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Development of COst-effective REclamation TECHnologies for domestic wastewater (CORETECH)

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INTRODUCTION

Last decades public sanitation mainly focussed on collection of domestic wastewater's in large sewerage networks, transporting the waste (water) from the site of production to the site of treatment (if implemented), using a substantial amount of clean, often potable, water. The generally applied aerobic wastewater treatment systems are extremely expensive and consume large amounts of energy. Also the more extensive pond systems are regularly applied for central treatment of domestic wastewater, especially in developing countries. Though relatively simple, pond systems require a large footprint, often resulting in overloading in case of population growth, moreover a large amount of precious water evaporates due to the large surface area and long detention time. Another negative aspect is the emission of the very strong green house gas CH4 to the atmosphere. In regions with arid climates, like the Middle East, where a shortage of water prevails, improvement of sanitary techniques and use of treated domestic wastewater can reduce the demand on fresh water sources and preserve the nutrients for reuse. In order to find the most optimal solution, the whole chain, from collection to crop choice is to be considered. The general objective of the research in the CORETECH project is to integrate Sanitary- with Environmental- and Agricultural-Engineering for a cost-effective and safe usage of the limited water and nutrient resources in the region.

WASTE (WATER) CHARACTERISTICS

A large fraction of the main components of domestic wastewater, organics, nitrogen phosphorus, potassium and pathogens, is originally produced in a very small volume, viz. as faeces plus urine (Zeeman et al, 2000b). 85%, 2%, 46% and 62% of the nitrogen, organic matter, phosphorus and potassium, respectively, present in domestic wastewater originates from the urine, while res. 11.5%, 52%, 35% and 25% comes from the faeces. The mean production of faeces plus urine amounts to *ca.* 1.5 l/p.d. This small volume contains 96.5%, 54%, 81% and 97% of the nitrogen, organic matter, phosphorus (when no phosphorus is used in washing powders) and potassium, respectively, produced per person per day. Moreover the faeces contain the largest amount of pathogens. All these compounds are diluted with clean water for flushing the toilets and moreover shower and bath water, washing water and kitchen water are added, before entering the sewer. In the sewer often also rainwater is added to it. Finally a large volume of water is transported to the wastewater treatment system, where the different compounds should be removed, consuming a lot of energy when conventional aerobic treatment is applied. The former clearly show that separation of toilet wastewater (black water) can prevent the pollution of the other wastewater streams (grey water) with organics, nutrients and other salts and **pathogens.**

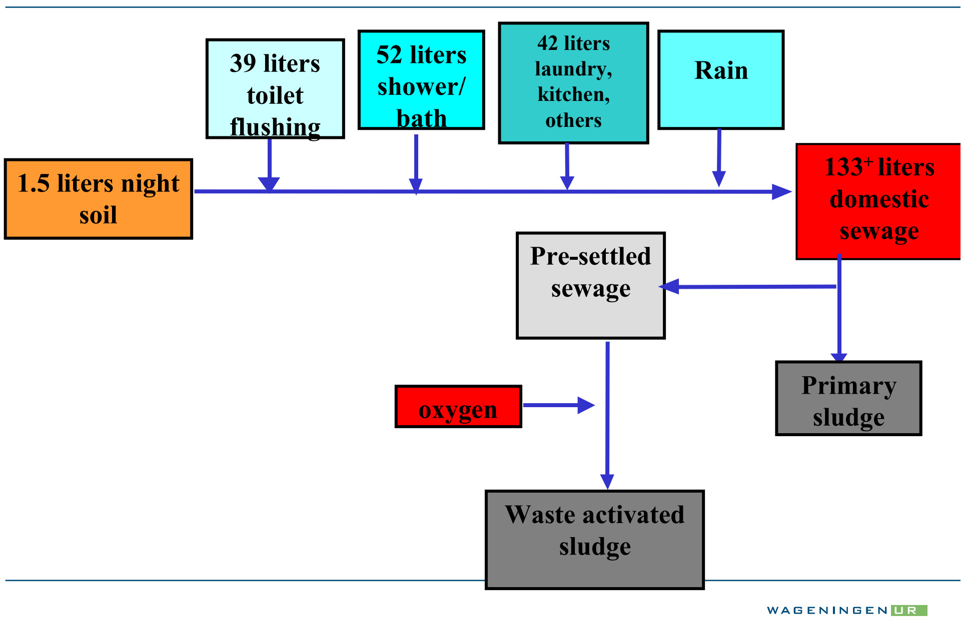


Figure 1, Dilution of night soil (= faeces plus urine) as a results of the transportation with (drinking) water and the combined collection and transport of different domestic wastewater streams

Due to the limited presence of water as resource, the conventional sanitation systems (Figure 1) are highly questionable under arid climate conditions. Minimising water consumption at the household requires other sanitation techniques. The applied collection and transport system will determine the composition and concentration of the waste (water) and therewith the treatment technology to be applied to meet certain requirements for irrigation and fertilisation. The extent of treatment will for an important part be determined by the crop choice and irrigation technique (Martijn et al, 2001). Several sanitation concepts can be distinguished (Zeeman et al, 2000b). The applicability of a certain concept will, amongst others, be determined by the existing situation. In many villages already some treatment of domestic sewage is applied, for example by a septic tank system. Latter systems can be improved in order to increase the removal efficiency and /or extend with a post-treatment system. Some concepts are discussed below

COLLECTION AND TREATMENT

House-on-site (pre)treatment can be an option, particularly for rural areas. In such systems house-on-site (UASB)-septic-tanks (Zeeman & Lettinga, 1999) for the treatment of black water or total sewage (depending on the existing collection and transport system), can be combined with small bore sewer systems, connected to a community-on-site post-treatment to meet the required effluent criteria. The application of house-on-site pre-treatment has the advantage that the SS solid concentration of the sewage is highly decreased, creating the possibility to apply these small bore sewer system, which are less expensive and much easier to apply. Separation of black and grey wastewater has the advantage that the toilet wastewater which contains the bulk of the pathogens,

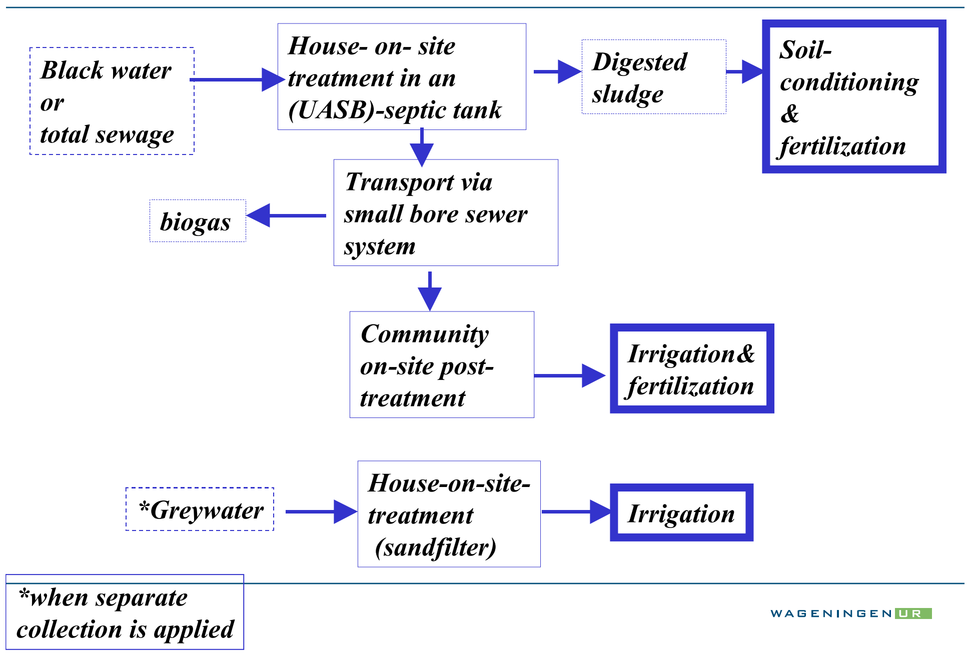


Figure2, Combined house-/ community on-site collection ,transport and treatment of sewage.

nutrients and salts, is separated from the diluted water streams, which has important advantages for the post-treatment and use of diluted streams.
In many existing situations total domestic sewage is collected and transported to a central place where it is either (partly) treated or discharged. In these situations **Community on-site treatment** of total domestic sewage in a UASB-reactor or a UASB-septic tank could be profitable (Zeeman et al, 2000b).

When toilet wastewater is collected with or without a very limited amount of flushing water, the so-called night soil is produced, which could be digested **House-On-Site** in an ACcumulation (AC) system (Zeeman et al. 2000a). The Production of night soil needs the application and development of other types of toilet systems. It is very important to limit the amount of flushing water to a minimum as it will linearly effect the size of the reactor and therefor the costs. Moreover when little flushing (=dilution) water is used, the nutrients keep concentrated in a small volume, which is much easier to handle for agricultural purposes. In Germany vacuum toilets are now applied in a new housing estate, producing a concentrated night soil slurry that is transported under vacuum to a CSTR (Completely Stirred Tank Reactor) in the centre of the estate, where it is anaerobically digested in combination with kitchen wastewater (Otterpohl, 2001). Latter systems do need the use of energy for collecting and transport, which makes them not always applicable. Development of simple systems for collecting and transport of concentrated slurries is necessary. Moore (2000) introduced a toilet system based on the ‘displaced air principle’ with 75% less water use than the conventional 6 litre toilets. Figure 3 shows a concept for the house on site treatment of night soil and grey water.

When C**ommunity On-Site Treatment** is applied a small storage tank for the collection of night soil is to be installed at the household; the content should be regular emptied and subsequently transported to the community on-site digester (CSTR or AC-system). The profit of community on-site treatment could be the better possibilities of using the gas as larger volumes are produced. The profit of house on-site treatment is the fact that no transport is to be provided. After digestion and an eventual subsequent hygienisation step, the digested slurry can be used for soil conditioning and fertilisation. Grey water can be treated house on-site as indicated in Figure 3 and used as 'clean' irrigation water.

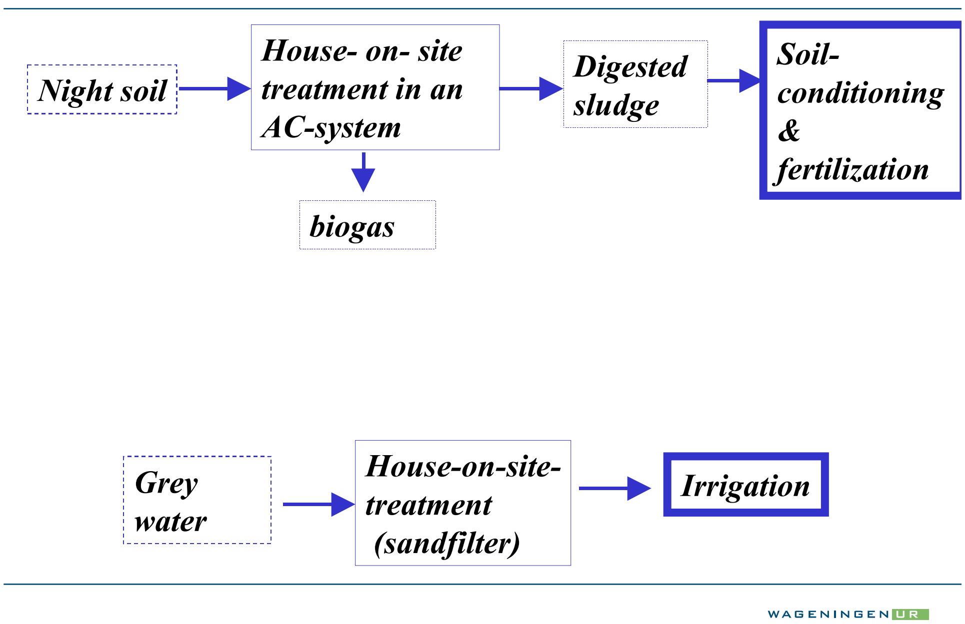


Figure 3**,** Separate collection of night soil and grey water and subsequent house onsite treatment and reuse.

Within the CORETECH project the two above-mentioned on-site sanitation systems will be compared with the application of community on-site treatment in a UASB-system with additional post treatment. This desk study implies, the technological performance (including effluent quality), economics, environmental effects (e.g. diffuse methane emission) and social acceptance for the Middle East Region.

TREATMENT TECHNOLOGIES researched within the CORETECH project

UASB -septic tank system

The UASB-septic-tank system is a promising alternative for the conventional septic tank (Bogte et al, 1993 and Lettinga et al, 1993). It differs from the conventional septic tank system by the upflow mode in which the system is operated, resulting in both improved physical removal of suspended solids and improved biological conversion of dissolved components. The most important difference with the traditional UASB system is that the UASB-septic-tank system is also designed for the accumulation and stabilisation of sludge. So an UASB-septic-tank system is a continuous system with respect to the liquid, but a fed-batch or accumulation system, with respect to the solids. The system is researched for Middle East conditions on a pilot scale for both black water and total sewage at the Birzeit University, Palestine. The reactors are designed based on results of a developed mathematical model, where hydrolysis of entrapped solids is described by first order kinetics and methanogenesis based on Monod kinetics.

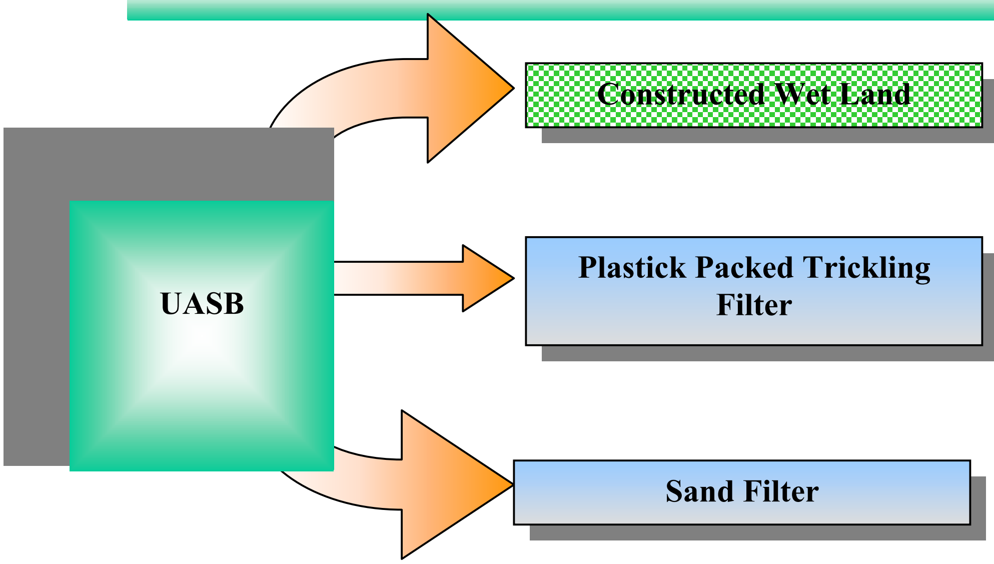
AC-systems

An AC-system is a very simple system where storage and digestion are combined (Zeeman et al, 2001). The system is similar to a pit latrine system, but with the important difference that the system is both liquid and gas tight. An important advantage of an AC-system is that it needs less attention as compared to a CSTR system (Zeeman &Lettinga, 1999). The latter makes the system very attractive for house-on-site application. The storage period should at least be long enough to overcome the winter season where no fertilisers can be used on the fields. The system will be researched in The Netherlands with nightsoil collected with vacuum toilet systems, under controlled temperature conditions, varying between 15 and 25°C to simulate Middle East climatic conditions. Reactor design is based on model calculations, according to Zeeman et al (2000a).

Post-treatment

For the post treatment a multiple approach is chosen, covering natural extensive systems, overland flow systems, ponds, constructed wetlands and sand filtration , which can be implemented in rural areas and villages, but also compact systems, as rotating biological contactors, trickling filters, and rapid sand filters, suitable for implementation in more densely populated. In Egypt, at the NRC, three post-treatment systems have been selected and are researched on a pilot scale. These include: wetland, sand filtration and plastic-packed trickling filter (Figure 4).

Figure (4) The Different Treatment Schemes



The choice of these systems have been based upon initial assessment of cost and technological complexity and feasibility. The chosen technologies are in general, simpler in design and operation than most conventional processes and require minimal external energy sources. These characteristics are important when implementing a treatment system in a community where economic resources and technological skills are limited. In addition at Wageningen university, a biorotor system is researched for post-treatment of anaerobic effluents. At the Agricultural Research Institute in Greece, a slow rate wastewater treatment with simultaneous production of plant biomass is under research. Four different plant species are being compared, viz. Eucalyptus, Giant reed, Acacia and Poplar.

Development of appropriate irrigation/fertilisation methodologies will be coupled to the (community) on-site treatment systems. Its goals are to select the most suitable agricultural crops, including the cropping pattern, which can be grown on the treated sewage, to study the environmental impact of the usage of treated sewage on the soil and underground water reservoirs with regard to the fate of micro pollutants. Moreover to assess and develop improved methods for the identification and enumeration of various kinds of pathogenic organisms in treated effluents, crops and soils. Agricultural aspects will be discussed in an additional paper (Martijn et al, 2001).

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