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Transport and Logistics basics in the context of new sanitation concepts

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1 Introduction

For the development of new sanitation concepts there exist basically two objectives:

On one side the trial to reach the MDGs regarding water. This means the need for save water and sanitation has to be halved by 2015, which involves in the case of sanitation at least 400,000 new systems a day (*Mara & Alabaster 2007*), mainly in developing countries. On the other side we want to gain a more sustainable approach in regions, where water distribution and wastewater management systems already are established. For this later case the development of new systems allows additionally the opening of new markets and thus new and positive effects for their economy.

Since the two objectives for new sanitation concepts mentioned above lead to quite different needs and approaches in planning and since they also require different techniques, in the following it is referred to systems for category I (implementation of sanitation system required) and category II (up-scaling of existing sanitation system). While new sanitation concepts promise solutions in both cases, one of the big challenges in both cases is the implementation of new concepts in larger cities. Herefore many different aspects have to be considered, of which transport and logistics is one.

For the development of each new system positive economics are a strong driving force. To underline the potential of new sanitation concepts, we try to avoid terms as waste. Instead we often speak of products in general (meaning e.g. faecal matter or urine) which can be converted to new products (e.g. fertilizing product). For each product raw material is needed, also transport, conditioning, and distribution. A few examples of this simplified setup are shown in Table 1.

When developing new systems only some obstacles can be predicted while even more will arise throughout the process. In case of new sanitation concepts the need and research for different treatment methods was obvious. At the same time, it became clear, that also the involvement of the users as stakeholder group had to be considered. This is mainly done by integrating them into the

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process of planning and facilitating combined with information and education. The transport system of products and later on the distribution of possible goods from the new sanitation concepts are now the next step focus is drawn to. Similar to the treatment techniques, available and known methods have to be applied in a new context.

Table 1: Examples of a setup of collection, transport, conditioning and distribution of products from new sanitation concepts

Category	Collection system	Product A	Transport of product	Responsibilities for transport structure and treatment	Place of treatment facility	Treatment / conversion of product A into B	Distribution of new product B	Transport of new product B
I	dry toilet	feaces, urine	manual	private	on-site	storage of urine, composting of feacal matter	private	wheel based
I	low flush UD toilet	brown water, urine	wheel based	community based	semi-central	brown water digestion or humification	private sector utility	-"-
II	vacuum UD toilet	brown water, urine	vacuum pipes	private sector utility	semi-central	nutrient extraction, brownwater digestion	-"-	-"-
II	conventional toilet	black water	gravity pipes	-"-	in-house	nutrient extraction, black water loop	-"-	-"-
	..	..						

2 Transport systems for wastewater and products from wastewater

Transport systems can be differentiated in several ways:

- according to the sanitation system (wet or dry)
- according to the location (in-house, private property or offsite, public property)
- according to type of transportation system

The choice of sanitation system and the location do affect the type of transportation system that can be used. For wastewater generally three different transport systems are possible:

- Piping systems based on gravity
- Pressure piping systems (vacuum and over-pressure)
- 'Dry transport systems' (manually or automated)

In the piping systems (gravity and pressure) water is the medium for transportation. Therefore, these are used nearly exclusively in so-called wet sanitation systems. The transportation properties of water are unique because of its excellent solving properties. For purification of the water or even for reuse of e.g. nutrients these dissolved or suspended substances have to be extracted.

2.1 Gravity piping systems

Piping systems based on gravity within houses and gravity sewer systems are the ones mostly used for wastewater transport in conventional wastewater management. The system is characterized by little energy demand for the transport itself, but a need of a certain amount of water as transport medium. Investment costs for the construction and maintenance of sewer systems can be high. Alternative, less costly solutions can be small bore sewerage (*Mara 1996*).

2.2 Pressure piping systems

Pressure based transport systems and/or pumping stations are used for wastewater if the gradient does not allow flow by gravity.

Vacuum systems are known from toilets in trains, airplanes, and some new building projects. For longer distances distributions stations can be implemented.

In both cases the energy demand for transport is higher than in gravity transport systems. Investment and maintenance costs are distributed differently form gravity systems but will be also high.

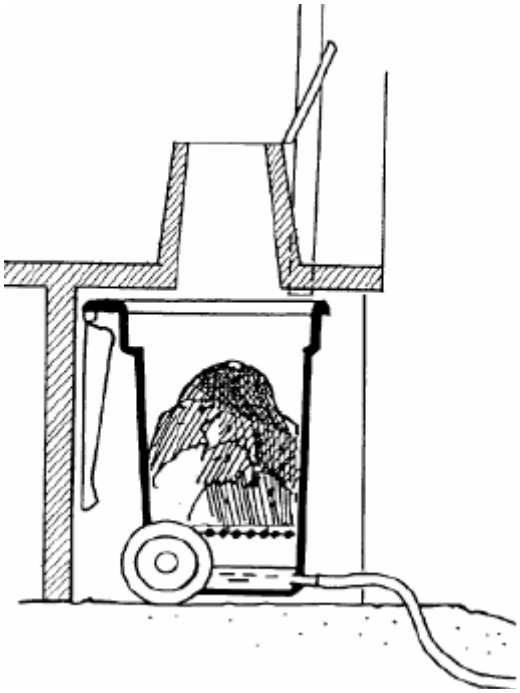

Figure 1: Collection bin for excreta (*Esrey et al. 1998*)

2.3 Dry transport systems

In dry sanitation systems faeces or excreta are collected in buckets or bins. Depending on the height of the building toilet and collection bin can be connected by downpipes. Downpipes are normally vertical flow systems. Systems with an angle of 60° are under investigation. Highly organic loaded leachate can be circulated or collected and treated separately. Collection containers have to be ventilated well to avoid odour nuisance.

From the perspective of the users dry systems often are not favoured because of aesthetic reasons (*Drangert 2004*). But with proper design they do have not to stand back behind flushing systems. Dry systems combine the advantages of small volumes to handle and saving water for more important purposes.

In cases where treatment is not conducted at the place of collection transport form the collection place to a place of treatment is needed. Transport systems have to fulfil high hygienic standards to avoid direct contact from people with the collected faecal matter. Thus, most commonly used are containers on wheels with closable lid (Figure 1). In systems with larger distances collection trucks, similar to waste collection are possible.

Brown- and blackwater dry transportation system outside of private property can be handled accordingly to the faecal sludge transport via honey-suckers from pit latrines, which is well known and often conducted. With low flush toilets volumes of 5 l $p^{-1}d^{-1}$ can be reached (*Jenssen et al. 2003*) which are not far from common volumes of household waste.

2.4 Standards and guidelines for transportation in new sanitation systems

Standards and regulations for the planning and construction of gravity piping systems and pressure piping systems are available for the conventional wastewater management, developed over the last hundred years. Similarly regulations for waste disposal are normally available.

Source separation that is often applied in new sanitation concepts is changing the characteristics of the medium that has to be transported. Therefore regulations for following separated wastewater streams have to be derived:

- Black- and brown water
- Yellow water and urine
- Faeces and excreta (faeces and urine)
- Greywater, respectively greywater and brown water (systems with UD only)
- Stormwater

Volume and consistence influence the efficiency of a transportations system. In terms of transportation black- and brown water do not differ from each other. In-house piping systems for toilet water are known and can be applied. The transport outside of houses with a shallow gradient, especially in cases with low flush toilets, is only be able in pressure or dry systems. Yellow water (urine and flushing water) and urine or faeces and faecal matter from dry toilets (separating or non separation) make no significant difference in transport.

2.5 Responsibilities for wastewater transport systems

The responsibilities for discharge systems within houses and onsite the private property on one side, and on the other side the discharge systems outside of private property are normally in hands of two different groups with their own regulations for design, realization, and maintenance:

- Private sector
- Public sector (municipality)

In new sanitation systems often short resource loops are yielded for. However, especially with the idea of transporting new sanitation concepts into cities community solutions will often involve also the public sector. Therefore guidelines and regulations for transport of the new substrates have to be developed respectively existing regulations for wastewater transport have to be modified to suit also the products from new sanitation concepts.

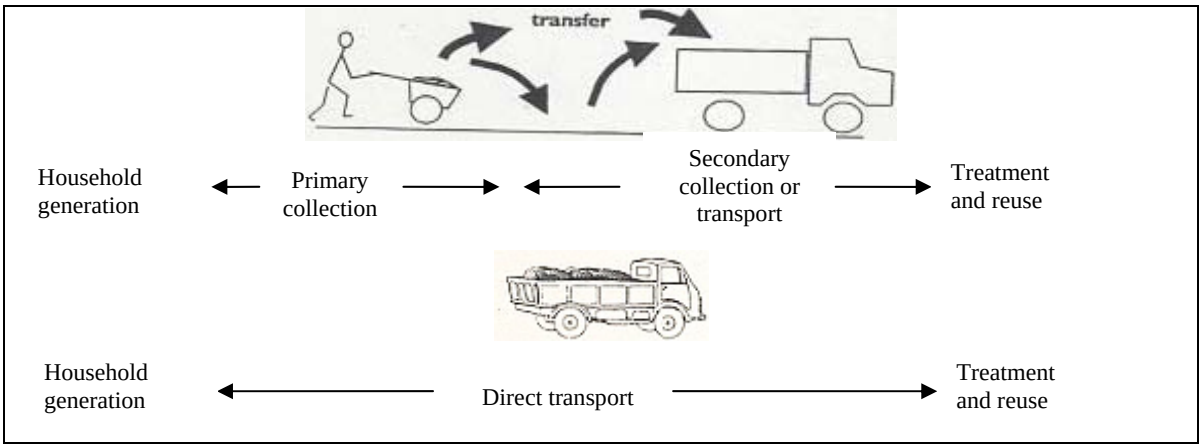

Figure 2: Example of transport with transfer and direct transport

2.6 Logistic systems

Well planned logistics concepts for any aspect of business help to save money and other resources. Additionally in future sanitation systems different concepts might coexist. Thus, logistic and its processes become even more important, involving all aspects of handling goods and services including storage, transport, and commissioning of those (*Arnold 2004*). The different steps can be divided in four main fields:

- Procurement logistics: how can the raw material find its way to the production site?
- Production logistics: how can the production/treatment be handled?
- Distributional logistics: how can the finished good arrive at the costumer?
- Disposal logistics: how can waste be collected and finally disposed or recylced?

These four process steps can be applied to context of new sanitation concepts, where last one loops back into the first one. Collection and transport logistics can be distinguished depending on how the collection, transport, and distribution of resources and products are organized. Products from source separating systems can be transported directly to a treatment facility and distributed from thereon, or transport and distribution can be spread over transfer stations (Figure 2). Transfer stations can help to increase efficiency at long distance transport (*Tchobanoglous 1993*). They can also be used for an intermediate treatment step or for storage.

Jenssen and Etnier discussed different aspects of collection and transport of source separation systems and give in Figure 3 a nice overview over some examples of different sewage system infrastructures (*1997*).

Many different options for treatment have been developed, tested in laboratories in first demonstration projects. Some of these techniques can also be implemented in large urban concepts. However, distribution systems of the products are mostly not specified so far.

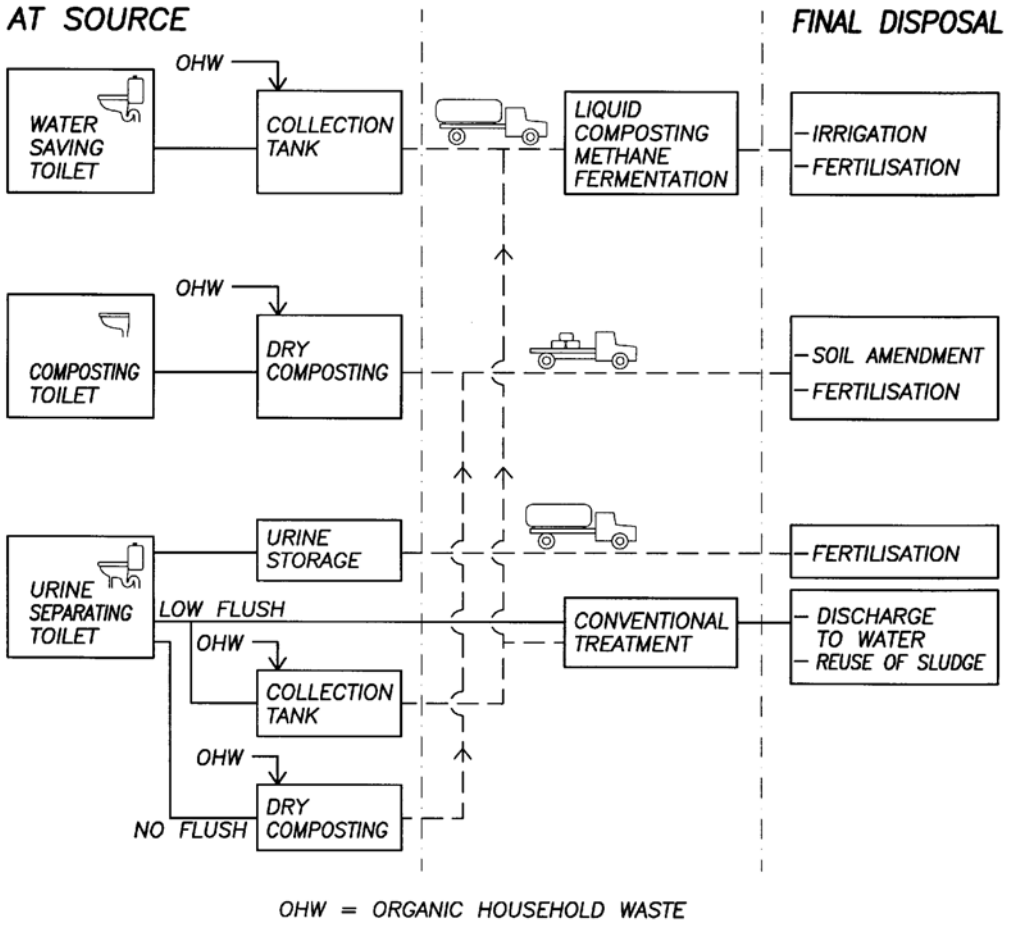

Figure 3: Logistics of blackwater and organic waste handling dependent of toilet type (*Jenssen & Etnier 1997*)

3 System selection

For each location individual solutions have to be developed. As stated before the demand can be categorized and is characterized in the following.

3.1 Systems for category I

In category I systems are needed that allow reaching hygienic conditions with effective techniques simple to build up, to use, and to maintain. Since the current situation is urgent, the timeframe for implementation is short (5 - 10 years).

As collection systems, also due to more or less temporarily lack of water, dry separation toilets and pour-flush toilets are the choice next to flushing systems.

These types lead to two different transportation systems, independent where treatment will be located: on-site, decentralized, or at a centralized treatment facility. While dry and extremely low flush collection systems need a wheelbased transport (e.g. wheelbarrow / sucking-truck / container transport

system), flushing systems of whichever kind allow also a piping system. Regarding a piping system, for category I the conventional sewerage systems has proven to be not the best choice. Investment costs are high, and lack of water will lead to clogging of pipes and thus high maintenance that cannot be served. Small bore sewerage as announced by (*Mara, Sleigh, & Tayler 2001*; *Nance 2005*; *Neder & Nazareth 1998*) proved in some examples transport at less than one half of the costs of a conventional sewerage (*Mara & Alabaster 2007*). While the infrastructure for wheelbased transport is normally present especially in urban areas, transport vehicles and labour is needed over time. Similarly the investment costs of any sewerage system have to be spread over a longer time. The advantage of a wheelbased system is, that it is visible for the user, thus costs for transport are more obvious. Often dry transport systems are already established, since in urban areas faecal sludge from holding tanks is transported by honey-suckers outside the city. Besides of these considerations the conditions present at each individual region will be the driving forces for either the one or the other system. In the end combined systems might be the most reliable ones: wheel based transport for relatively small volumes of sludge, faecal matter, and urine and small bore sewer systems for greywater.

For planning water supply and sanitation improvements for low-income communities, eawag derived detailed principles for urban environmental sanitation (*Eawag 2005*).

Next to choosing the right transport system the responsibilities need to be discussed. For category I there are mainly two different models: 'World Bank consumer model' (*Ruiz-Mier & van Ginneken 2006*) and 'public or private sector utility' (*Mara & Alabaster 2007*). However, according to (*Mara & Alabaster 2007*) this is not philosophically relevant, although it is recognised that the type of ownership of a water supply and sanitation service provider will have an institutional impact on utility performance and service deliverability especially of poor households. Therefore good regulation is needed.

Since the start- and end-products of new sanitation concepts have different characteristics and their handling yield for different aims, individual transport and distribution systems for product A and B have to be build up. Similar to the organization of the transport system for the 'raw products' (A) of sanitation a transport and also a distribution system of the new products (B) has to be established.

Here, next to the transport and distribution systems, most important are the economical aspects and the question how a flourishing market for products from new sanitation concepts can be established. Besides of market analytics and economical feasibility studies guidelines and standards should be helpful for education, which in the end will be the main driving force.

Target of new sanitation concepts will be a system having the capacities in financing itself by integration of water supply, sanitation and urban agriculture.

3.2 Systems for category II

For industrialized countries, speaking of category II, the urgency is mainly not as pressing, thus the timeframe does not have to be as tight as for category I (up to 20 years). Established systems are complex and changes in direction of a new system have to be implemented stepwise. Aims of most new sanitation systems are nutrient recovery and high water savings. Following this, again mainly two different ways of transportation for the products seem most promising. On one side there is again the wheelbased transport, although traffic and air-pollution situation at many places seem not to allow such a system (which is also true for systems in category I). Over long time with new technology such as fuel cell engines and logistic concepts for a decentralized collection at nighttimes, costs should become comparatively to the existing system. Especially because of the stepwise application different systems will have to exist next to each other, which from the perspective of the author might be one of the best solutions anyways.

The distribution system of fertilizer products will most likely be dominated by private companies, but at first its development is highly depending on the market that has to be evolved. For transport and logistics existing structures form recycling products can be used.

4 Outlook

The two defined categories can be divided further into subcategories, according to their collection-transport-treatment and -distribution system. Concepts respectively scenarios are developed for some of the SWITCH demo-cities which will also include a more detailed description of different transport and distribution systems. Accra, Beijing, Hamburg, and Lima represent good examples for the defined categories. Thus another stone in the puzzle 'need for solutions in sanitation' will be available.

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