Ecological sanitation – principles and technologies

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Abstract In order to reach the UN Millennium Development Goals for significantly reducing the number of people without access to adequate sanitation, new holistic concepts are needed, focussing on economically feasible closed-loop ecological sanitation systems rather than on expensive end-of-pipe technologies, thus enabling all countries to finance and maintain sustainable sanitary systems. Such ecological sanitation systems advance a new philosophy of dealing with what to date has been considered as merely waste and wastewater. They are based on the systematic implementation of the reuse and recycling of nutrients, organics and water as a hygienically safe, closed-loop and holistic alternative to conventional solutions. World-wide over the last few years increasing numbers of pilot and demonstration eco-sanitation projects have been implemented. These have contributed to the further development of a variety of ecosan technologies and operating and reuse options and have provided a large amount of experience with this new, holistic approach.

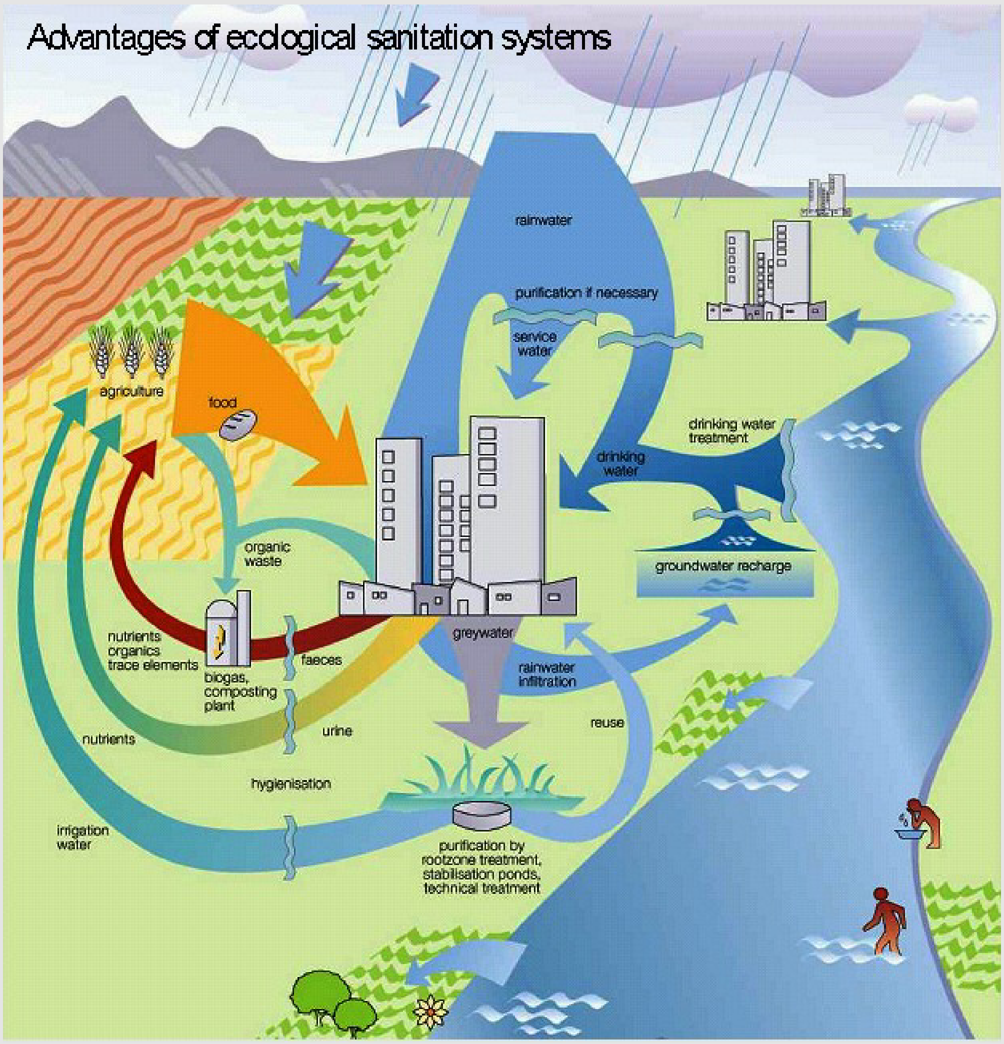
Keywords ecological sanitation, millennium development goals, ecosan technologies

Introduction

The problems raised by the decreasing quality and quantity of fresh water resources around the world are becoming increasingly serious. All indicators show that the situation is getting worse and that we now face a serious world water crisis that will affect us all. The poor are suffering most from a decrease in availability of fresh water resources, and from sanitation related diseases and a damaged environment.

Still 1.1 billion people remain without access to a safe water supply and 2.4 billion have no access to basic sanitation, with the vast majority of these people living in developing countries. Currently more than 90 % of wastewater and excreta world-wide is discharged to the environment with little or no treatment. In 2000, the estimated mortality rate due to sanitation related diarrhoeal and other diseases was estimated at around 2.2 million. Over 2 billion people were infected with schistosomes and helminths, most of them children under the age of 5, with 300 million of those infected suffering serious illness.

It was against this backdrop that the member states of the United Nations adopted the target to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 within the Millennium Development Goals (MDGs). Traditionally the international focus has been on providing drinking water treatment to those without access, however the health benefits that have resulted from such projects have been limited due to an inadequate focus on hygiene and sanitation, and have often proven to have been counter-productive as the improvement in the water supply has resulted in larger volumes of wastewater being produced with no adequate management system in place to deal with it. The MDGs however represent a clear commitment to address sanitation with the same priority as water supply. They also represent a huge challenge to the international community and, for both economic and ecological reasons, will require a revolution in our wastewater and excreta management strategies if sustainable sanitation systems are to be developed that will respect the needs of developing and emerging countries.



- Improvement of health by minimising the introduction of pathogens from human excrement into the water cycle
- Promotion of recycling by safe, hygienic recovery and use of nutrients, organics, trace elements, water and energy
- Conservation of resources, through lower water consumption, substitution of chemical fertilisers and minimisation of water pollution
- Preference for modular, decentralised partial-flow systems for more appropriate cost-efficient solutions
- Possibility to integrate on-plot systems into houses, increasing user comfort, and security for women and girls
- Contribution to the preservation of soil fertility
- Improvement of agricultural productivity and hence contributes to food security
- Promotion of a holistic, interdisciplinary approach (hygiene, water supply and sanitation, resource conservation, environmental protection, urban planning, agriculture, irrigation, food security, small-business promotion
- Material-flow cycle instead of disposal

Figure 1: Principles and advantages of ecological sanitation

Ecological sanitation – a paradigm shift to reach the MDGs

The modern misconception that human excreta are wastes with no useful purpose has resulted in the end-of-pipe sanitary systems that we have today. In nature however, there is no waste. All products of living things are used as raw materials by others as part of a cycle. Considering the environmental damage, the health risks, and the worsening water crisis, resulting from our present sanitary practices, a revolutionary rethink is urgently needed if we are to correct this misconception and realistically have a chance of achieving the Millennium Development Goals of providing sustainable sanitary services to over 1.2 billion people over the next 11 years. A new paradigm is required in sanitation, based on ecosystem approaches and the closure of material flow cycles rather than on linear, expensive and energy intensive technologies. This paradigm must recognise human excreta and water from households not as a waste but as a resource that should be made available for reuse.

Ecological sanitation is this urgently needed new holistic paradigm in sanitation. It is based on an overall view of material flows as part of an ecologically and economically sustainable wastewater management system tailored to the needs of the users and to the respective local conditions. It does not favour a specific sanitation technology, but is rather a new philosophy in handling substances that have so far been seen simply as wastewater and water-carried waste for disposal. Ecological sanitation introduces the concept of sustainability and integrated, eco-system oriented water and natural resources management to sanitation.

The basic principle of ecosan is to close the nutrient loop between sanitation and agriculture, with the objectives of:

- providing affordable, safe and appropriate sanitary systems
- reducing the health risks related to sanitation, contaminated water and waste
- improving the quality of surface and groundwater
- improving soil fertility
- optimising the management of nutrients and water resources

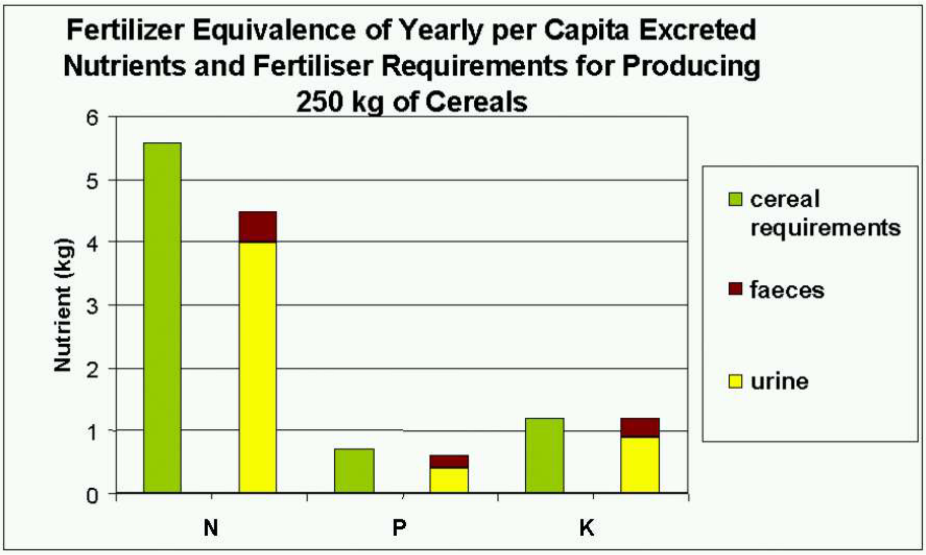


Figure 2: Balance between nutrients excreted by humans and nutrients required for producing their food

Closing the loop enables the recovery of organics, macro and micro nutrients, water, and energy contained in household wastewater and organic waste and their subsequent productive reuse - if necessary after adequate treatment - mainly in agriculture, or for other reuse options. An essential step in this cycle is the appropriate treatment and handling of the materials throughout the entire process, from collection through to reuse, ensuring a series of barriers are erected that will reduce the risk of disease transmission to within acceptable limits, thus providing comprehensive protection of human health.

Ecosan systems restore a remarkable natural balance between the quantity of nutrients excreted by one person in one year and that required to produce their food. It can therefore greatly help to conserve limited resources, preserve soil fertility and safeguard long-term food security. Annually farmers around the world buy and use 135 Mio tons of mineral fertiliser for their crops, while at the same time conventional sanitation dumps 50 Mio tons of potential fertiliser equivalents into our water bodies - nutrients with a market value of around 15 Billion US dollars. Closing local nutrient cycles by recovering and using the nitrogen, phosphorus, potassium, micro nutrients and organics contained in excrement is therefore not only important because it helps minimise the energy and resource intensive production of mineral fertilisers, but also because it makes such agricultural inputs available even to the poorest farmers in developing countries often engaged in subsistence farming.

Ecosan in practice

As an integrated alternative, the implementation of an eco-sanitation project requires an interdisciplinary approach that goes beyond the narrow disciplines and technological aspects of domestic water supply and wastewater management to address issues such as agricultural use, sociological aspects of acceptance and cultural appropriateness, health and hygiene, town planning, economic and small-enterprise promotion, institutional administration, and so on. Such an approach also makes a large contribution to the integrated management of water and other natural resources.

Eco-sanitation opens up a wider range of sanitation options than those currently considered. To optimise cost efficient, high quality treatment and recycling options, two principles are very often applied in ecosan systems:

- Firstly, flow streams with different characteristics, such as faeces, urine and grey water (see Figure 4), are often collected separately. This allows the application of specific treatment processes and optimise reuse.
- Secondly, unnecessary dilution of the flow streams is avoided, for example by using dry, low flush or vacuum transport systems. This minimises the consumption of valuable drinking water and produces high concentrations of recyclables.

Rainwater harvesting and the treatment of organic domestic and garden wastes and of animal manure can also be integrated into ecosan-concepts. Such a separation of the flow streams also allows a more active involvement of the solid waste management sector, where there is already a great deal of experience in the logistics, treatment and marketing of discarded resources.

The separate wastewater flows can be characterised as follows:

- black water – a mixture of faeces and urine with or without flushing water from toilets
- yellow water - urine only or mixed with or without flushing water from toilets
- brown water – black water with no urine
- grey water - domestic water without faeces and urine

However, whilst often making treatment easier and less expensive, the separate collection and treatment of the flow stream is not a prerequisite in ecosan systems, and ecological sanitation is also possible in centralised and combined flow systems.

Ecosan systems strive for resource efficiency. In reducing unnecessary water consumption and avoiding the contamination of water bodies, ecosan systems can have an impact on reducing the costs of raw water treatment and drinking water supply. Additionally the recovery and agricultural use of the organics and nutrients contained in wastewater improves soil structure and fertility, increasing agricultural productivity and thus contributing to food security. The recovery of energy through the anaerobic digestion of faeces, organic waste and animal manure may also represent a significant step towards energy efficiency, providing biogas for cooking or possibly for electricity generation.

Ecosan approaches very often require marketing strategies for the recovered nutrients, innovative logistics to return them to farmland, and directions for their safe application in agriculture. These requirements often result in new service enterprises being established as a result of new ecosan schemes which can also serve to kick start other income generating measures, for example for the construction and easy and safe operation of the installations.

Technological options for ecological sanitation

As ecological sanitation does not prescribe a particular technical solution, but rather tailors sanitary systems to fit the needs of social, economic and environmental sustainability in a given context, a wide range of technologies can, and currently are, being used in ecological sanitation systems. These range from quite simple low-tech systems to sophisticated high-tech solutions:

Vacuum toilets and sewerage

- Faeces and/or urine, greywater, shredded biowaste and a low amount of flushing water are evacuated through vacuum-pipes
- Vacuum toilets are a high-comfort solution for high density urban environments
- The material collected by vacuum sewerage is appropriate to be treated in biogas digesters

Gravity sewerage

- Conventional collection system for mixed wastewater, mostly centralised systems that generally favour unsustainable end-of-pipe solutions
- May be part of ecosan systems, e.g. for wastewater collection in high density areas or for large-scale wastewater reuse

Small-bore-sewer systems

- Gravity sewer system with reduced pipe diameters and low-cost design
- Especially suitable for decentralised collection of greywater or mixed wastewater

Solid-liquid separation

- The solids are separated from liquids shortly after mixing in a flush-toilet by filter-bag or cyclone systems
- No changes within the bathrooms are required
- The separated solids are appropriate for treatment in biogas digesters or by composting

Urine diversion

- Urine and faeces are separated at source before mixing
- Allows for separate and specific handling of urine and faeces
- Urine as nutrient-rich and pathogen-poor resource can be recovered

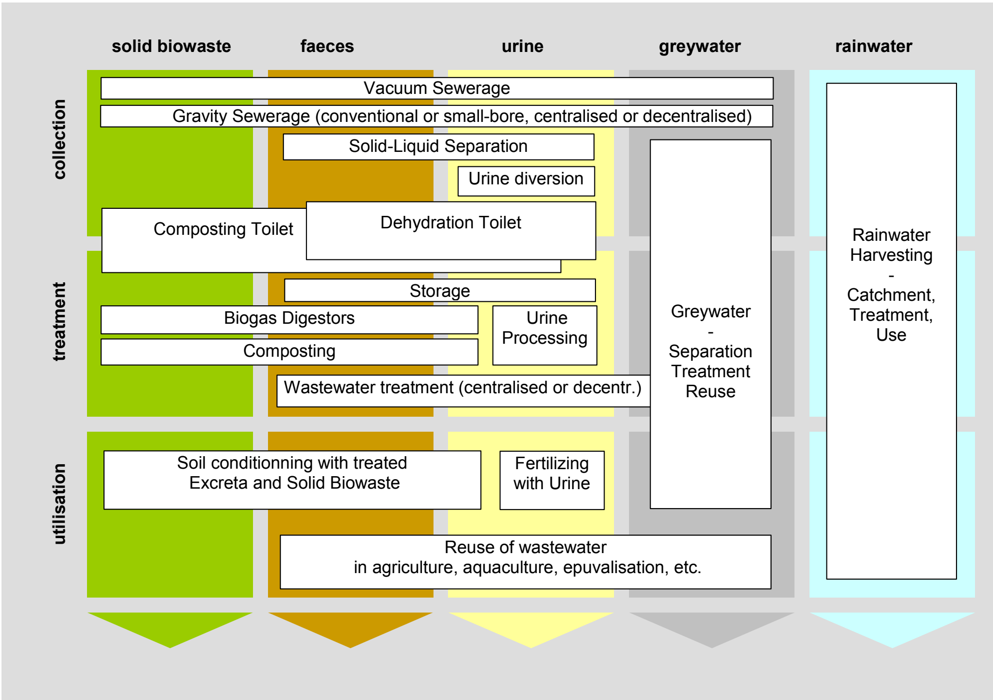


Figure 3: Technical components available for the collection, treatment and use of the nutrients, organics , water and energy contained in wastewater flow streams

Composting toilets
- Waterless toilet systems that receive excreta and sometimes urine or organic biowaste and a dry organic additive
- Treat waste by aerobic decomposition
- Produce a valuable soil-conditioner with low pathogen content

Dehydration toilets
- Waterless toilet systems that receive and dry excreta by heat and ventilation
- Produce a material easy and safe to handle, that can be further processed to a valuable soil conditioner

Urine processing
- Processing of urine to a hygienic, solid or liquid fertilizer product, eg. by concentration, precipitation, adsorption etc.

Biogas digestion / anaerobic treatment
- Faeces and solid bio-waste are stabilized by anaerobic treatment
- Allow energy recovery
- The end product is a valuable fertilizer/soil conditioner, if hygienization is guaranteed

Wastewater treatment
- Treatment of mixed or partly separated wastewater in natural or intensive systems to allow reuse of water and nutrients
- Centralised or decentralised systems

Hygienization by storage

- Prolonged storage of urine, of faeces, or of semi-processed material from latrines, composting or dehydration toilets allows complete die-off of pathogen organisms, which enables safe reuse in agriculture

Post-composting

- Composting provides sufficient stabilization and hygienization for material from pit latrines, composting toilets, dehydration toilets etc. and allows its safe use in agriculture
- Often realized as co-composting together with other organic materials

Fertilizing with urine

- Use of urine as N-P fertilizer by direct application or of urine products (dry or liquid)
- Specific methods of application may be required to minimize nitrogen losses

Soil conditioner from faeces and solid biowaste

- Use of organic matter for maintaining and restoring soil fertility
- Hygienically safe if properly managed

Epuvalisation

- Wastewater treatment by natural processes such as constructed wetlands, including nutrient recovery through biomass production and harvesting directly from the treatment process

Aquaculture

- Wastewater treatment in pond systems and harvesting of the produced biomass through fish cultivation

Wastewater reuse

- Centralised or decentralised reuse of wastewater for irrigation in agriculture or for other purposes
- Allows reuse of water and nutrients
- Adequate wastewater treatment required, degree of treatment depends on type of reuse

Greywater – separation, treatment and use

- includes greywater separation from urine and faeces, diverse treatment techniques, and reuse options

Rainwater harvesting

- includes rainwater catchment, rainwater collection and transport, rainwater treatment and rainwater use

Water saving techniques

- are diverse measures on household level to reduce water consumption

All these components can be combined in various ways, as visualised in figure 3, to optimally address the treatment and resource recovery needs in a particular area. This flexibility in the choice of system technologies makes eco-sanitation suitable for all countries around the world – not only in industrialised nations, but also in developing and emerging countries.

Whilst centralised ecological sanitation systems are possible and may even be necessary in densely populated urban areas, precedence is normally given to appropriate modular and decentralised facilities. The essential advantage of such decentralised, modular components is their flexibility, their reduced costs as no long sewers are needed, and the availability of recyclates for local use. The advantage of this for developing countries is clear.

Neighbourhoods can become involved in the development of their own sanitation system, increasing its suitability to the given context, its acceptance by the users of both the sanitation facilities and the recyclates, and the feeling of ownership of the system.

References

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