)	decrease in nutrients
microorganisms (including other pathogens)	decrease in organisms
sunlight	increase in sunlight
pH	increase in pH

[Esrey, S. et al, 1998]

Bacteria, viruses and protozoa usually die-off within several months, sometimes less. Helminth eggs survive for many months, and eggs of the species Ascaris can survive for years. Of the methods for pathogen destruction, high temperature composting is best able to destroy most pathogens quickly but in reality it is difficult to achieve. This means that some pathogens may survive.

It is generally assumed that if the pathogens most resistant to destruction are destroyed effectively, then all other pathogens will also be destroyed. Two pathogens that meet these criteria (widespread and resistant to destruction) are Ascaris lumbricoides, (the common roundworm) and Cryptosporidium parvum (a type of parasite, protozoon, that causes diarrhoea).

Cryptosporidium parvum cysts have been shown to be very resistant to destruction. They may even survive environmental stress, such as freezing, high temperatures, and water treatment with chlorine and ozone, better than Ascaris.
In tests it was shown that the most effective methods to destroy Ascaris eggs and C. parvum were drying and heat. [Esrey, S. et al, 1998]

1.5. ECOLOGICAL SANITATION - A SOLUTION

Ecosan which means "ecologically and economically sustainable wastewater management and sanitation" is an alternative to the linear wastewater disposal concepts used worlwide nowadays. It simultaneously addresses the three environmental and health threats of water scarcity, lack of fertile land and water pollution and is promoted as an appropriate technology for community settings especially in developing countries without sewerage or plentiful water. The ecosan idea is based on an ecosystems approach where the nutrients and organic matter contained in human excreta must be considered as a resource which can contribute to food-production systems after proper treatment. The recovering and recycling of nutrients are done in a safe and non-polluting way, with zero discharge leading to the closure of the nutrient cycle (see figure 1-10). The basis of ecosan is the integration of the non-mixing of excreta and urine in a dry toilet, also called dry sanitation or urine diversion systems. It has been heralded as solving many of the problems encountered with other sanitation systems. These include fly breeding, smell, groundwater contamination, short pit life and pit collapse. It is also claimed to achieve sufficient destruction of disease-causing organisms (pathogens) to enable safe handling of faeces. Reviews in the literature have reported on the variety of technologies adopted around the world according to local conditions.

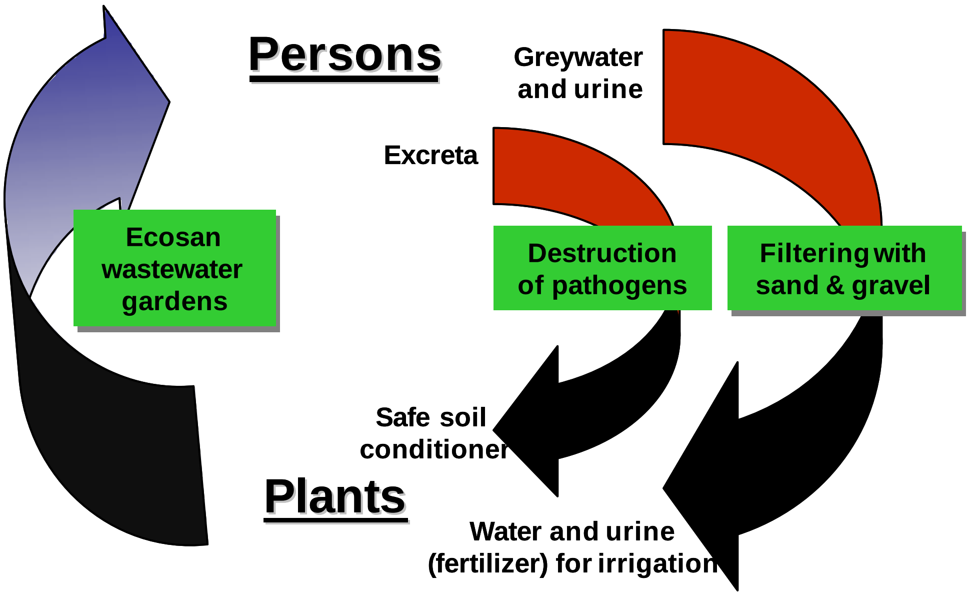


Figure 1-10*: Closing the cycle: Ecological sanitation and urban agriculture*

1.5.1. ECOSAN SYSTEMS

In recent years a great number of ecosan systems have been implemented around the world. Most of them in developing countries as low -tech or medium -tech solution but likewise in industri alised countries as high -tech concept. A ll of those systems , to a certain extent, meet the criteria of

- disease prevention,
- environment protection,
- return of nutrients,
- acceptability,
- affordability and
- simplicity.

The variety of these systems which are explained in the book "Ecological Sanitation " by Esrey et al. 1998 makes it possible for the most cases to find one that is appropriate for the prevailing conditions. The most ecosan toilets consist of two chambers. One chamber is used for approximately 6 -12 month, depending on the climate and the after processing of the substrate. After this time or if the chamber is full it is sealed and the second chamber is used for the same time. When the second chamber is full as well the contents of the first, which are a path ogene free dry substrate can be easily emptied. Th en the cycle starts again. Usually the nutrient rich and patho gene free urine is diverted and used in different ways . In the following the two basic principles used to achieve pathogene destruction are desribed shortly.

1.5.1.1. ECOSAN TOILETS BASED ON DEHYDRATION

Toilets based on the process of dehydration generally do not mix the faeces and urine because it would be rather difficult to dehydrate the faeces without urine diversion. The moisture content should as quickly as possible be brougth down to below 25% [Esrey, S. et al, 1998] where a rapid pathogen destruction, no smell and no fly breeding takes place.The urine is diverted and either collected (direct use or strorage) or flows into a soak-pit or garden. The faeces are collected in one of two chambers below the toilet seat and are dried by the addition of lime, ash or earth to the chamber after each defecation. Once the chamber is full, it is sealed and the other chamber is used. When the second chamber is full, the first chamber is opened. The contents of the first chamber are removed and used as a soil conditioner, buried or composted depending on the circumstances.

1.5.1.2. ECOSAN TOILETS BASED ON DECOMPOSTION (COMPOSTING)

Toilets based on the process of biological decomposition use bacteria, funghi, algae, earthworms or other organisms to break down the faeces, producing compost. Many designs permit (or recommend) the addition of other organic matter such as vegetable scraps, straw, wood shaving or coconut husks. The temperature and airflow are carefully controlled in such designs to optimise conditions favourable for composting. It is important that airflow is sufficient to maintain aerobic conditions in the faeces pile. The material in the composting vault should have a moisture content of 50-60%, the carbon:nitrogen balance should be within a range 15:1 to 30:1 and the temperature should exeed 15° C. [Esrey, S. et al, 1998] The end-product compost is a excellent soil conditioner, free of human pathogens when the right conditions are achieved and adequate retention time is allowed in the digester. In Esrey, S. et al, 1998 it is stated that composting systems could often benefit from urine diversion although most examples of composting toilets collect urine and faeces together. Since the urine is contaminated with pathogens once it has had contact with the faeces, it is more problematic to use it directly as fertilizer and it must be dealt with in some other way. Some composting systems allow the separated liquid to infiltrate into the ground, while others have adopted strategies to get rid of it through evaporation. While much of the nitrogen in urine is lost in composting systems, the resulting humus, or compost, retains other nutrients and is a valuable soil conditioner.

1.5.2. RECYCLING OF NUTRIENTS

Ecological sanitation is the conversion and reuse of faeces and urine for productive purposes. Normally faeces and urine are seen as wastes that need to be disposed of down pits or through sewers thus polluting the environment. The idea of ecological sanitation is that faeces and urine are actually resources which when properly used, can return nutrients to the soil and plants, reduces the need of chemical fertilizer, restores good soil organisms to protect plants, increases crop yields and strengthen the soil's water holding capacity.

The nutrients contained within faeces and urine (see table 1-4) are frequently of better quality than the commercial fertilizer s being applied – at great cost – to crops throughout the world. Even if commercial fertilizer s were cheaper and easily accessible to the poor, other hard questions are being asked about the long -term consequences of commercial fertilizer application such as the dangers of polluting rivers and the reduction in the carrying capacity of the land over time. Ecosan there fore offers a viable, low -cost and sustainable alternative to the limitations of commercial fertilizer s as well as an effective means to eliminate harmful excreta from the immediate environment. [Breslin et al.]

***Table 1-4**: C-, N-, P- and K- contents of Black- Yellow- and Greywater*

	org. Carbon [kg/p*a]	**Nitrogen (Kjeldahl) [kg/p*a]**	**Phosphorus [kg/p*a]**	**Potassium [kg/p*a]**
Blackwater (faeces)	17,00	0,50	0,20	0,17
Yellow water (urine)	6,00	5,00	0,40	1,00
Greywater	5,50	0,30	0,50	1,10

[Otterpohl et al , 1999]

During the last years various composting systems have been developed in different countries. The end product - humus - is a valuable soil conditioner but much of the nutrient value is lost during the composting process. As seen before the best way to rec over the soil conditioning qualities of the faeces and the high nutrient content of the urine is to collect them separately.

1.5.2.1. URINE

Most of the plant nutrients in human excreta are found in the urine. An adult may produce about 400 litres of urine a year containing 4.0 kg of nitrogen, 0.4 kg of phosphorus and 0.9 kg of potassium. Interestingly, these nutrients are in ideal forms for uptake by plants: nitrogen in the form of urea, phosphorus as superphosphate and potassium as an ion. The total quantities of nutrients in urine are more appropriate when compared with the quantities of nutrients in the chemical fertilizers used in agriculture.

The heavy metal concentrations in human urine are much lower than those of most chemical fertilizers which is an important advantage.

When urine is collected for use as a fertilizer, it is important to store it in such a way as to prevent odours and the loss of nitrogen to the air. Swedish research indicates that most of the nitrogen in urine, which is initially in the for m of urea, is quickly converted to ammonia within a collection and storage device. However, ammonia loss to the air can be minimized by storage in a covered contain er with restricted ventilation . When urine is applied on open soil it can be undiluted. If u sed on plants it must be diluted to prevent scorching, typically one part to 2 -5 parts of water. [Esrey, S. et al, 1998]

In figure 1-11 the alternative ways of urine handling / usage can be seen. In chapter 1.6 "Greywater use in ecosan systems" the system of wastewater gardens will be explained thoroughly.

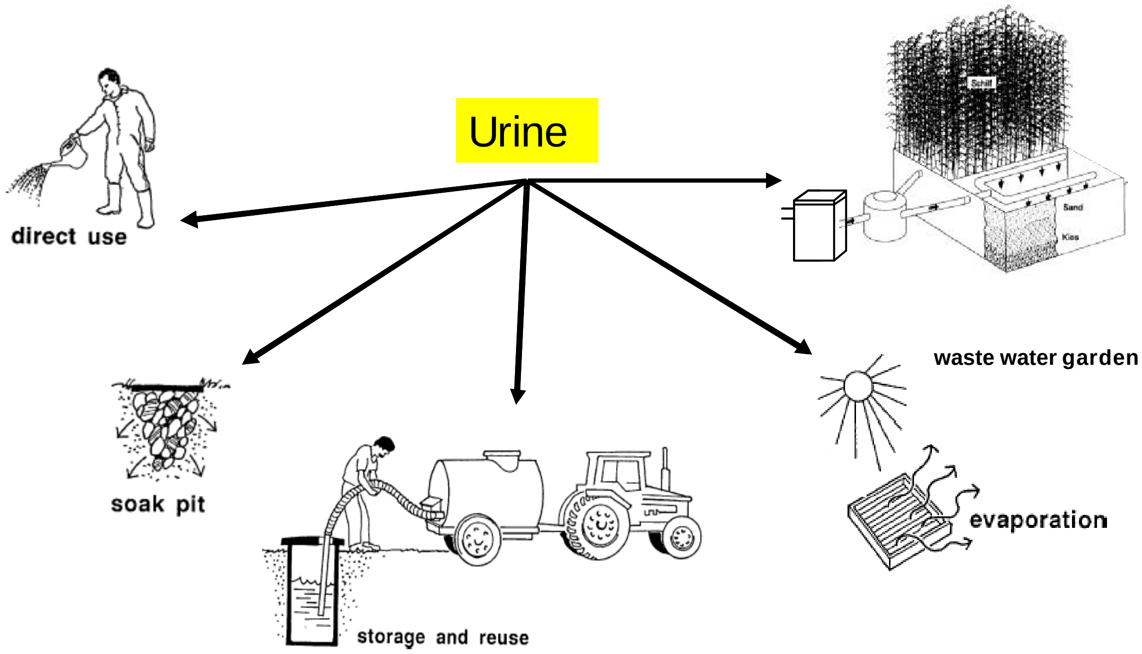


***Figure 1-11**: Alternative ways of handling/using urine from diverting toilets [modified from Esrey, S. et al, 1998]*

1.5.2.2. FAECES

Human faeces consist mainly of undigested organic matter such as fibres made up of carbon. The total amount per person per year is 25 -50 kg containing up to 0.55 kg of nitrogen, 0.18 kg of phosphorus and 0.37 kg of potassium. [Esrey, S. et al, 1998] Although faeces contain fewer nutrients than urine, they are a valuable soil conditioner. After pathogen destruction through dehydration and/or decomposition the resulting inoffensive material may be applied to the soil to increase the organic matter content, improve water holding capacity and increase the availability of nutrients. Humus from the decomposition process also helps to maintain a healthy population of beneficial soil organisms that actually protect plants from soil -borne diseases. The simplest form of recycling is when the individual household can use the product as fertilizer in its own garden or on its own farm land. In urban situations not all householders will have either the land or the inclination to use the product themselves.

1.6. GREYWATER AND URINE USAGE IN WASTEWATER GARDENS

Greywater is the water which is generated from food production, bathing and washing. Normally these waters are disposed of together with urine, faeces and flushing water which is then named black water. In many parts of the world household and / or greywater is disposed of in the streets or via a sewer drain. These waters which are rather clean can easily be recycled in the way of pouring it over garden areas by hand instead of irrigating the areas with valuable and scarce tap or well water. Although greywater does not generally present health risks and will not pose pollution hazards, the best way to apply it is to design a subsurface irrigation system which prevents human contacts.

A low tech solution of these irrigation systems are so called wastewater gardens. These gardens are similar to constructed wetlands which are acknowledged as ecosystems of primary importance including water quality functions like nutrient stripping, biodegradation of toxic compounds, human pathogene reduction and waste water treatment. (Denny, 1997). The waste water garden system is thus able to remove significant amounts of phosphorous and nitrogen which are valuable plant nutrients when used correctly, but can be a harmful pollutant when introduced to the environment. These gardens have a number of advantages compared to conventional systems:

- Stop pollution of ground - and receiving waters
- Less expensive than conventional systems
- Very low maintenance and long life
- Gardens produce food for humans or animals
- No odour or mosquito breeding since the water is kept subsurface
- Recycling of water and nutrients (closing the cycle)

In figure 1-12 the scheme of a wastewater garden is shown like it is applied in Mali (see chapter 2.2.1 "Description of the ecosan facilities in Mali"). A system like this is designed for the treatment of washing water and urine which enters the decanter via a pipe, then flows into the gravel-charcoal filter and eventually enters the garden. Due to the fact that ecosan toilets are build above ground the whole system can work with gravity flow.

The decanter allows a first separation of sand, grease and other substances which pass the screen installed in the washroom. After that the water is lead into a gravel filter which also can be equipped with charcoal. Here the fine solids are hold back in order not to plug the pipes in the garden.

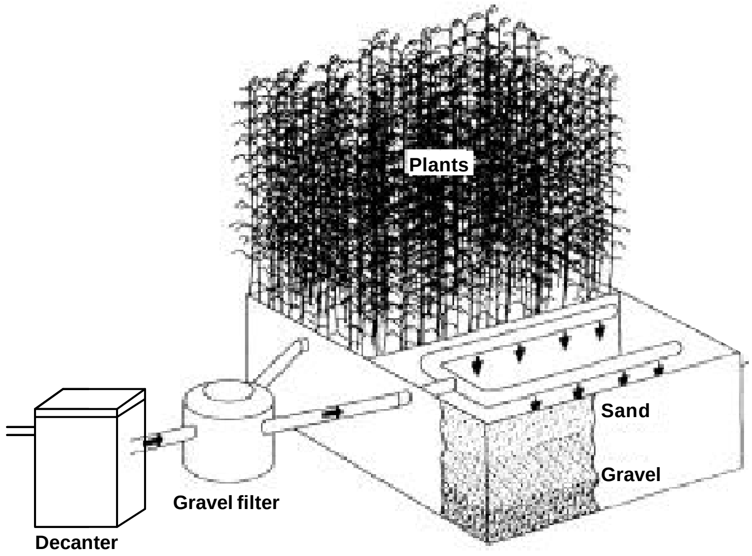


Figure 1-12: *Scheme of a wastewater garden with decanter and gravel-charcoal filter*

The gravel basins can be planted with typhus although these plants have no benefits for the users. Other plants which consume high amounts of water and which crops grow above ground can also be planted adding additional income for the user. However the typhus plants are especially suitable for a situation prevailing in the basin. With their roots areating the soil or gravel thus establishing favourble conditions for a dense and rich microflora. The oxygene leakage from roots creates oxidized conditions in the otherwise anoxic substrate and is believed to stimulate both aerobic decompostion of organic matter and growth of nitrifying bacteria. (Brix, 1997) It is improved due to the root system directly by oxygene emission (rhizome effect) and indirectly by the extention and opening of the pore space. (Pauly et al., 1997; Brix, 1997) Thats why aerobic regions predominantly can be found in the direct vicinity of the roots. The upper horizont consists of vertical, young as well as old roots while the lower horizont consists of a horizontal more dense root system what results in a complete ventilation. (Wissing, 1995)
The second quality of tyhpus plants is the high evaporation rate. Depending on the climate they are able to evaporate between 600 and 1600 mm per year, what corresponds a maximum evaportion of 3.9 mm per day and m^2 and about 1400 l/m^2 * year respectively. (Pauly, 1999)

2. SCOPE

2.1. THE ECOSAN PROJECT IN YOFF, SENEGAL

The Ecosan toilet is part of the planned Ecological Village in Yoff. The " Association Pour la Promotion Economique Culturelle et Sociale de Yoff (APECSY) has the aim to promote an African urban district designed for sustainability, recognizing the relationships among community, the natural environment, and the built environment especially concerning sanitation and waste management.
APECSY as administrator of private owned land engaged the consulting group COTERRE to design an ecological village .

The ecosan toilet as one part of the whole program should be constructed first as study or pilot plant. This was done in order to:

- verify that the planned installation is constructable
- discover weak spots which can be modified for the next installations
- see if the dimensions of the systems are well chosen
- clarify if the composting process is working as predicted
- see if the users will adopt to the new system (social and cultural aspects)
- clear the question of maintenance required for the system

These information gathered over two years should serve as a basis for the improvement, modification and planning of new plants installed in the ecological village.

History of the installation

09/99	-	construction of pilot plant
10/99	-	education training for the family members
11/99	-	start of usage by the family
11/99	-	start of the evaluation program where a APECSY technician visited the installation 2 -3 times a week and filled out a check list (see Appendix A)
06/00	-	first degreasing of the system, first chamber is ¾ full with faeces
09/00	-	closing of the first chamber and start using of the second
08/01	-	construction of living house thus removing the garden
11/01	-	end of usage because the family moved to anther house again without toilet and shower
11/01	-	end of evaluation program

2.1.1. DESCRIPTION OF THE ECOSAN FACILITY

The toilet which is working on the composting process (see figure 2-1 and 2 -1b) was designed for a family with approximately 18-20 members (father, 2 wifes, 15 children). The system as shown in figure 2-2a to 2-2c is a double -vault solar heated toilet with an attached reed bed wastewater treatment basin.

The installation consists of two toilet chambers which are used alternat ing and are buil t half above ground in a sealed manner to prevent rainwater inflow and contaminant outflow . While the first chamber is used as toilet the second one serves as wash room. Both the shower water and the diverted urine a re lead together via pipe s in a decanter and afterwards through the reed bed. When the first chamber is full it is sealed and becomes the wash room while the second one serves as toilet. If the second chamber is filled up the contents of the first chamber are emptied and put to the garden as soil conditioner. In order to guarantee a save substrate the composting time has to be at least 12 months before being removed from the chamber . (see chapter 1.4 "Pathogene reduction ")
Through two decanters the urine, washing water and househol d water is lead into the reed bed where it is purified and after the third basin stored in a tank. This water is used to irrigate a garden which was constructed next to the toilet house.

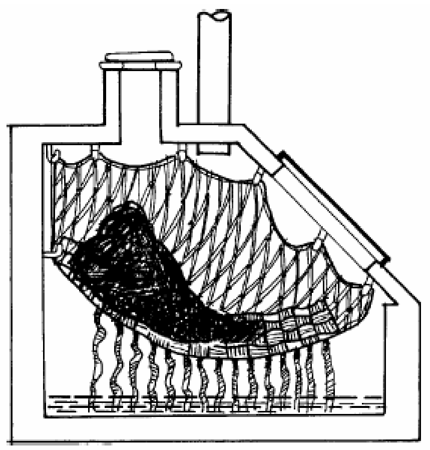


Figure 2-1a: *Scheme of the composting toilet chambers (from Esrey et al., 1998)*

Figure 2-1b: *Photo of toilet composting chamber*

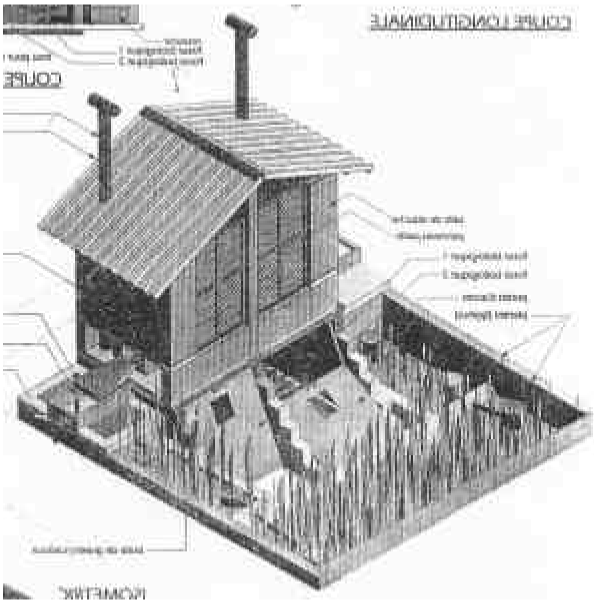


***Figure 2-2a**: Scheme of the ecosan system in Yoff*

***Figure 2-2b**: Model of the ecosan system in Yoff*

***Figure 2-2c**: Photo of the ecosan system in Yoff*

<u>Construction and gravel basins</u>

The structure is constructed on-site of concrete bricks , coated with plaster and later coated with waterproofing liquid to guarantee watertight basins . A strong concret mix (high proportion of cement) is recommended.

The gravel basins are designed to avoid dead corners, within a lengh to with ratio of 2.5:1 to 10:1. The bed s are approximately 60 cm deep which is needed for the reeds.

The water level in the basins is kept about 5 cm below the gravel surface . The surface area of the station is 9.6m ^{2} which can accomodate about 20 persons.

The gravel basins were filled with gravel increasing in fineness with each basin. As gravel was very costly and difficult to obtain the question is wether some other material (coconut husks, charcoal, etc.) could be used in addition or instead of the gravel. However the performance of gravel is good and has been well establishe elsewhere. The gravel should be washed before it is placed in the basins, to avoid plugging by gravel dust and so shorten the pH adjustment ti me.

Buckets

As can be seen in figure 2-2b in each basin are two perforated buckets lined with a cloth to maintain the water level in the basins and to protect the connecting pipes and the gravel from clogging.

Pipes and Decanters

The pipes leading to the decanter are 50mm PVC pipes with a small slope. The water flows into the first, then to the second decanter, which serve as settling tanks for separating out sand, grease, fats and oils which are abundant in the diet. The household water is fed into the system by a sink equipped with a sieve. The decanters are designed for an 24 hour detention time. A problem is that if the water stands too long in the decanter - capacity is too large - it can stagnate and start smelling. If the decanter is undersized, water will flow out of the system too quickly, not provinding enough time for the solids and fats to settle out leading to the plugging of the gravel beds.

Plants

In the gravel basins the typhus plants serve as aerators, leading oxygene into the gravel bed, thus allowing beneficial aerobic bacteria to thrive. (see also chapter 1.6 "Greywater and urine usage in wastewater gardens")

Maintenance

The maintenace is done by the users. This includes regular cleaning of the toilet and wash room, cleaning of the sink, cutting the plants and emptying the cloth in the buckets. For all other maintenace jobs for example degreasing of the decanter, inspecting and cleaning drains and filters, assuring gravel cleanliness, clearing ventilation pipes and emptying the toilet chambers or cleaning the pipes if plugged, APECSY is responsible. After some operation time repairs may include cleaning and replacing gravel in one or more basins, pumping out basins to repair leaks, repairing cracks, replacing or repairing pipes and replacing the net.

2.2. THE GTZ - PROJECT IN KOULIKORO, MALI

The toilets and gardens in Koulikoro are one part within a project of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) which is named "Improvement of the community situation with respec t to water and sanitation".

2.2.1. DESCRIPTION OF ECOSAN FACILITIES

Two ecosan toilets in Koulikoro are based on the dehydration or dessication process which is illustrated in figure 2-3 and 2-4 and described in chapter 1.5.1.1 "Ecosan toilets based on dehydration" . While the othter five installations have normal pit latrines with urine diversion only. They were designed to serve a family with approximately 15 -25 persons.

As can be seen in the figure below the system consists of two vaults and are built above groun d. This is normally done to prevent groundwater contamination and rainwater inflow however in Koulikoro the second reason is the rocky underground. Differently to the system in Yoff, in Koulikoro the toilet system consists either of one or two room s with d ifferent order:

1. one room with shower and both toilet holes
2. two rooms where one is washroom and the other toilet room with both holes
3. two rooms where one is washroom and toilet room and one toilet room

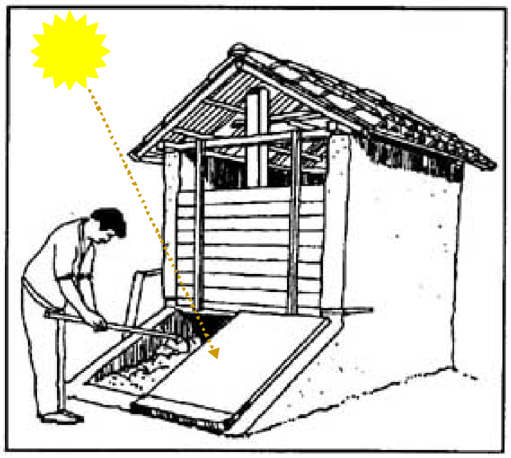


Figure 2-3*: Double vault toilet with solar heaters (from Esrey et al., 1998)*

Figure 2-4*: Photo of an ecosan dehydration toilet in Koulikoro*

The operation of all three is the same independet of ecosan toilet or pit latrine . The urine is diverted from the faeces and is led toge ther with the washing water into a decanter passing a first metal s creen to retain sand, fabrics and other materials. Then it flows through a gravel - charcoal filter and eventually via pipes in the wastewater garden where it simultaneously serves as irrigat ion water and fertilizer for the plants . The ecosan dessication vaults have metal lids which are painted black in order to absorb the sun's energy and assist the deyhdration process.

The chambers are used alternating in a yearly modus assuring the pathogens to die off in the unused chamber (see also chapter 1.4 "Pathogene destruction"). When the first chamber is emptied after two years of operation the stabilised faeces are removed and distributed on the fields to improve the soil quality.

Figure 2-5: *Photo of a complete ecosan station*

Construction of the toilet

The two ecosan toilets where constructed completely new whereas the other five existing toilets with pit latrines where just modified to fit the new conditions. The basis of the ecosan toilets was made out of natural stones and cement. At one toilet even the decanter and filter unit where fabricated in this way. This construction technique was applied in order to work with locally availbalbe material and to save money because the cement in Mali is very costly. The upper part of the toilets as can be seen above is constructed of sun-dried cement stones. Another thing in which the toilets are different are the roofs. One ecosan toilet is equipped with a roof and the rest out of financial and reasons not. Also it is not common for a toilet in this region to have a roof.

Construction of the wastewater garden

The construction of the wastwater gardens (see also chapter 1.6 "Greywater and urine usage in wastewater gardens") is done in concrete-bricks, coated with plaster to obtain watertight basins. The ground of the basin is either natural rock or a manufactured with cement. The basins differ in their size corresponding to the size of the family and space available. Sometimes less space was available then needed thus the height of the soil layer in the garden was increased to compensate it. As can be seen in figure 2-6 below drainage pipes distribute the water in the basin. The soil in the basins consists of three layers. The first layer on the bo ttom is gravel in which the pipes are layed out. Above or around the pipes a fabric , for example old rice sacks which are locally available is placed in order to prevent roots from damaging or plugging the drainage pipes . Above this fabric or gravel a lay er of sand is distributed which is topped with normal soil.

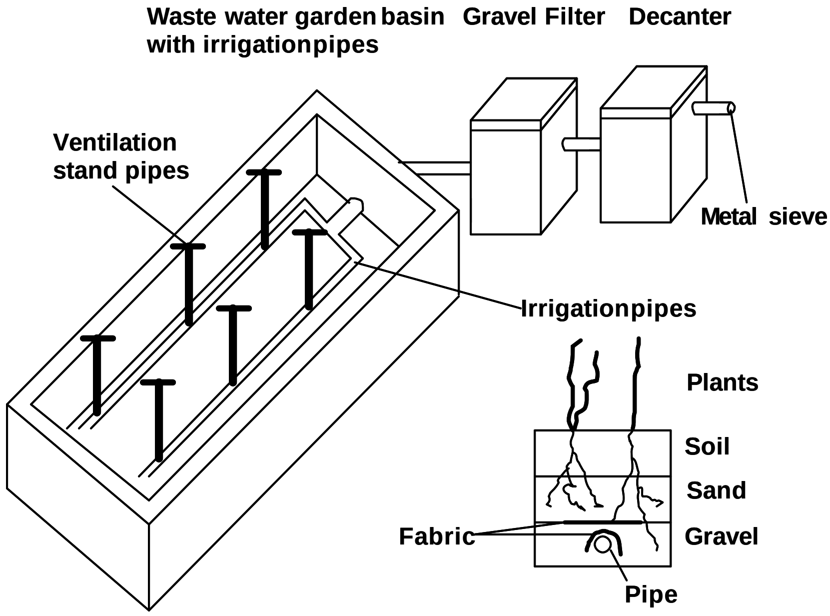


Figure 2-6: *Scheme of a wastewater garden basin with filter and decanter unit and cross-section of garden*

In the figure above ventilation stand pipes are depicted which are co nnected to the irrigation pipes and are installed to supply the soil bacteria with additional oxygene. (see also figure 2-11 in chapter 2.2.3)

<u>Decanter and pipes</u>

The decanter are constructed on -site of reinforced concrete or concrete bricks coated with plaster. At one station the basins are constructed with natural rocks and cement which resulted in leaking basins after some time. They vary in size but are all roughly 0.6m x 0.6m with a depth of about 0.6 to 1meter. All the pipes used in the installation s are 50mm PVC pipes. In the figure s 2-7 and 2-8 below the general cross section and the top view of the decanters constructed is shown.

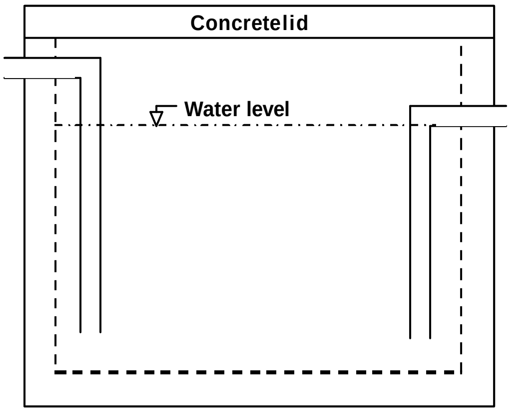


Figure 2-7: *Cross section of a decanter*

Figure 2-8*: Top view into a decanter (outflow pipe on the left is partly missing)*

Gravel filter

The gravel filters are constructed as the decanter. Only the installation of pipes (see figures 2-9 and 2-10) are done in a different way to secure optimum water distribution over the gravel bed.

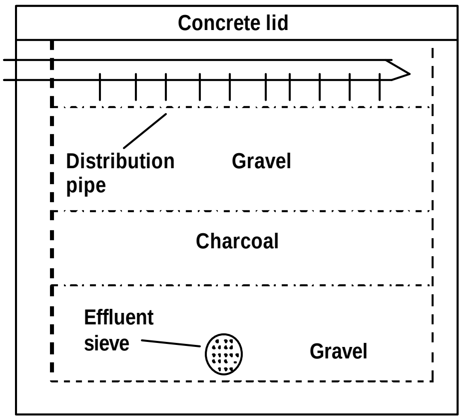


Figure 2-9*: Cross section of the filter unit*

Figure 2-10*: Top view of the filter unit*

Plants

As already mentioned in chapter 1.6 different plants can be grown in order to evaporate respectively take up and clean the water. In order to gain benefits and have an incentive to maintain the garden and the whole system crops are planted in the gardens. Regional crops that need or bear large amounts of nutrient rich water are Banana trees, Papaya trees, Ladyfinger , Tomatoes and even small Baobab trees.

Maintenance

All the maintenace work is done by the users. That means regular cleaning of the toilet and washroom as well as assuring a clean metal screen. The users have been shortly introduced that they have to degrease or remove solids and sludge from the decanter and guarantee a proper gravel filter if necessary remove the gravel and renew it. They also have the responsibilty for the garden and the regular planting of crops as well as maintaining the water flux throughout the whole system. Also they are obligated to empty the drying chambers after the appropriate time and applying the dried faeces to the fields.

2.2.2. THE DRY TOILET AND WASTEWATER GARDEN AT MAMADOU TRAORÉ

The ecosan dehydration toilet and wastewater garden were constructed in June 2000 for about 25 persons. As the family has increased since then approximately 30 persons are using the toilets nowadays.

In the figure below the condition of the wastewater garden is shown which is not in use any longer because of clogged irrigation pipes. Now the water is lead directly into the street like before the construction was built. This is the result of a number of circumstances, listed below:

1. The corrosion of the first metal screen in the toilet or washroom lead to a narrowing of the holes and an eventually blocking of the screen. The screen was then stabbed enableing the flux of disruptive material e.g. sand, hairs and residues of the natural sponges into the decanter.
2. This material in the decanter was settling or floating on the water surface (see figure 2-12). After some time the vertical pipes in the decanter were removed because of the foreign material clogging them. This made it possible for fabrics and other material to enter the gravel filter especially when the pipe was removed because it was plugged.
3. After some time of operation the pores but especially the surface of the gravel filter got clogged and water was standing in the filter or was overflowing.
4. Due to the overflowing gravel filter the gravel was removed in order to solve the problem.

These four steps lead to the plugging of the irrigation pipes.

Figure 2-11: *Photo of wastewater garden*

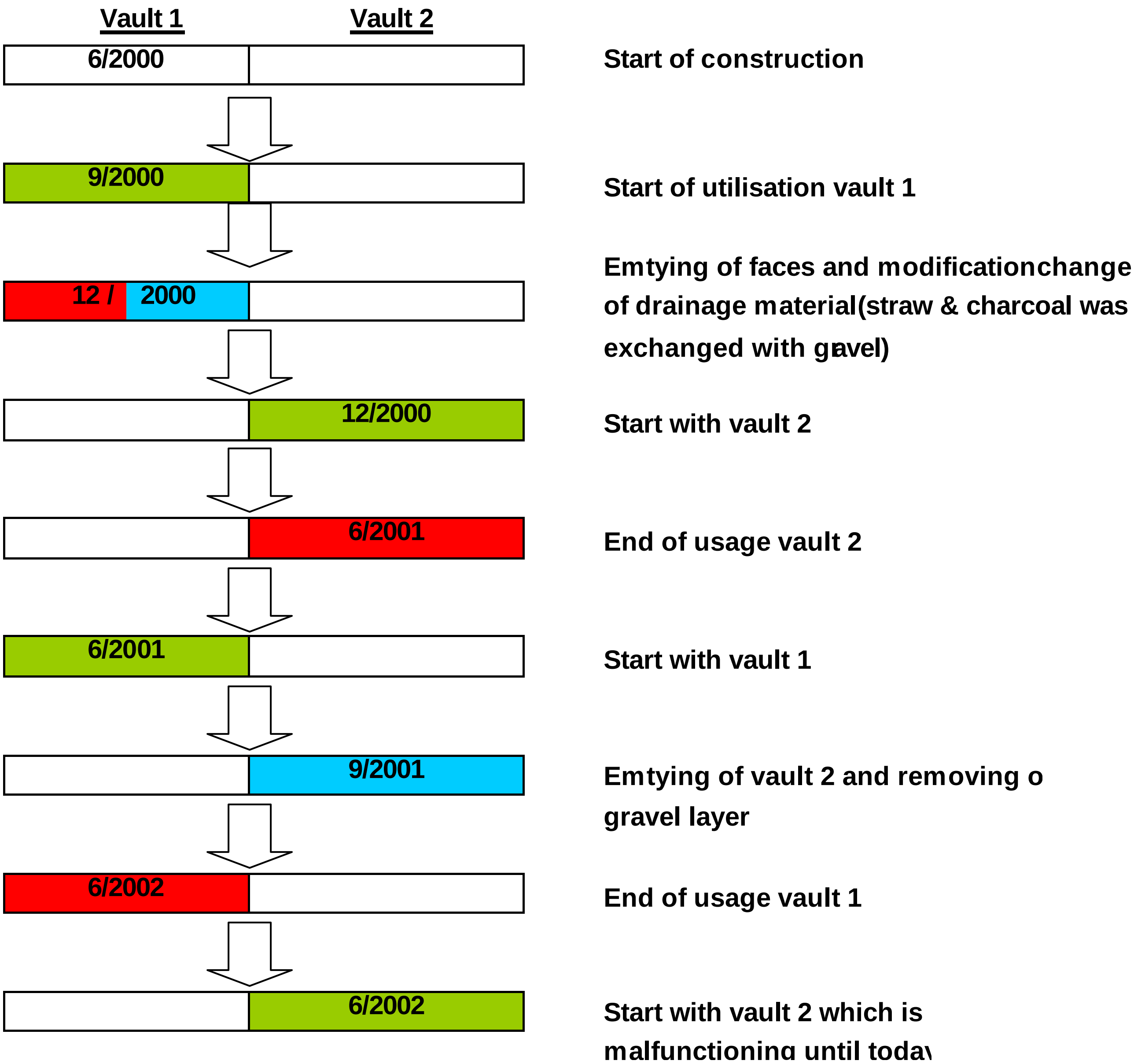
Figure 2-12: *Top view of decanter with floating material*

Another thing which is connected to the failure of the wastewater garden is the missing fence. Due to this reason the animals (chickens and goats) which live on the property eat the plants especially the young ones. As a result there is no vegetation thus no benefits for the family what makes them care about the well function of their garden.

The pictures below give an insight into the toilet and washroom. In this installation the two toilet holes and the shower basin are placed in one room. This leads to the problem that only one person at the same time can use the shower or the toilet. A wall separating the toilet holes from the washroom would lead to an improved situation. Another disruptive element is the missing door which creates a lack of privacy even though the entrance is chosen in that way that it blocks any view. A fault which was done in the planning was the wrong placing of the toilet holes respectively the construction of the foot-rest and urine channels. When using the toilet one is facing the wall directly infront thus turning the back against the entrance. This is controversial to the normal human behaviour.

Figure 2-13a and 2-13b: *Photos of toilet and shower room*

In the next part the history of usage and emptying of the two dessication vaults is explained.



It becomes clear that after the first period of modifications which is rather normal for a pilot plant inconstancy and not following of the instructions took place. The vault 2 was just used for six months and for no reason the family started using vault 1. Also the faeces were removed from the vault 2 already after three months what poses a serious health risk to the people handling it. The reason for this was the missing knowledge that the material is not safe yet and the need for soil conditioner for the fields

In the figure 2-14 and 2-15 the two dessication chambers are shown. The right one is unused in the moment and filled with faeces resting there in order to dry. The left one is in use. This chamber is malfuncioning due to three facts:

1. The decanter and former gravel filter (the gravel was removed because it was clogged) which are filled with water are leaking through the wall into the dessication vault.

2. The gravel drainage layer in the vault was removed with the faeces because the mixture of faeces and gravel sticked together.
3. Fine particles in the water have clogged the drain pipe and the gravel in front of it where normally the excess water from the anal cleasing is drained. Now about 5 to 10 cm of wat er are resting in the chamber.

Due to these reasons a dessication in the chamber is not longer possible. One result of this situation is the bad smell of the wet faeces when is becomes warm.

Figure 2-14*: Unused dessication chamber filled with faeces*

Figure 2-15*: Used dessication chamber filled with water and faeces*

In point three above is was mentioned that the drain pipe and the gravel are clogged. Owing to a fault in planning the drain pipe is located in the back of the left chamber which makes it impossible to clean when full. For further plants the slope of the chambers has to be changed in order to install the drain pipe where it is accesible also when the chambers are in operation.

But in order to prevent the inflow of the water from the dec anter and / or filter unit in the first place they have to be constructed out of watertight material. It is obvious now that it is not possible to construct watertight basins of natural stones and cement.

2.2.3. THE DRY TOILET AND WASTEWATER GARDEN AT YOUSSOUF TRAORÉ

The dehydration toilet and wastewater garden were constructed in July 2001 for about 20 persons in the meantime the family counts 19 persons.

The system is constructed how it is described in chapter 2.2.1. In difference here just the basis is con structed with natural rocks and cement in order to even out the rocky underground. The walls of the toilet and decanters are constructed with cement bricks. This installation has no roof and no toilet door. Due to better maintenace and less users the irrig ation pipes are not clogged so that plants are able to grow. Also a fence was "constructed" with some bricks so that animals were not able eat the plants.

Figure 2-16: *Wastewater garden of Y. Traoré*

On the left the waste water garden which is only 5.6m^2 in size with the ventilation pipes can be seen. In average the family uses 300 liter of water per day which results in a surface load of 53.6 l/m^2. In late January when the picture was taken only Papaya trees could be found. Normaly the family also plants Ladyfinger, Tomatos, Chillies and Dah which grow very well. However they are not plantig in the dry season because the watering with tap water is too expensive. Due to that they just have one harvest per year. This issue decribed above depicts one problem discovered concernig the understanding of the whole system that watering is not necessary.

Under point 2.2.1 it was mentioned that there are three different orders of wash- and toilet room. At Youssouf Traoré the system consists of a wash room (see figure 2-17) and a toilet room (see figure 2-18) with the two holes. On the contrary to the washroom the toilet room does not have a door thus it is possible to see the right toilet hole from the courtyard. Due to this situation the toilet hole was not changed after one year as intended. In the figure 2-18 it also can be seen that one has to sit with the back towards the door when using the toilet. Also it can be seen how urine and water has flown over the concrete floor into a pipe leading it into the decanter.

Figure 2-17: *Washroom of Y. Traoré*

Figure 2-18: *Toilet room of Y. Traoré*

Below on the left the unused dessication vault can be seen. On the right the vault which is used since July 2001 is shown. Even though it is used for 18 month now the vault is not full and is functionning well. No bad smell or odours are reported by the users in the toilet who are putting ash to the faeces 3-5 times a week. In the hot season there are a lot of mosquitos in the decanter and some insects in the toilet superstructure.

***Figure 2-19**: Unused dessication chamber*

***Figure 2-20**: Used dessication chamber with faeces*

Out of economic reasons this system has no roof which leads to a surplus of water in the wastewater garden during the rainy season posing a challenge to the plants . It can also lead the overflow of the basin and of the decanter and filter units. At this site the same problem of the first metal screen is prevailing. It has been stabbed through after approximately 10 month s.

***Figure 2-21**: Metall cleanout access door and drainage effluent chamber*

With difference to the system at Mamadou Traoré the slope of the chambers is leading towards the opening. In the picture aside the black metal access doors can be seen as well as the chamber into which the eff luent water from the dessication vaults is lead. Here the pipe respectively the gravel inside infront of the pipe can be cleaned easily even when the vaults are in operation.

2.2.4. THE SEPARATING TOILET AND WASTEWATER GARDEN AT SOUMALIA TRAORÉ

The toilet sys tem at Soumalia Traoré is not a dessication toilet. It is a normal pit latrine where the urine is separated and lead together with the washwater into the wastewater garden. The faeces are stored in a vault which has to be emptied in the normal way. The toi let structure stayed nearly the same - one room only - with some modification for the urine separation. The decanter and filter units as well as the garden were constructed next to the toilet. The system is used by about 10 -11 persons which consume around 200 Liter per day which results in a surface load of 19.2 l/m^2 (garden size 10.40m^2).

***Figure 2-22**: Wastewater garden of S. Traoré*

In the garden 15 Papaya trees, 2 Banana trees, 2 little Baobab trees and another decorating plant could be observed. The family is also harvesting Ladyfinger three times a year.

The decanter has been desluged 5 -6 times and the gravel filter has been renewed three times since the construction in January 2001. Even though the education programm was the same as in the other f amilies where the gardens failed partly completely the maintenance of the garden and decanter / filter units were very good. In order refill the gravel filter material from the streets was taken and put through a sieve to obtain clean and suitable gravel. This good maintenace and interest in the installation might have two reasons. Firstly Soumalia is a plummer and thus a skilled craftsman and secondly the women of the family sees the benefits the garden poses for her in form of three Gombo harvests and a l ot of Papaya and Bananas for free.

However, there are some problems. The toilet superstructure is made of banco (see figure 2-23) which is clay mixed with millet husks and straw . This construction material is very sensitive to rain, washing away with every new shower. In the rainy season a lot of fine clay particles together with the husks and straw is washed into the decanter, entering the gravel filter and eventually plugging the complete system. As can be seen in figure 2-22 the outer wall of the property bordering the wastewater garden is also made out of banco. During the rain banco is washed into the garden and thus destroying the Gombo shoots and clogging the soil.

In this garden no ventilatio n pipes have been installed.

***Figure 2-23**: Toilet room of S. Traoré made in Banco*

2.2.5. THE SEPARATING TOILET AND WASTEWATER GARDEN AT THE FAMILY KOITA

The system which was constructed in January 2001 has no dessication toilet but a normal pit latrine with urine separation like desribed in chapter 2.2.4. The difference is the order of the toilet holes in the two rooms. Each of the rooms has a toilet hole which can be used because the system is based on a normal pit latrine. Also it is possible to shower in each of the rooms.

When planned the family consisted o f 12 people while now there are 15 people living on the property. The family is using approximately 300 Liter per day which results in a surface load of about 24.5l/m ^{2} (garden size 12.25m ^{2})

In the garden several Banana and Papaya trees can be found. Ladyf inger and Tomatoes have been planted but each time the chickens which fly into the garden over the fence are eating the shoots.

The metal screen infront of the decanter was destroyed which lead to the clogging of the gravel filter. After the renewing of the filter it clogged again but no gravel was available to replace it. Now no gravel was found in the chamber. After some time it was noticed that the irrigation pipes were plugged thus one pipe was removed leading to standig water (see figure 2-25) in the garden.

Figure 2-24:*Wastewater garden Fam. Koita*

Figure 2-25: *Waterhole in wastewater garden*

The toilet construction is not equipped with a roof leading to excess water in the garden. It was mentioned that the walls (app. 1.65 m) of the toilet co nstruction are too low.

2.2.6. THE SEPARATING TOILET AND WASTEWATER GARDEN AT THE FAMILY SISSOKO

The toilet and garden sytem which is shown in figure 2-5 above is not functioning anymore. The wastewater garden is now used as a chicken coop and the diverted urin e is lead toget her with the washwater in the street again. The system was planned for 15 people resulting in a surface load of around 40.8l/m ^{2}. Now approximately 33 people are living on the property which had lead to the overflowing of the wastewater garde n respecitvely of the whole system. Owing to the excess water supply the plants in the garden eventually died.

Due to the overflowing garden the underground in the vicinity got very soggy. Due to this situation a nearby building which was constructed in b anco collapsed.

2.2.7. THE SEPARATING TOILET AND WASTEWATER GARDEN AT THE FAMILY A. TRAORÉ

The system of a normal pit latrine and wastewater garden (8.6m^2) was planned for about 25 persons. Now approximately 15 -20 are usin g the system which results in a surface load of about 52 l/m^2.

Figure 2-26: *Garden at Adama Traoré*

Due to missing maintenace the gravel filter is overflowing from time to time. Then the water is running through the courtyard into the street again. After the water emptying of the gravel and decanter units (it is supposedly the cleaning) the system works for some days till it star ts overflowing again. In the decanter about 15 -20 cm and in the gravel filter around 8 -10 cm of sludge were found. Also the toilet is not used every time for urinati ng but a stall which is attached to the toilet stucture serves as latrine and shower room. This is due to the fact that the elder persons in the family find it difficult to climb the stairs .

Enough water was found under the surface even though the family thought the garden is dry. Here the same problem with chickens exist as like in the majority of the gardens.

2.2.8. THE SEPARATING TOILET AND WASTEWATER GARDEN AT THE FAMILIES AMADOU AND FASSIRI KONÉ

In t his case two families are attached to one wastewater garden. Each of the families has their own pit latrine with urine diversion and decanter. One single gravel filter is supplied infront of the irrigation pipes. The two families add up to about 35 people using the toilet and washroom. This results in a surface load of around 58 l/m^2 with a garden size of 17.2 m^2.

Figure 2-27: *Waterhole in the garden of Fam. Koné*

Due to a missing fence the plants which have been planted were eaten and new shoots got eaten immediately by the goats and chickens . Thus no pla nt can be found in the garden. Also the users think there is no water in the basin indeed water could be found in a depth of around 20cm . (see figure 2-27)

Due to no maintenace of the decanter and gravel filters the units were overflowing. The wastwater w as standing around the garden basins and the units but the users did nothing to clean the decanters or gravel filter in order to improve the situation. This might be due to the fact th at the installation was not cons tructed on their property but infront of their house in the street. In this situation neither family felt responsible.

3. RESULTS

In the next chapter the findings of the evaluation programm of Yoff and Koulikoro are decribed.

3.1. RESULTS OF THE EVALUATIONPROGRAM IN YOFF, SENEGAL

As mentioned above unfortunately there was only one ecosan toilet and the family who used it moved to a different part of the city thus the toilet was not used and maintained by them any longer. Only the guard of the new constructed house where formerly the garden was situated is using the toilet and washroom in the moment, but no maintenace work is done. Because of the situation the planned survey could not be carried out. Only two questionnaires (see Appendix B) one for the guard and the other for the family have been completed.

It can be stated that the toilet and washroom had been well used. Because the site was not equipped with a toilet on the premises, the addition of a toilet has had a large impact on the daily quality of life for the household. Girls and woman, particularly, had been very happy to have the convenience and privacy of an on-site toilet. In general all residents have been very satisfied with the system. They learned rapidly how to use it, and have been fairly consistent in use of bulking material after usage. They have also kept the inside of the cabinet reasonably clean. Upon occasion the cover was left open, but this was not a chronic situation.

One problem encountered was when a new resident or a guest was unaware of how to use the toilet thus a large amount of water went into the composting chamber and no bulking agent was added. This underlines the importance of household members instructing others in station use.

At the outset a period of adjustment along with close supervision of the APECSY technician who came twice a week was needed. Small children for example were afraid of the hole, and the women did not keep the sink or the station clean. Ashes or bulking material was not kept available and were not consistently used. In the opinion of the technician, overall family hygiene and awareness has noticably improved since the installation of the system.

Some other problem the users reported was the too slight slope of the urine diverting channel thus leading to a slow flow or even resting urine which had to be washed away with water. The lack of electrical light during the night is not posing a problem for them because they are accustomed to use candels or torches.

On the pictures below it clearly can be seen that the maintenace of the system is lacking thus the washroom and toilet room are dirty and mouldy. Sand in the washroom leading to the plugging of pipes.

Figure 3-1: *Washing room (Yoff)*

Figure 3-2: *Toilet room (Yoff)*

On the picture below the first basin can be seen which is totally covered with rubbish and filled with water. The maintenance work of degreasing the decanter as well as cleaning the filter cloth has not been accomplished therefore leading to the clogging and eventually to an overflowing bucket. This water which is saturated with grease, soap, sand and other objects finally lead to the clogging of the gravel resulting in water resting in the basin. Many mosiqutos and mosquito larvae were noticed in the water accompanied with a bad smell. In order to improve the situation but without cleaning the system the cap (marked by the arrow) of the pipe leading to the decanter was removed. Now the shower water and the urine flows directly into the basin. On this picture it also can be seen that the missing maintenace respectively cutting of the typhus plants lead to a shadowing of the metal doors.

Figure 3-3: *First basin and metal cleanout acces door of the ecosan system*

Concerning the household water collection point it can be stated that it was used by the family. The primary daily usage inconvenience seemed to be the cleaning of the sink, which if not done, attracted flies. A better sink design like a metal bowl with holes will help to improve this. It appeared that despite these inconvenieces, which lessen over time as new maintenance habits developed, the women still prefer to dispose water at the station rather than carry it offsite.

The women judged that the system saved them a great deal of time and unpleasant work like hauling the water as far as the beach.

It was noticeable that the garden was important not only in producing vegetables for the family to eat (they had an excellent crop of tomatoes, some of which were sold), but also in giving the elderly household head meaningful work which clearly gave him a great deal of purpose and satisfaction.

It was observed that the chamber which is in use for 27 months now is completely full. The net is hanging on the ground and the heap is too large in order to guarantee proper ventilation. APECSY knows about this situation but is afraid of emtying the substrate themselves because they are not used to handle compost of this kind. A company which deals with normal compost will be contracted in order to empty the chamber and dispose the substrate , because the garden it should be applied to was removed.

When investigating the material in the composting chambers sand like material was found in the ready composted chamber. Both heaps were inhabited by a great amount of earthworms and other soil organisms transferring the faeces and wood chips into soil. During the sampling of the used chamber a vertical substrate distribution was observed. In the upper 20 cm of the heap fresh faeces mixed with wood chips could be found containing no larger organisms. Underneath this cover larger organisms could be found digesting the material. The lower part of the heap consisted of sand like already converted material.

Changes in the design for future stations

- A different inflow sink for the household water has to be designed for example a metal bowl with holes for easy cleaning
- Pipes redesigned for easier cleanout, i.e. larger diameter, more openings / caps
- Increase slope of the pipes
- The decanter system has to be changed; two large decanters instead of the first gravel basin
- No separation of second and third basin
- Elimination of bucket system
- Increase the slope of the urine diverting channel
- Cabinet construction is too expensive, design of a low-cost frame
- Change of toilet hole cover
- Change of cover in the washroom to guarantee that no water enters the composting chamber
- Improved net hanging

3.2. RESULTS OF THE EVALUATION PROGRAM IN KOULIKORO, MALI

In the chapter 2.2.1 to 2.2.8 the installations in Koulikoro were described thoroughly. Detailed problems concerning each installtion were explained and solutions were partly given. In this chapter the general problems connected to the installations shall be explained and recommendations for their rectification are proposed .

Technical and maintenance issues

In all of the installations the first metal screen infront of the decanter was oxidised (see figure 3-4) so that the holes were blocked and eventually the screen was stabbed . Because of this removal of the screen foreign substances such as sand, hair and residues from the natural sponge were able to enter the decanter and gravel filter leading to the blockage. One solution for this problem which was implemented in some installations is the replacement of the metal screen with a selfmade plastic screen which is shown in figure 3-5.

Figure 3-4*: Oxidised metal screen*

Figure 3-5*: New plastic screen*

Another problem was discovered at the two dehydration toilets. For the dessication the faeces are resting on a gravel bed in order to drain excess water and finally lead it out of the vault. Due to the habit of anal washing fine faecal particles introduce the upper layer of the gravel bed via the percolating water. This results in a clogging of the gravel bed and after the drying period to the sticking of gravel and faeces. In one case the gravel was removed with the faeces thus no drainage was left in the vault leading to a complete failure of the dessication process. In order to solve this situation water permeable fabrics, e.g. old rice sacks could be used to create a border between the gravel and faeces.

The biggest problem encountered was the missing maintenace work by the users. The decanter and gravel filter units were not cleaned regularly at the most sites. This lead in combination with the missing metal screen to the transportation of excess disruptive substances into the system, where the residues of the natural sponges and sand pose a serious problem. In most of the cases the cleaning of the units especially the gravel filter was the skimming of water. Normally no water should rest on the gravel filter and when there is water standing for longer time the filter has to be renewed.

The first measure to solve this problem is an educational programm for the users to make them understand why they have to clean the units. Also it would be the best way to help them with their first cleaning. All this was done during the evaluation project.
A second measure to improve the situation has been implemented in the families of F. and A. Koné, A. Traoré and Y. Traoré. After the emptying of the old gravel and charcoal, new gravel which was either collected on the street or washed was filled in the chamber as depicted in the figures 3-6 and 3-7. With the implementation of the perforated bucktes in the gravel bed solids passing the decanter can settle in the lower part of the bucket while the water enters the gravel bed via the holes in the upper third. This system leads to a second decantation, even distribution of the water over the gravel and an easy emptying ot the solilds entering the bucket.

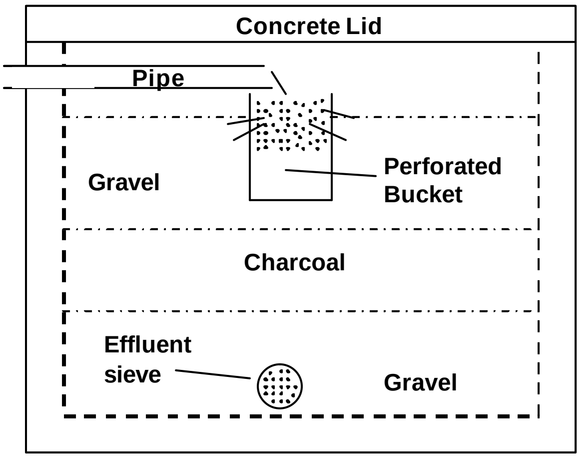


Figure 3-6*: Scheme of the new gravel filter setup*

Figure 3-7*: Photo of gravel filter with decantation / filter bucket*

During the visits of the different installations concrete corrosion was observed. In the picture 3-8 extensive concrete corrosion is depicted where big parts of the concrete floor are destroyed. On the right picture the corrosion is limited to the point where the urine hits the concrete floor resulting in an erosion. In both situations water and urine are resting in the holes and start smelling. But mainly it is a dangerous health hazard for the users.
One solution could be the installation of halved PVC pipes installed in the concrete floor in order to drain the urine into the decanter.

Figure 3-8: *Extensive concrete corrosion*

Figure 3-9: *Local concrete corrosion*

<u>Socio-cultural issues</u>

The socio-cultural problems are very complex and difficult to solve.

One problem a lot of families are facing is the destruction of plants and shoots by animals e.g. goats or chickens. Even though the families signed a contract with the GTZ saying that the families have to build a fence around the garden, most of them did not construct or bought a fence. The reason for this is that they do not see the long term benefits of the garden in form of food and life style improvement when they make a short term investment in form of a fence. Even though a fence is not very expensive or even could be selfmade (see for example Fam. S. Traoré) the families have other priorities.

One problem mentioned above is the belief that there is no water in the garden and that they have to water the plants in the dry season like the normal farmers. This is due to the fact that they can not see the water under the dry surface. In all of the gardens holes where dug to show that water is available all year-round (see figure 3-10). In some gardens water was standig in some 10-35 cm under the surface like groundwater (see also figure 2-27) and in other gardens the soil was wet.

Figure 3-10: *Examples of waterholes in the wastewater gardens.*

Due to the missing plantation water is not evaporated and restes in the basins. During the rainy season the basins are overflowing and the wastewater is running down the street.
Like done during the project it has to be demonstrated to the users that there is water under the dry surface. As well it has to be explained what happens to the water and why plants are necessary in the garden besides the food benefits.

One phenomenon which was discovered in the case of the families Koné is the problem of common property. Here it was not possible to have one common system for both families. In this case none of the families felt the responsibilty for the system so that no maintenace work was done and eventually the system failed to work.

Changes in the design for future stations

- Change of metal screen to a plastic screen infront of the decanter
- Modified gravel filter unit with buckets
- Covering of the gravel bed in the dessication vault
- Slope of the dessication vault leading towards the access doors
- No construction of water tight basins with natural rocks
- Construction of a fence around the garden
- Construction of a drainage at the end of the wastewater garden to remove excess water out of the garden basin
- Construction of a roof

4. CONCLUSION AND OUTLOOK

It can be stated that the users are very satisfied with their toilets and wastewater gardens. Their life style was improved by providing safe sanitation connected with water or food production.

The system of composting or dehydration of faeces and separating of urine under the Senegalese and Malian conditions is satisfactory. On the one hand it creates important and safe soil conditioner as well as cheap fertilizer for agricultural purposes. On the other it solves the problems which are connected to conventional sanitation systems such as nutrient loss, environmental pollution, soil degradation and spread of disease. The implementation of this system should be fostered in the future in order to establish sustainable and safe sanitation.

It could be realised how important an educational programm is for the users and that it should accompany the users for at least some months till they are adapted to the new system. For the first two or three years a half-yearly visit is recommended. This should be focussed on the emptying or changing interval of the dessication or composting vaults in order to assist the users.

The waste water gardens are an ideal approach to the specific and problematic prevailing situation in Koulikoro. They contribute to the solution of the problem connected to greywater in the streets. As well they permit a recovery of essential nutrients contained in urine without a contact to humans. When the courtyard of the families is big enough which is normaly the case in Koulikoro it is the preferred solution and also should be fostered in future.

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6. APPENDIX

Appendix A

	Yes	No	Remarks
Clean environment?			
TOILETS			
Cover is closed?			
Ash/sawdust is available for u se?			
Mosquitos come out of the hole?			
Clean?			
Smell?			
ACTIVE CHAMBER			
Contents are humid? (little, medium, very)			
Liquid on the ground? (little, medium, much)			
Insects in the chamber?			
Insects come out of the chamber? (little, mediu m, much)			
Window is clean ?			
Sun or light is blocked by typhus?			
CLARIFYING BASINS			
Water has been pourred into the sink?			
Sink is clean?			
Mosquitos / insects are around the sink?			
DECANTER			
How many cm are between the grease layer and the cover of decanter 1?			
How many cm are between the grease layer and the cover of decanter 2?			
Insects in the decanters?			
BASINS			
Paper or waste in the basins?			
1 Watersurface is under the gravel?			
Grease on the surface of the g ravel?			
Grease in the buckets/cloth?			
Condition of the typhus plants?			
2 Watersurface is under the gravel?			
Condition of the typhus plants?			
3 Watersurface is under the gravel?			
Condition of the typhus plants			
Mosquitos /insects around the basins?			
Problems?			
Typhus needs to get cut?			
Smell around the basins?			
Is the solar shield clean?			
Pump is working?			
Mosquito nets at the ventilation pipes is OK?			
Quality of the water in the last basin?			

Appendix B

Evaluation of the ecosan installations

Technical University of Hamburg -Harburg, Gemany

1) Is the latrine working ?	O	N
2) Is there evidence of excreta or urine on the ground around the latrine ?	O	N
3) Is there evidence of cracking or damage to the toilet pedestal or squat -slab?	O	N
4) Is the toilet pit full?	O	N
5) Is the toilet pit overflowing?	O	N
6) Is the floor, pedestal or squat slab soiled with excreta or urine?	O	N
7) Is there evidence of insects (flies, cochroaches) in the latrine?	O	N
8) Is there on offensive or unpleasant smell within the latrine superstructure or in the vicinity ?	O	N
9) Does the latrine fail to provide privacy (no door, door is not closing)?	O	N
10) Is the interior of the the latrine light or is the latrine door (if existing) usually left ajar?	O	N
11) Are there any problems for certain members of the household to use the toilet (due to their sex, age, mobility, ...)?	O	N
12) Are facilities for handwashing with soap available within or close to the latrine?	O	N
13) Is there a management system in place to maintain the latrine?	O	N
14) When the family is not maintaining the latrine, is APECSY doing it?	O	N
15) Has an educational program for the users been conducted?	O	N
16) Have you been more satisfied with the old toilet than with your new dry toilet (concerning smell, insects, price for emptying, ...) ?	O	N
17) Do you know how the system of the dry toilet is working ?	O	N
18) Does the managing of compost or urine poses a problem for you ?	O	N
19) Is there anything you would like to improve or modify at the toilet?	O	N

Comments:

Appendix C

Evaluation of the ecosan installations

Technical University of Hamburg -Harburg, Gemany

1. Is the latrine working ?	O	N
2. Are there any plants in the garden? What plants are still there and which have died?		
3. Is there evidence of excreta or urine on the ground around the latrine ?	O	N
4. Is there evidence of cracking or damage to the toilet pedestal or squat - slab?	O	N
5. Is the toilet pit full?	O	N
6. Is the toi let pit overflowing?	O	N
7. Is the floor, pedestal or squat slab soiled with excreta or urine?	O	N
8. Is there evidence of insects (flies, cochroaches) in the latrine?	O	N
9. Is there on offensive or unpleasant smell within the latrine superstructure or in the vicinity?	O	N
10. Does the latrine fail to provide privacy (no door, door is not closing)?	O	N
11. Are there any problems for certain members of the household to use the toilet (due to their sex, age, mobility, ...)?	O	N
12. Are facilities for handwashing with soap available within or close to the latrine?	O	N
13. Is there a management system in place to maintain the latrine?	O	N
14. Has an educational program for the users been conducted?		
15. Do you know how the system of the dry toilet is working ?	O	N
16. Does the managing of compost or urine poses a problem for you ?	O	N
17. Would it be possible to add the household water into the system ? (How much water is used per day?		
18. Are there any mosquitos breeding in the decanter?	O	N
19. What is the pH value in the decanter? (before and after the gravel filter)	O	N
20. Howoften per week it is necessary to clean the filter?		
21. Are the used pipes big enough?	O	N
22. Can the users utilise the fecal matter after drying?	O	N
23. Why do the users do not plant new plants after the harvest?	O	N

24. Do the plants have more fruits than normal?	O	N
25. Who is the responsible person in the family for the installation?		
26. How often it is necessary to clean the gravel filter?		
27. Are there any problems connected to the installation without roof during the rainy season? (too much water, ...)		
28. Have you been more satisfied with the old toilet than with your new dry toilet (concerning smell, insects, price for emptying, ...)?	O	N
29. Is there anything you would like to improve or modify at the toilet?	O	N

Comments: