Logistic Aspects of Ecological Sanitation in Urban Areas

Case study in Low-Income Community in Delhi, India

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During my research I have heard many times that transport of excreta is impossible, especially in India. For one thing, I hope that this report can (1) serve as an illustration that it is possible and nothing difficult and (2) be a start for further research into the field of transport within ecological sanitation as this is an essential but overlooked aspect. With the rapid worldwide urbanization nowadays, there is a real potential for ecological sanitation and subsequently a need for large-scale transport.

Through this research I was given the opportunity to go to a part of the world very different than the country I live in. I vividly remember how I felt the first week in Delhi: lost, alone and not able to comprehend how I ever would be able to do research here. I could not read the signs, people did not understand (your) English and I had difficulty understanding the Indian English, which made even the simplest things such as transportation very difficult. But step-by-step I learned my way around. This whole experience is very valuable to me, as I could really become a part of the Indian life. Therefore, I would like to thank WASTE and FODRA for giving me the opportunity to go to India.

I would especially like to thank Stan Maessen of WASTE for his advice, suggestions and his practical mindset and Madhab Nayak and Sitaram of FODRA who gave me much of their time and a great deal of input. I would also like to thank my supervisors from the university, Irna van der Molen and Peter Schuur, very much for their support: Irna's experience in development countries and Peters open mindedness and enthusiasm. Furthermore, I would like to thank all the people that gave me the possibility to meet and interview them. I would especially like to thank Manus Coffey for giving me inspiration how to approach the calculations, Mr Khambati, Mr Sharatchandra and Mr Dengel for their feedback on my ideas and Wilma van Esch of the Dutch Embassy for her interest and giving me the feeling I could always go to her.

Finally, I would like to thank my family and friends for their interest and support while I was in India, especially my parents, José and Jasper. This made a big difference; they gave me an extra reason to do my best every day. I'm also grateful for all the pre-reading Jasper has done.

Eck en Wiel, October 2005

Marieke Slob

EXECUTIVE SUMMARY

Introduction

This master thesis is the closing report for the study Industrial Engineering and Management and the assignment is executed for the organisation WASTE. WASTE wants to have more insight in the logistic aspects of ecological sanitation (EcoSan). Applications to date have tended to concentrate on rural areas where reuse of excreta often takes place at the household level or at a nearby location. In this case, excreta transport activities are very limited. In urban areas reuse on-site is not always possible, because of space restrictions. With experience in urban areas still being quite limited, there is a knowledge gap concerning the logistics of getting the matter from households to central treatment facilities and/or reuse locations. This study has therefore worked out a transport system for the collection and transport of excreta from the households in a specific urban community to farmers outside that specific city. The research question of this research is:

What is an effective and efficient system to transport excreta from households to central treatment locations in a low-income area (Saboli) in Delhi, India?

Saboli is quite similar to many densely populated urban areas in Delhi and other cities in developing countries.

Methods

The Integrated Sustainable Waste Management concept served as the framework for the development of the criteria for a good transport system. The relevant aspects were applied and adjusted to the specific characteristics of excreta removal and EcoSan and to the context of India, mostly through literature study and semi-structured interviews. This resulted in a set of criteria that was used to compare and assess different formulated collection and transport options. Possible options were identified by studying the current waste removal methods in Delhi and by formulating main logistic systems. The situational conditions of the specific area in which the transport system had to be fitted were studied through a field study, which comprised observations and interviews with inhabitants, NGOs, responsible authorities, users and salespersons of relevant equipment. The concerns and criteria of the community and farmers on storage, collection, transfer and toilet and water use were gathered through several semi-structured group interviews with community members and nearby farmers. Appropriate options were further analysed on financial implications.

Conclusions

For urine collection, collection with a tractor trolley combination equipped with a pump is the most effective and efficient system for large-scale collection. For faeces collection, the use of a household double vault system and collection with a simple tricycle is advised: the tricycles transport the faeces to a transfer trolley located nearby the collection area and secondary transport takes place with a tractor. Advice is also given how initial investments for a limited participation level of 100 households can be kept small. For urine transport the initial investments required for purchasing equipment are ± 47.000 rs (€ 900). For faeces transport the work can be done within two days at that participation level and it is advised to hire a tractor with trolley and driver and a few daily labourers operating simple tricycles or wheelbarrows instead of buying the necessary equipment. This way total yearly costs for faeces are limited to a few thousand rupees (± € 75) initially.

The collectors are in favour as the working conditions will be much better than the manual scavenging they have done. The farmers see potential in urine and faeces as fertilizer and want to experiment with it. The users easily relate to the production and reuse of dried faeces, but cannot easily relate to urine as fertilizer. As for the costs of the transport itself, the yearly costs for faeces are very low considering the willingness to pay. The costs for urine transport are several times higher. When flushing water is added the costs might be too high for the farmers and households to bear, requiring outside subsidy. EcoSan is viable in Saboli when subsidy is provided for the reconstruction of the household toilet systems and when the fertilizer costs for the farmers are lower compared to

their current fertilizer costs. Suggestions are also given how the storage at the household can be designed and how storage and application at the farmer level can be realised in a low-cost way. Finally, it was concluded that the steps and rational of thinking in this research can serve as a guideline for different regions and settings. Several recommendations and issues for further research have been listed.

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GLOSSARY

Ablution water	The water used for cleaning the anal region
Double vault system	System in which two alternating faeces chambers are used, one active and one for storage, to realise some degree of dehydration. The retention period in the chamber gives the faecal matter time to dispose of liquids (see Figure 1.6 and Photo 8.4)
Drain	Pipe or channel for carrying wastewater, effluent, rainwater or surface water
Ecological Sanitation / EcoSan	A specific kind of sanitation that also aims to reuse, e.g. in agriculture, the nutrients, trace elements and organic matter present in excreta (see also ‘Sanitation’)
Excreta	Waste matter discharged from an organism, including both faeces and urine
Faeces	Bodily waste discharged through the anus
Fawari	A specific kind of spade used in India. See Photo 5.4 for a picture
Latrine	Place or building, not normally within a house or other building, for deposition, retention and sometimes decomposition of excreta
Micro-credit groups	Groups, often run by and for women that operate cooperative loans (often without collateral) and savings schemes that allow their members to fund essential purchases
NGO	Non-governmental organisation
Pathogen	A specific agent (such as a bacteria or virus) that causes disease
Pit latrine	Latrine with a pit for accumulation and decomposition of excreta from which liquids infiltrate into the surrounding soil
Pour-flush latrine	Latrine in which a small quantity of water is poured to flush the excreta through a water seal
Retention time	Time taken for a volume of liquid to pass through a tank or treatment process, or the time during which a solid or liquid is held in a container
Sanitation	The means of collecting and disposing of excreta and liquid waste in a hygienic way so as not to endanger the health of individuals or the community as a whole
Slab	Floor on which an arrangement is made to sit, squat or stand to relieve oneself
Soak-away	Hole in the ground filled with e.g. stones, through which wastewater can seep away into the surrounding soil
Urine diverting toilet	Most commonly used ecological toilet which has a specially designed pedestal or squatting pan to avoid the mixing of urine and faeces in the toilet (see Figure 1.5)

Water seal — Water held in a U-shaped pipe or hemispherical bowl connecting a pan to a pipe, channel or pit to prevent the escape of gases and insects from the sewer or pit

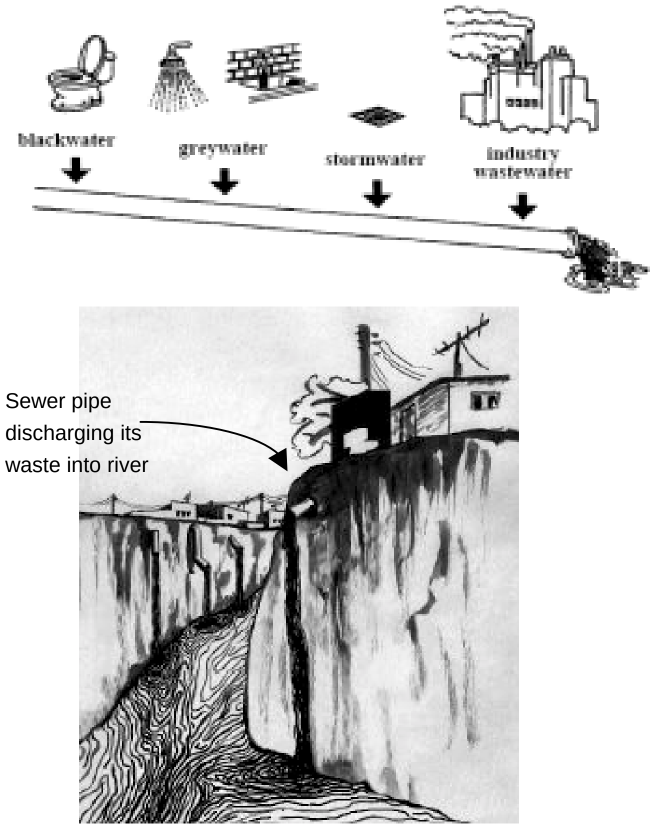

Figure 1.1 The waterborne sanitation system or “flush-and-discharge” model - Most flush and discharge approaches shift the burden of disease and responsibility to communities downstream. (Pictures: Esrey (2001))

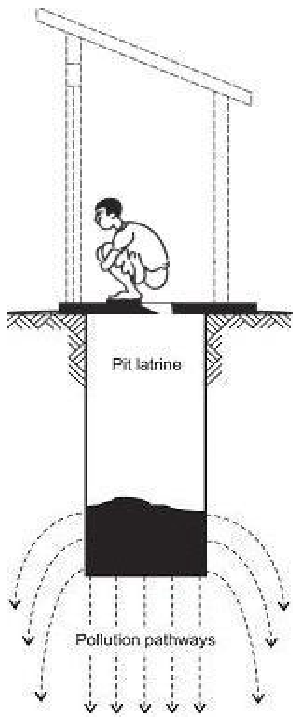

Figure 1.2 The simple pit latrine or “drop-and-store” model (Picture: Adapted from Harvey (2002))

1 INTRODUCTION

This report is the closing thesis for the master Production and Logistics Management of the study Industrial Engineering and Management Science at the University of Twente. The assignment is executed for the organisation WASTE. WASTE wants to have more insight in the logistic aspects of ecological sanitation in urban areas, because they are in the process of introducing ecological sanitation as a sustainable sanitation option in cities in under-developed countries to address the current urban sanitation problems (for more information on WASTE and the urban sanitation programme see Annex 1). This study has therefore worked out a transport system for the collection and transport of excreta from households to central treatment locations for a specific urban community in a developing country (Saboli community in Delhi, India. See Section 1.3 why this area has been chosen).

1.1 Background

The quality of drinking water and sanitation facilities are related to good health and sound environment. In wealthier communities this connection is taken for granted, but in the developing world poor water supply and sanitation remains one of the leading causes of illness and death. According to the WHO/UNICEF (2000), every year about 2.2 million people die from diarrhoea, mostly children. Intestinal worms infect about 10% of the population of the developing world. This causes malnutrition, anaemia and retarded growth, depending upon the severity of the infection. 200 million people in the world are infected with schistosomiasis, of whom 20 million suffer severe consequences. Improving hygiene, water supply and sanitation could control this enormous disease burden. One of the primary causes of contamination of water is the inadequate or improper disposal of human (and animal) excreta. This often leads to a cycle of infection (resulting primarily in diarrhoeal diseases) and contamination. According to the WHO sanitation guide (Franceys, 1992) sanitation refers to *the means of collecting and disposing of excreta and community liquid waste in a hygienic way so as not to endanger the health of individuals or the community as a whole*.

Conventional sanitation systems

With reference to Werner (2004) and Esrey (2001) conventional forms of wastewater management and sanitation fall either under the category of water-borne systems (systems in which water is used as a medium to transport wastes, e.g. sewers) or pit latrines. The design of these technologies is based on the premise that excreta is a waste and that waste is only suitable for disposal. It also assumes that the environment can assimilate this waste. The water-borne sanitation systems transport the excreta and other wastewater away form urban areas and thereby improve the public health of the urban population (Figure 1.1). When this resulted in the heavy pollution of water bodies, such as rivers and seas, wastewater treatment plants were added to the system to protect the environment and water sources. However, the water-borne systems are not working correctly in many countries. The technologies are very high in investment, maintenance and operation costs. This has led to wastewater and excreta being discharged worldwide either poorly treated or not treated at all (for an illustration: Narain, 2002). Currently more than 90% of wastewater and excreta worldwide are either only poorly treated or not treated at all at discharge (Werner, 2003).

The conventional sanitation system in developing countries is the pit latrine (the excreta is accumulated in a large hole in the ground), because the costs of water-borne systems are too high and water for flushing is not (widely) available. Although the pit latrine and similar systems are simple and relatively low in costs, they are difficult to use or not useable in crowded areas, on rocky grounds, high groundwater level areas or areas that periodically get flooded. Furthermore, the design of the pit latrine (and of most other on-plot systems (systems where treatment of the excreta takes place at the same location where defecation takes place)) aims at retaining only the solids and at infiltrating as much of the liquids in the surrounding soil as possible to reduce the frequency of emptying or having to make a new pit (Figure 1.2). However, the liquids infiltrated into the soil contain pathogens, viruses and bacteria, because they have been in contact with excreta, and thereby contaminate the groundwater (Winblad, 2004).

Need for a shift to ecological models

The conventional systems do not provide a solution to wastewater management and sanitation, because the health of the individual and the community as a whole is still endangered as explained above. On top of this, there is a growing awareness and need to safeguard the limited resources in the world. This is particularly urgent with regard to fresh water and mineral resources. With the ongoing water scarcity (UNEP, 2002) the application of waterborne systems is becoming more difficult, because water is used for transportation of the waste. Clean water is too precious to be flushed down the toilet. Another problem is that the nutrients and trace elements that are present in excreta (through the food that is consumed by the people) are not channelled back into the agriculture fields. Mostly they end up (along with the waste water) in water bodies where they become unusable and polluting or the nutrients and trace elements remain concentrated and covered up in a hole in the ground. To restore soil fertility, chemical fertilizers are currently used to produce adequate amounts of food. During the "Green Revolution" (see Section 2.3) nutrients were given the status of being limitless. However, as Rosemarin (2004) sets out, the components in chemical fertilizer are scarce and are likely to become the subject of geopolitical conflicts given the highly skewed distribution in the world.

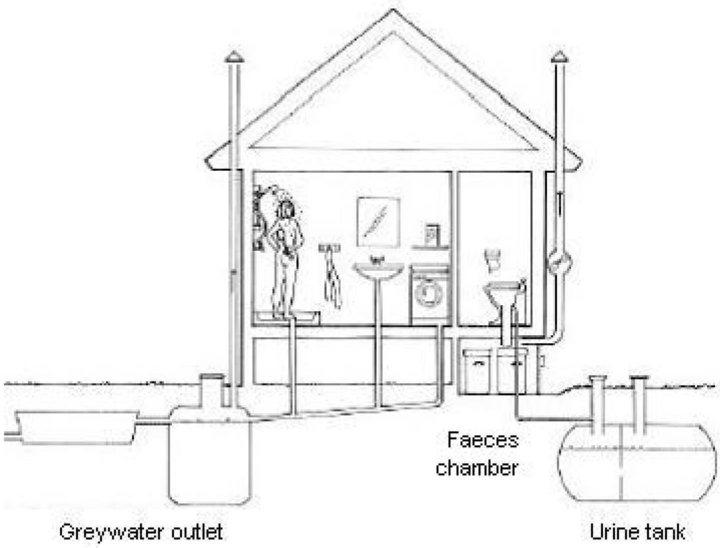

Figure 1.4 A house where faeces, urine and grey water are separated. On the right is a urine-diverting toilet with a faeces chamber and a urine tank (Picture: Winblad, 2004).

Rosemarin shows for example that the economically extractable reserves for phosphorus are estimated to be exhausted within the next 130 years. Phosphorous cannot be substituted by alternative resources and is at the same time an essential nutrient for all forms of life (think of food production). According to Rosemarin recycling from sanitation can be a partial remedy, because a significant percentage can be recovered by using sustainable agriculture and sanitation. However, mixing and diluting excreta with water, as is done in sewage systems, make recovery of the nutrients very costly. Therefore, changes in the conventional sanitation and wastewater systems and adaptation to more sustainable practices for sanitation are needed in order to make recycling economically viable. Ecological sanitation is an approach that regards human excreta and wastewater not as waste but as a resource that should be made available for reuse.

1.2 Problem definition

The basic principle of ecological sanitation (EcoSan for short) is to close the loop between sanitation and agriculture (Figure 1.3). In making organic matter, plant nutrients and trace elements available to agriculture, soil fertility is preserved and long-term food security is safeguarded. The main objectives are to:

- reduce the health risks related to sanitation, contaminated water and waste;
- prevent the pollution of surface and ground water;
- prevent the degradation of soil fertility;
- optimise the management of nutrients and water resources.

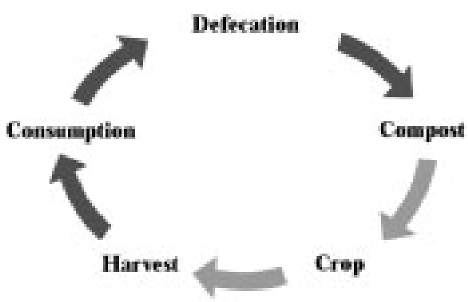

Fig 1.3 Closed loop diagram of EcoSan: linking defecation and agriculture (Picture: Esrey (2001))

EcoSan does not favour a particular technology, but is rather a new philosophy in handling substances that have so far been seen merely as a waste to be disposed of. Excreta can provide a fertilizer for farming and urban agriculture, also for those who currently cannot afford or use chemical fertilizers.

Separation of faeces, urine and grey water

In practice the commonly applied EcoSan strategy is the separate collection and treatment of faeces, urine and grey water (e.g. kitchen, shower and water used for washing clothes) and the use of little or no water for flushing (Figure 1.4). In the water-borne systems, the 400-500 litres of urine and 50 litres of faeces excreted by one adult person over a year are flushed away with 15,000 litres of water. Water from bath, kitchen and laundry may add up to another 15,000-30,000 litres for each person. Further down the pipe rainwater from streets and rooftops and wastewater from industries are often added. This means the dangerous component containing the pathogenic viruses and bacteria, the 50 litres of faeces, is allowed to contaminate huge amounts of clean and grey water (Winblad, 2004). Furthermore, the mixing of urine and faeces with (large amounts of) (grey) water, as is done with sewer systems and septic tanks, makes treatment of the water and the recovery of nutrients difficult and costly.

Figure 1.5 Several examples of urine-diverting slabs. On the left two sitting toilets and on the right three squatting toilets. From left to right: A plastic fabricated toilet (Picture: WASTE), a pedestal of fibreglass (Picture: Esrey, 2001), a squatting pan in a bathroom in Palestine (Picture: WASTE) and a Chinese design of a squatting pan (the lid over the faeces drop hole can be pushed aside and closed with the foot; Picture: Marieke Slob). Below right is a pan made with sand and cement (Picture: Shayo, 2003).

Urine contains most of the nutrients and faeces most of the organics. Separating these streams keeps the nutrients concentrated in urine and the organic matter in faeces and makes sure that the pathogens in the faeces do not contaminate the urine and wastewater. Each of the streams can be treated separately, using techniques such as composting and dehydration, in order not to compromise health. This is done preferably on the spot (at the source of excretion) to minimize handling of hazardous material. After faeces have been treated, they are free from pathogens and odour.

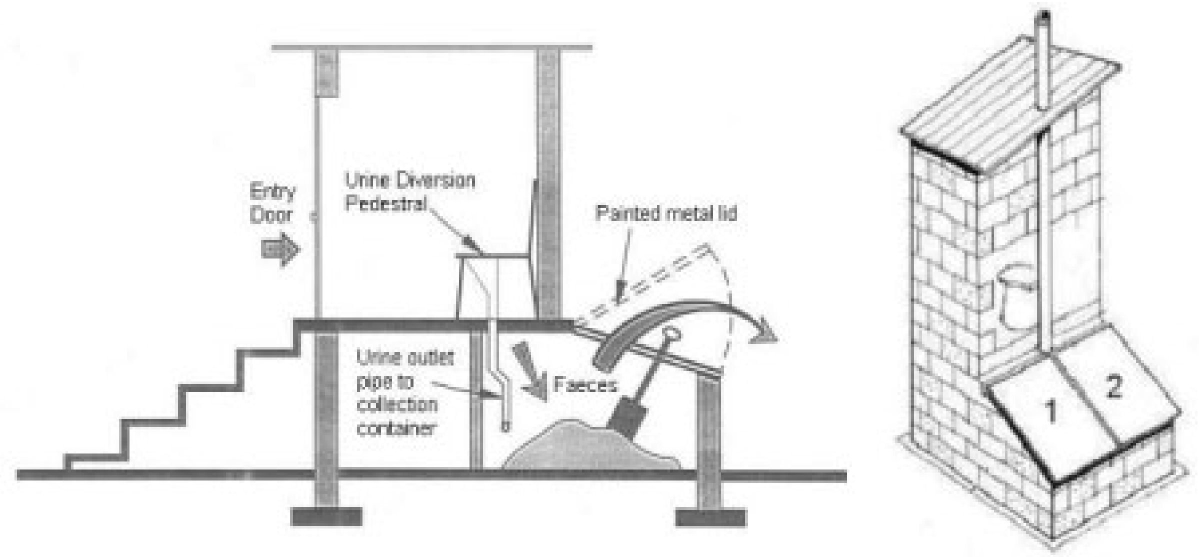

Figure 1.6 An example of a double vault system: the urine is diverted away and the faeces are collected in a separate storage. Once the active chamber is full, one can switch to the second storage container. When the second container is also filled, the first chamber can be emptied with e.g. a shovel and one can switch back to using the first chamber. By that time the faeces in the first container have been dried and are (mostly) free of pathogens and smell. Pictures: left adapted from Austin (2002) and right adapted from Winblad (2004).

Toilet design

As conventional toilets are designed to dispose of excreta by combining urine and faeces and flush them away in water or bury them in deep pits new designs are needed. Ecological sanitation covers a wide range of techniques for toilet design and for collection and treatment of urine and faeces. These range from low-tech to high-tech solutions, as well as for rural and urban settings and systems. A distinction can also be made between on-site and off-site systems referring to the place where the final treatment takes places.

A variety of ecological toilets are currently in use, most distinguishable as either urine-diverting or non-urine-diverting of which the urine-diverting toilet is the most commonly used. Urine diversion requires a specially designed pedestal or squatting pan. To avoid mixing of urine and faeces the toilet user has to sit or squat over a ‘dividing wall’ so that faeces drop behind the wall and urine passes in front of the wall. Figure 1.5 shows some examples. The urine can be collected in a container and the faecal matter in a chamber underneath the toilet. Urine can be used as fertiliser immediately or after limited storage time, but faeces are safe only after treatment and/or after prolonged storage for at least several months. Therefore often two alternating faecal chambers are used, one active and one for storage (Figure 1.6).

Non-urine diverting toilets are for example composting toilets. An appropriate moisture level and airflow must be maintained in the chamber to enhance optimal degradation of human excreta. The product, in the form of humus, can be returned to the soil.

Difficulties and challenges

To speak with the words of Werner (2003): “Individual, successful and promising examples of ecological sanitation already exist in various countries, but a great deal of research and development work needs to be done before EcoSan is established internationally as a way of solving the many different problems”. As she explains: we do not have a solution for every situation yet and we do not know what is more economical. We do not know what the cost will be on a large scale and so far there are not many pre-manufactured components available. Often, laws prohibit applying human urine and faeces, requiring special permits to implement EcoSan (Werner, 2005).

In addition, Kroh (2003) for example raises several questions with regard to the (potential) success of EcoSan such as the issue of acceptability of the users and other stakeholders. Often EcoSan systems impose a higher

burden on the users and existing conventional systems need to be taken into account as well, because it will usually not be financially feasible to replace an existing conventional system by an EcoSan system in case the existing system has not yet been fully depreciated.
Another aspect that needs attention is that applications to date have tended to concentrate on rural areas, with experience in urban and peri-urban areas still being quite limited. Faced with rapid worldwide urbanization there is an increasing need for solutions in these urban areas. Most of the time the rural projects consist of simple decentralised facilities in which storage, treatment and reuse of the excreta takes place on site, either at the household level or at a nearby location. In urban areas, on-site facilities are not always possible or the most appropriate option, because often space is very restricted. So far little research has been done on the possibility and implications of ecological sanitation in areas where on-site systems are not possible.
A difference with on-site systems is that when treatment and reuse cannot be situated nearby, the excreta have to be transported from the households to some sort of central treatment facility and reuse location. Figure 7a and b on the next page schematically illustrate the difference in transport requirements.

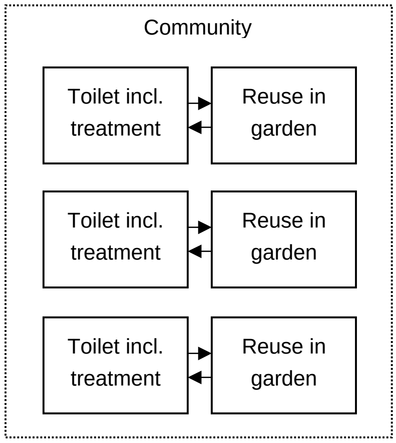

Figure 1.7a Schematic overview of transport requirements (arrows) in an on-site system

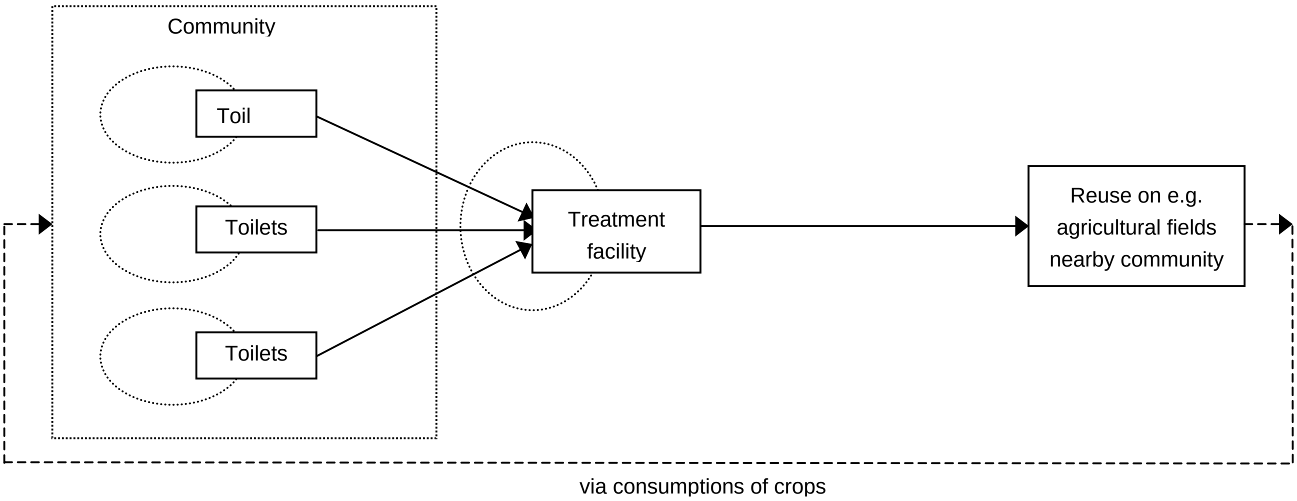

Figure 1.7b Schematic overview of transport requirements (arrows) in a system whereby reuse takes place outside community

How to design the toilet, how to treat excreta and how to reuse the material is more or less known, but there is a knowledge gap concerning the logistics of getting the matter from the households to central facilities and reuse locations. Questions like: what containers and vehicles should be used, should transport be done directly or is it more efficient to use transfer points, have not been investigated yet. Let alone the best way of managing the transport safely and hygienically.

1.3 Research questions

In order to gain insight into the logistic aspects of ecological sanitation in urban areas this study will work out a transport system for a low-income area in Delhi, India. This location is chosen for practical reasons. English is spoken reasonably and the local partner of WASTE participating in the urban sanitation programme in Delhi (FODRA, see for more information Annex 1) is working with a more densely populated community in comparison to the other partners of WASTE in India. In the other areas reuse can also take place within the community itself, because people have larger plots in these areas. This decreases the actual need for transport.
FODRA, participating in the urban sanitation programme since 2004, has been working in Saboli community for more than seven years now. Saboli comprises several adjoining clusters in North-East Delhi. With the success of micro-credit groups (groups that operate cooperative loans and savings schemes that allow their members to fund essential purchases, often run by and for women) FODRA has gained much knowledge on the community and has gained trust within the community. This community is therefore chosen as the focus area of this research, because research results could be attained more quickly by cooperating with FODRA instead of going to an area where no previous contacts were present. Considering the time constraints of this research, this was important. Saboli community is quite similar to many areas within Delhi and other cities in developing countries (more information on the characteristics of Saboli in Section 5.1).

The research question of this research is:

What is an effective and efficient system to transport excreta from households to central treatment locations in a low-income area (Saboli) in Delhi, India?

This study will not cover the whole chain from generation and storage of the excreta at the households via transport and treatment to the reuse of the excreta. Focus will be on the part of collection and transport from the figurative doorstep of the houses to the treatment locations. The treatment facility is only seen as the destination of the transport system. Determination of the type of treatment and the location lie outside the scope of this research. As Saboli community is an existing situation the currently built houses and road conditions are constraining factors. There are no existing or planned treatment locations as of yet.

In order to answer the research question several sub questions have to be answered. Each sub question will be accompanied by a short explanation on the reason the question is asked.

1. What is the Integrated Sustainable Waste Management concept?

- principles and dimensions
- relevant elements for the design of EcoSan projects

The Integrated Sustainable Waste Management concept (ISWM) will be used as analytical framework for this research to assess whether a system is effective and efficient. ISWM promotes technically appropriate, economically viable and socially acceptable solutions, which do not degrade the environment, to waste management problems. It has become the core concept for understanding and planning waste management in cities in developing countries in general. The ISWM model includes aspects that vary from institutional, socio-cultural, technical, economic, and environmental to policy and legislation.

2. What are the criteria to decide what is the best transport system?

- criteria of ISWM concept
- logistic aspects of EcoSan projects, strengths and weaknesses of earlier EcoSan projects
- social, cultural, technical, affordability and public health aspects that should be taken into account

The ISWM concept is a general framework for all types of waste management, but is particular formulated with solid waste management in mind. Excreta removal and/or EcoSan have specific logistic characteristics. Therefore the relevant aspects that have been put forward in sub question 1 have to be applied and adjusted to the specific characteristics and situation of excreta removal, EcoSan projects and India. This will result in a set of criteria that can later be used to assess what the best transport system is.

3. What are the current waste removal methods in the context of the low-income area of Delhi?

- logistics of excreta and solid waste removal
- stakeholders
- possibilities for overlap with the solid waste flows

Much can be learned from the current waste removal methods, not only the removal methods for excreta, but also for solid waste. The collection and transport of solid waste has many similarities to the manner in which excreta could be removed when an ecological point of view is taken. The transport of excreta in sewer systems is not appropriate, which might necessitate transport by road. Transport by road is common in the solid waste field and much could be learned from the already gained experiences. The current methods also give ideas for possible options, such as the vehicles and containers that could be used. Also, integration with solid waste collection services could potentially save resources.

4. Which main logistic systems can be identified for excreta collection?

- main possible modes of collection and transport
- appropriateness of logistic options to be worked out in detail in India
- parameters of design

There are many different concrete transport systems possible. In order not to disappear in all the possible options and variations a few main systems will be identified. In these main systems there has not been a choice yet for the particular handling and transport equipment. This can be filled in more concretely in a later design stage together with the assessment of different (equipment) options. A choice will be made which system has the most potential for the specific area and this research. This system will be worked out in detail. The system will also be looked into from a logistic point of view to gain more understanding of the dimensions of the system. The parameters of design will give information on the variations and choices that have to be made within the main system.

5. What are the situational conditions of the specific area in which the transport system has to be fitted?

- economic, development and health situation
- current excreta removal, solid waste removal, treatment and fertilizing methods
- number of inhabitants, toilet and water use, location and size of community, road conditions
- concerns and criteria of community and farmers on storage, collection and transfer

The community that functions as the source of the excreta that has to be transported, the farmers that function as the destination and the area in between make up the setting of the transport system. Knowing the dynamics in this area is very important, because the system has to be fitted to this particular situation. Moreover, looking at the whole chain reduces sub-optimisation of the separate steps in the chain and makes sure delivery is useful to the next party.

6. What is an effective and efficient design for the transport system?

- handling, collection, transfer and transport equipment options
- social, cultural, technical, public health and financial implications on formulated criteria

- required number of equipment and personnel

Based on the criteria for a good design and the analysis of the current methods and situation, options for each step in the transport system will be formulated. The designs will be assessed on their health, social, cultural and technical implications. The appropriate options will be further analysed for the required number of equipment and personnel. This will give detailed insight on their financial implications.

1.4 Methodology

This section will give an explanation of how the research questions were answered.

Integrated Sustainable Waste Management concept

The ISWM concept was studied first, because this formed the framework for the whole research. The concept is extensively described and explained in tools developed by WASTE, a non-governmental organisation (NGO). Drawn from practical experiences in developing countries, WASTE and its partners started working on a framework to describe, theorise and address the common problems with waste management assessment and planning in low-and middle-income countries below the equator. This framework was formalised as Integrated Sustainable Waste Management or ISWM.

Criteria for a good transport system

From the ISWM framework general criteria were drawn. These criteria needed to be translated and supplemented to excreta removal and EcoSan. For the literature study on EcoSan and its logistic aspects mostly grey literature was used, such as accounts of projects, conferences proceedings and books with findings from several years of experience. Scientific studies other than focussing on the chemical and biological aspects of EcoSan have not been performed so far, but many organisations do have links with universities and some papers have been peer reviewed by scientific committees. In the literature not much has been written on the logistics of EcoSan in particular. Therefore, semi-structured interviews with practitioners of (eco-)sanitation and solid waste management with experience in developing countries were conducted. Scientific books, focused on low-cost sanitation and solid waste collection methods and developing countries were analysed for relevant criteria.

Current waste removal methods in the context of the low-income area of Delhi

The different sanitation and solid waste collection methods were studied through scientific books, focused on low-cost methods and developing countries. In a later stage, observations of these processes in different parts of Delhi supplemented this study. Several NGOs and the municipal of Delhi showed different kinds of methods on-site and semi-structured interviews were conducted on the way of working and the problems.

Main logistic systems

The main logistic systems were identified on the basis of existing excreta and solid waste removal systems. Based on the context of the specific area, the expertise of the researcher and the knowledge need in research, the logistic system that had the most potential was chosen. Scientific books on logistics were used to describe the network model.

Situational conditions of the specific area in which the transport system has to be fitted

Understanding of the economic, development and health situation was gained through observation and open interviews with inhabitants and members of the local NGO FODRA during numerous visits. Furthermore, semi-structured interviews with the doctor and the solid waste collector were also performed, together with an observation of their work.

Two databases, developed by FODRA were also studied for this. They have much quantitative data on more than half of Saboli community, such as the number of inhabitants, family size, income, availability and location of individual toilets. The Geographical Information System (GIS) database was set up in 2002 by interviewing with a questionnaire more than half of the present households (± 4400 families) in Saboli. The objective was identifying and analysing the basic problems and initiating partnership with local authorities to tap available resources/

services. Although the database is very valuable, because half of the families in the area are included, the quality of the data and the consistency was not very good. That is why, where possible, most information was derived from the EcoSan Database, because in this database on the other hand most fields were completed and the database manager checked the database afterwards. This database was developed in 2004 and inventories the sanitation and solid waste situation of Saboli in more detail. With almost 1300 families surveyed this still gives a good indication of the community (currently about 15% of total number of families).

The concerns and criteria of the community and farmers on storage, collection, transfer and toilet and water use were gathered through semi-structured group interviews with community members and nearby farmers (during all the group meetings a translator assisted for all the interactions.). The sessions in the community were with:

- 4 community women groups: 10-30 women per group, mixed group qua caste level, but having relatively same low economic profile;
- 1 group with formal and informal community leaders (mostly men, mixed group qua caste level);
- 1 group with sweepers working in the community (4 men, all Dalits (or untouchables)).

With each group one meeting was held. The awareness of the groups differed from already being aware of EcoSan to not knowing that the current pits contaminate the groundwater. No more groups have been interviewed or a survey has not been conducted, because the dynamics were the same in the different groups.

Group meetings were seen as the most appropriate, because a new concept had to be discussed. This meant in practice that they could not relate to their own experiences yet. Having the persons interact with each other about what the system would look like, the problems and solutions, made them able to think about it deeper and visualise it better than they would have been able to do during an individual interview or survey. The goal of the meetings was also more on the dynamics and the opinions, rather than on individual facts. The drawback of group meetings is that the results can be more coloured, because people especially do not like to talk about sensitive subjects in public. Favourable answers will be given in front of the group. To capture this drawback the employee of FODRA, the local NGO, was away most of the time and the results were discussed and/or checked with the director and programme coordinator of FODRA and other persons interviewed. Also, adopting an EcoSan toilet system is an issue that the individual cannot implement without others knowing about it, meaning social acceptability is also an issue in the actual choice.

To deepen the interaction and to make sure everyone was talking about the same thing, pictures, a simple model of their current system and an EcoSan system was used, made out of a shoebox (see Annex 2), a plastic mug to assess the amount of water used for toilet activities and a bottle of dried faeces was brought along.

Most groups consisted of women, because health, hygiene, toilet and water use are issues women are concerned with and the women groups were easily accessible. Under the guidance of FODRA many women groups have been formed: self help groups focussed on the micro-credit programme and groups focussed around health related issues. No men groups are currently present in the community.

Concerning the farmer groups, four sessions were conducted:

- 2 groups (± 15 men each group) with which one explorative session and one session focussing particularly on storage, application and criteria was held. The farmers had previous knowledge of EcoSan through contacts with FODRA;
- 2 groups (4 and 10 men) with which one meeting was held: focus on storage, application and criteria. The groups had no previous knowledge of EcoSan to get a more unbiased response.

Each group represented one village part. Three of the village parts were Hindu communities and one village was a Muslim community; they have different attitudes towards faeces and urine (see Section 6.4). In all groups the

EcoSan concept was explained first (the group with previous knowledge requested this). The pictures and shoeboxes, used in the meetings in Saboli, were also used for this purpose. Pictures and photos of different storage and applications options were also used to start the discussion.

Although women also do a lot of work in the field, no meetings were held with women. When it became clear in the meetings what application method was the most sensible for the men farmers, the relevance was not high anymore. The women will most likely not do these jobs when the urine and faeces will come in the future, because currently the women do not do the similar jobs (applying the animal manure, chemical fertilizer and irrigation). This was asked in a conversation with a few women after a meeting (this conversation was in absence of men).

Design of the transport system

The technical options were identified through the same literature study and observations as for the current waste removal methods. Furthermore, open and semi-structured interviews were conducted with NGOs working with sanitation or solid waste collection, the responsible authorities for sanitation and solid waste of the municipal of Delhi, salespersons and users of relevant equipment, the community and farmer groups as described above and other practitioners in waste management.

Based on the analysis of the options and the criteria, supplemented with criteria and concerns determined during the group interviews and specific conditions of the area, a design was made for the transport system. The implications on the social, cultural, technical and public health aspects were determined on the basis of the interviews done in the analysis phase. The financial implications were determined by interviewing several salespersons on local markets and several tractor and tricycle owners. A full cost-benefit was not preformed, because the benefits are mostly social and health benefits, which were not measurable within this research.

1.5 Scope and limitations

Because of the time limitations of this project this study was limited to one area in Delhi. To use the results of this study for other parts of the city or regions a translation to the local conditions has to be made. Also, only one main system is chosen for further research in India. The focus of this study is on the structural planning, not on the operational planning such as vehicle scheduling and routing, but on the long-term decisions such as the design of the structure and what equipment to buy and construct.

This study will not give a complete picture of the investments and cost of an ecological sanitation system, because only a small part of the whole chain is studied. Only the cost of transporting and handling the matter from the households to the treatment facilities will be investigated, not the costs of for example the treatment facilities and the toilets in the homes. Also, the possible revenues and financing possibilities will not be investigated. WASTE has experience with this. The institutional, legal and political aspects of the transport system and a full stakeholder analysis will not be looked into either. These aspects will be dealt with by WASTE. The question to what extent people are interested in ecological sanitation in general lies outside the scope. Other studies have focussed on this. Only the acceptance and social implications of the transport and handling options will be explored.

Sewer systems lie outside the scope of this research. They are not seen as a sound ecological sanitation solution, because of their high investment and maintenance costs and their large usage of water for transport and their many leakages. Also, only solutions in which urine and faeces are stored and transported separate are taken into account, because this is a principle of ecological sanitation.

1.6 Outline report

Chapter 2 will give an introduction to the Integrated Sustainable Waste Management concept and will adjust the relevant aspects of the concept to the specific characteristics of excreta removal and to the context of India. This will result in a set of criteria for a good transport system. Chapter 3 will describe the current sanitation and solid waste practices and the logistic organisation. The main logistic systems for excreta removal will be identified in

Chapter 4 and a choice for one main system will be made. A list of factors that should be considered in selecting the most appropriate collection system will also be given.

The next two chapters will focus on the source and destination of the urine and faeces to be transported. Chapter 5 will focus on the source: Saboli community. Knowing the situation and dynamics of this community is very important as it gives the setting of the collection system. Next to the general context, the current sanitation, solid waste disposal and health situation is discussed. The chapter also gives insight into the viewpoints, concerns and criteria of the community on the storage and collection of urine and faeces in their houses and community. Chapter 6 will focus on the farmers nearby Saboli: the destination of the urine and faeces. Looking at the whole chain makes sure delivery is useful to the next party. Next to the general context, the current use of fertilizer and current application and storage methods are discussed. Some concrete possibilities for storage and application of urine and faeces are given and the chapter finishes with the viewpoints, concerns and criteria of the farmers.

Now that the setting is known, the next two chapters will focus on the question how the collection in Saboli and the transport to the nearby farmers could be designed effectively and efficiently. Chapter 7 will deal with the collection and transport of the urine and Chapter 8 will cover the logistics of the faeces, as both substances have very different characteristics. Both chapters will present and compare possible collection and transport options and assess each option from a health, technical and social/cultural point of view. The acceptable options will be further analysed on investment and costs level. From this, conclusions can be drawn which option is the most effective and efficient. Some suggestions for the actual design of the household containers will also be given and both chapters will conclude with several social and technical issues that should not be overlooked before implementation. Chapter 8 will also remark on possibilities for integration of the collection services for faeces, urine and solid waste. The conclusions and recommendations of this research will be presented in Chapter 9.

2 FRAMEWORK – CRITERIA FOR A GOOD TRANSPORT SYSTEM

This chapter will cover the Integrated Sustainable Waste Management concept (ISWM). This concept will be used in this research as the framework for the development of criteria for a good transport system. The first section gives an introduction to the nature and rationale for developing this concept and it explains the principles and dimensions of the model. The section will conclude with how the ISWM concept is used for this research. The relevant aspects that have been put forward in the ISWM concept have to be applied and adjusted to the specific characteristics of excreta removal and EcoSan projects and to the context of India. This is the focus of respectively the second and third section. This will result in Section 0 in a set of policy and design criteria that can be used to assess what the best transport system is later in this research.

2.1 The Integrated Sustainable Waste Management concept

There is a tendency, in waste management and sanitation, to move directly from problems to solutions, without an analysis of what is actually occurring. The most obvious answers are more money or more equipment, even when money and equipment are not the essence of the problem. Too often approaches used in developed countries are directly copied, without taking the local context into consideration. The models used in developed countries are capital- and technology-intensive and labour extensive. Exporting these models to developing countries, where they may be less appropriate, has proven not to be effective. As a result, money and equipment are used incorrectly and at large expense for the many problems that they cannot solve. Assessments and plans often end up in drawers or initiated projects die after the external organisation leaves, because no one owns (or even understands sometimes) the recommendations, recommendations are not appropriate to the local circumstances, local knowledge is ignored or certain groups are excluded, local decision-makers lose confidence in planning processes and local people and organisations do not feel responsible for the outcomes.

ISWM seeks to avoid this by regarding the process as important as the results, using participatory action research and multidisciplinary teams and an explicit concern for disadvantaged groups and environmental resources. Furthermore, the ISWM insight is that most waste management problems have to do with something other, or more, than money and equipment. Some problems have to do with the attitude and behaviour of citizens, waste management staff, private enterprises and waste pickers. Other problems are caused or made more serious by factors that are not technical or financial, but relate to managerial (in)capacities, the institutional framework, the environment, or the social or cultural context. In these cases, it is not money or equipment that provide solutions, but rather changing social, institutional, legal, or political conditions. The ISWM concept was developed to reflect this reality, as a means to articulate a vision of waste management that would pay attention to all these various aspects. ISWM provides some tools to look more in depth at the actual needs of communities and municipalities in the South (source and more information on the ISWM concept: Klundert (2001) and Anschutz, (2004)).

2.1.1 Principles of ISWM

The ISWM builds upon four basic principles:

- Equity — All citizens are entitled to an appropriate waste management system, irrespective of their social or economic status. This goes beyond a moral duty, because pollution affects other parts of the city through diseases, insects, rats, air and water pollution; poor living conditions foster social unrest; and unclean neighbourhoods and sick labourers affect the city's economy and slow down development.
- Effectiveness — The waste management model applied leads to the safe removal of all waste and all nutrients are recovered.
- Efficiency — The benefits of clean areas and reuse are balanced by all beneficiaries paying a reasonable cost to keep them that way, using the optimal combination of labour, money, equipment, machinery and management and taking into account equity, effectiveness and sustainability.
- Sustainability — The waste management system is appropriate to the local conditions, feasible from

a technical, environmental, social, economic, financial, institutional and political perspective and it can maintain itself over time without exhausting the resources upon which it depends.

2.1.2 Dimensions of ISWM

ISWM recognises three important dimensions in waste management: (1) the stakeholders involved in and affected by waste management, (2) the (practical) elements of the waste system and (3) the sustainability aspects of the local context that should be taken into account when assessing and planning a waste management system. The ISWM model is depicted in Figure 2.1.

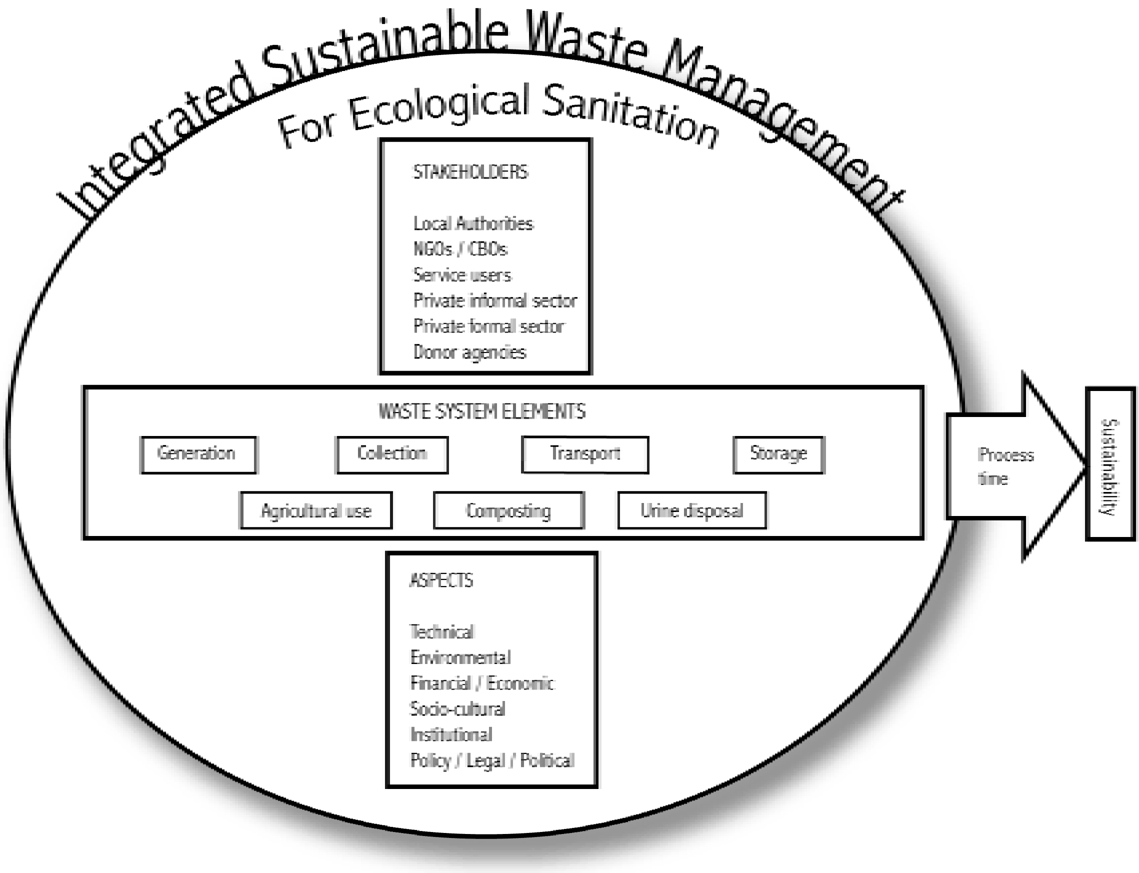

Figure 2.1 The ISWM Model for Ecological Sanitation.

Although the ISWM model is developed for solid waste management it also fits other infrastructure management such as water and Sanitation management (Source: IJgosse, 2004)

Stakeholders

A stakeholder is a person or an organisation that has a stake, an interest in, in this case, waste management. A number of potential stakeholders are listed in Figure 2.1. Stakeholders have various interests and roles in waste management, but they can cooperate for a common interest. Their influence and importance varies. The challenge of the ISWM process it to get them to agree to co-operate for a common purpose, that of improving the waste system. Stakeholders differ in each city and they need to be identified in the local context.

System elements

The waste system elements (techniques, steps and infrastructures) are the stages in the movement, or flow, of materials from generation, via collection and transport, towards storage/ treatment and reuse. The history and character of the local situation influences which system elements are present and which are absent or underdeveloped. An ISWM process seeks to supplement the existing system so that all elements are represented.

Sustainability aspects

ISWM aspect	Areas to investigate
Technical	1. Waste quantities, waste composition, density 2. Capacity of collection or treatment technology (how much waste can be collected, how many people can be served, which areas can be served with it) 3. Physical infrastructure (condition of roads, traffic) 4. Sturdiness of equipment/technology 5. Local availability of spare parts
Environmental	6. Effects of technology on the environment 7. Effects of technology on opportunities for reuse and recycling 8. Working conditions and environmental health of waste workers
Financial-economic	9. Capital and labour cost 10. Operation and maintenance costs compared with waste management budget 11. Feasibility of covering depreciation (cost of replacement)
Socio-cultural	12. Average level of awareness among population 13. Willingness and ability to pay 14. Cultural attitudes towards waste and implications for waste handling, separation at source, recycling 15. Gender and sex roles relating to management of waste within the household
Institutional	16. Skill level waste management staff 17. Procurement methods for imported spare parts
Policy/legal/political	18. Political priorities (e.g. increase employment, reduce imports, improve environment) 19. Policy and regulations regarding technologies and equipment 20. Contracting rules; biases in contracting procedures

Figure 2.2 Areas to investigate for each sustainability aspect in ISWM when selecting waste management technologies (Source: Klundert (2001)).

The ISWM concept distinguishes six aspects, or lenses, through which the existing waste system can be assessed and with which a new or expanded system can be planned. The aspects cover the range of factors influencing waste activities and taken together, predict or influence the sustainability of the entire system:

- *Technical and performance aspects* concern the observable practical implementation and maintenance of all of the waste elements: what equipment and facilities are in use or planned; how they are designed; what they are designed to do; whether they work in practice; and how clean the city is on a consistent basis.
- *Environmental aspects* focus on the effects of waste management on land, water and air; on the need for conservation of non-renewable resources; pollution control and public health concerns.
- *Financial-economic aspects* relate to budgeting and cost accounting within the waste management system and in relation to the local, regional, national and international economy. Some specific issues are: privatisation; cost recovery and cost reduction; efficiency of municipal solid waste management systems; macroeconomic dimensions of resource use and conservation; and income generation.
- *Social-cultural aspects* include the influence of culture on waste generation and management in the household and in businesses and institutions; the community and its involvement in waste management; the relations between groups and communities, between people of various age, sex, ethnicity and the social conditions of waste workers.

- *Institutional and organisational aspects* relate to the political and social structures which control and implement waste management: the distribution of functions and responsibilities; the organisational structures, procedures and methods implicated; the available institutional capacities; and the actors such as the private sector who could become involved.
- *Political/legal aspects* address the boundary conditions in which the waste management system exists: setting goals and priorities; determination of roles and jurisdiction; the existing or planned legal and regulatory framework; and the basic decision-making processes.

Integration on different levels

ISWM strives for an integrated approach. It aims at the integration of:

- Various stakeholders, governmental or non-governmental, formal or informal, profit- or non-profit oriented. Fostering cooperation and relationships between these stakeholders over a longer period of time will lead to lasting results.
- Looking at all the six aspects, not merely the technical and the financial aspects.
- Various collection and treatment options. The 'dominant' system may not work in e.g. low-income areas or on hillsides, so that uniformity means these areas tend to be marginalized and receive little or no waste collection. ISWM promotes a customized and decentralised approach, looking at specific requirements and conditions, to provide service to the various neighbourhoods and communities.
- The waste management system and other urban systems such as water, drainage, energy, urban agriculture.

2.1.3 Usage of ISWM in this research

ISWM can be used for two main purposes:

- To assess and monitor existing waste management systems;
- To plan a new waste management system, including the selection of appropriate technologies.

In this research the concept will be specifically used as a framework for the development of the criteria for designing a good transport system. Selecting appropriate waste management technologies is difficult and depends on the local context in which the technology will be applied. The ISWM concept gives for each sustainability aspect in Figure 2.2 a list of areas to investigate when selecting appropriate technologies.

However, this is not enough. The areas are not yet criteria and the criteria have to be specific for the project and local context. The ISWM concept is a general framework for all types of waste management, but particularly formulated with solid waste management in mind. Excreta removal and/or EcoSan have specific characteristics. Therefore the relevant aspects that have been put forward in the ISWM concept have to be applied and adjusted to the specific characteristics of EcoSan projects and to the context of India. This will result in a set of policy and design criteria that can later be used to assess what the best transport system is. These will be presented at the end of this chapter. Note that not all elements in the ISWM model are subject of this research, strictly only the transport and transfer elements. Furthermore, as indicated in the scope of this research (Section 1.5), not a full stakeholder analysis will be performed and the political/legal and institutional aspects will not be covered.

2.2 Specific characteristics of excreta removal in EcoSan projects

Human excreta consist of faeces and urine. Both differ much from other waste materials such as plastics or glass and they differ also a lot from each other. Urine is not a solid, but a liquid and faeces contain potentially dangerous pathogens for example. This section will focus on the specific characteristics of excreta and its removal in EcoSan projects.

Generation quantities

Table 2.1 first starts with the generation quantities for urine and faeces. This determines the quantity that has to be transported. A person excretes much more urine than faeces. Faeces consist mostly of water and can be dried to 70-90% of its fresh volume. Urine, almost only water, is not dried, because in that case not only the water evaporates, but also most of the nutrients.

Table 2.1 Generation quantities per person per year

Characteristic	Urine	Faeces
Volume	400-500 litres/person/year	50 litres/person/year
Density	1 kg/litre	± 1 kg/litre
Influence of storage	Volume and weight reduction through evaporation is negligible when stored in a closed container	70-90% of volume/weight after a year depending on climate and ventilation

Source: the volume differs among publications. It depends for example on the circumstances such as the amount of transpiration during a day. In consultation with WASTE these number have been chosen as an average.

Figure 2.3 Pictures of initial set-up of the Bangalore Public Toilet Project (Source: Baumeyer, 2003) Clockwise:
1. Collecting chamber with drums. Under each toilet cabin are various drums: one 120-litre drum to collect the urine, one for the faeces, and some reserve drums.
2. Loading of the drums on the lorry. The urine is collected together in 2 to 4 drums before transportation, in order to save place in the lorry.
3. The urine drums are emptied in the reservoir by the operator. First the material is emptied by the mean of a 10 litres drum (on the right) and the rest of the urine is pulled in the reservoir with the help of the second operator;
4. Emptying of the faeces drums into the trenches.

Pay attention that the anal cleansing material is often added to the faeces stream. In India this would be water as will be explained in the next section. This water will have pathogens in it, because it has been in contact with the faeces and should therefore be handled with care. Annex 3 gives more information on the nutrient amount present in urine and faeces. The purpose of this research is to transport the excreta without or with limited loss of these nutrients.

Earlier EcoSan projects

Earlier EcoSan projects have mostly been small-scale projects in the sense that reuse in these projects has been in the garden of the households producing the excreta. The transport necessary in these projects is not comparable qua scale to a whole urban community as illustrated in Figure 1.7a/b. There have been several projects collecting excreta from housing blocks, but these were mostly in more developed countries with transport in the form of (vacuum-)pipes. Weak points in projects with pipes are blockages and leakages.

In one project in Bangalore, India, a urine-diverting public toilet (8 toilets) in a slum was built. The faeces and urine were collected in large plastic drums located under each slab under the floor and every day a lorry came to replace the full drum with empty drums. The full drums were taken to a composting site several kilometres away. During handling the large plastic drums were closed off with lids and then manoeuvred manually into the truck (Figure 2.3). After a few years of operation, it was decided to replace the drum system with fixed tanks under the public toilet and to empty these tanks with a suction tank. Johannes Heeb and Martin Wafler, both project employees, explained in an interview that the biggest problem in the initial set-up was cleaning of the drums each time (very strong smell and unhealthy work). With the new set-up this is resolved. Another reason was that the community itself and the authorities objected to the manual handling (even though the drums were closed during handling). Suction is a mechanised system that is not related to scavenging. The government approved of the new system and asked them to develop more of these toilets. The transportation costs are possibly lowered as well, because in the initial set-up the trolley could not be fully loaded (only one layer of drums could be placed into the body of the lorry).

Urine diverting

Urine diverting is often applied in EcoSan projects and also in this research. The consequence is that the urine and faeces need to be stored and kept separately. Unlike faeces, urine does not need extensive treatment and is almost immediately reusable. When faeces and urine are collected together, the urine has to undergo the same (prolonged) treatment as the faeces. Furthermore, the treatment of faeces becomes much easier when faeces are kept as dry as possible (reducing the moisture level speeds up the die-off process of the pathogens). Another reason for urine diverting is that with separate treatment less nutrients are lost. In the composting process more nutrients are lost through evaporation and leaching. In the case of India urine diverting is also a good choice, because the transport of faeces could be unattainable in the near future because of cultural/social objections (see next section). At least in this case the nutrients in the urine can be used as agricultural input, which is still a considerable amount.

Presence of pathogens, bacteria and viruses

The presence of pathogens, bacteria and viruses in excreta and the large impact it can have on the public and occupational health are a great factor to consider during the design of a transport system. Therefore some more information on transmission routes, diseases and factors influencing die-off of pathogens can be found in Annex 4 . The conclusion for the handling of urine is that urine does not constitute a significant public health problem, but cross-contamination with faeces may occur. This imposes health risks and therefore contact with urine should be avoided. The exposure to untreated faeces is always considered unsafe and treated faeces should be handled with care, because some pathogens are very persistent (depending on the type of treatment). Health protection measures to prevent pathogens from reaching the handlers of excreta are:

- Designing equipment and handling in such a way that spillage of excreta and direct contact with the urine and faeces is minimised and that it is possible to clean the equipment;
- Hand washing and wearing gloves;
- Primary treatment at the source of excretion to reduce the number of pathogens in the faeces before handling takes place. Therefore, sanitizing faeces at the source of excretion, by e.g. a double vault, should always be strived towards and is often implemented in EcoSan projects. A second advantage of primary treatment is a considerable reduction in the volume and weight of faeces, reducing the required resources for collection and transport.

Table 2.2 Characteristics of urine and its consequences for storage and handling

Characteristic	Consequence for storage and handling
Liquid	Suction and pouring is possible during handling
Minimal presence of pathogens, bacteria and viruses	No extra measures needed for prevention of disease transmission during handling and transport
Bad odour	Watertight closure or prevent movement of the urine (then the ammonia production giving the smell is slowed down)
Transformation of nitrate in ammoniac during contact with oxygen	Watertight closure to stop loss of nutrients. This means also no vent pipe.
No pressure build-up	Only pressure equalisation needed to accommodate incoming volume of urine in container
Alkaline	Prevent contact with eyes and skin
Corrosive	Use of corrosive resistant material, such as plastics or high quality concrete. Use of metal should be avoided (stainless steel is possible).
Crystallisation	- Minimize places where urine stands still - Sections where urine stands still should be easily reachable and replaceable - Pipes need to be cleaned regularly (how often is a matter of experience and depends for example on bending and inclination of pipes).

Table 2.3 Characteristics of faeces and its consequences for storage and handling

Characteristic	Consequence for storage and handling
Dry faeces are solid	Dry faeces can be dug out during handling
Fresh faeces (with anal cleansing water) is liquid and partly sticky	Suction and pouring possible for fresh faeces is watery enough. Care should be taken that containers are emptied completely.
Presence of pathogens, bacteria and viruses	- Primary treatment before handling strongly advised - Health risk related to dried faeces is substantially reduced, but care should still be taken. - No direct contact and no spillage of fresh faeces
Bad odour of fresh faeces	Possible measures: - Watertight closure - Vent pipe that causes an upward airflow - Situating the pit not directly under squatting hole (use of a chute) - Addition of ash or paper to speed up drying process
Attraction to insects and rodents	Possible measures: - Watertight closure to prevent access to the faeces - Closing of vent pipe with a wire mesh - Situating the pit not directly under squatting hole (use of a chute)
Possible pressure build-up of methane gas (in anaerobe conditions)	Vent pipe is necessary.

Other specific characteristics

Besides the hazardous character of urine and faeces there are a few other specific characteristics that have an impact on the storage and handling. These characteristics with the subsequent consequences are listed in the two tables on the left: Table 2.2 and Table 2.3.

2.3 Context of India

The context of India in relation to excreta transport is structured around the different aspects that are identified in the ISWM concept:

Social/cultural

Povery, health, education and gender
Poverty reduction remains India's most compelling challenge despite good progress in the 1990s. The percentage of people living below the poverty line of $1 a day is 35% and below $2 a day is 80% of the population (1990-2002; UNDP, 2004). Health and education are also a significant challenge. Of the total population 40% over 15 years old cannot read and write. Almost half of all children under the age of five are malnourished and 34% of newborns are significantly underweight. With regard to gender the overall picture remains one of stark inequality. Bias against women and girls is reflected in the demographic ratio of 927 females per 1,000 males. Many of India's women are malnourished because of anaemia, which is present in 60% of the female population (World Bank, 2003). This means options have to be low-cost, focus on improving the hygienic environment, improving nutritional contents of food, and special attention has be taken to reach women and to obtain their needs and opinions. This is especially important, as toilet management and hygiene in the household are in general the responsibility of women.

Anal cleansing method
Water is used in general for anal cleaning in India. Hindu and Muslim religion both specify the use of water for (anal) cleansing (very water scarce areas use e.g. stones). Warner (1990) gives an indication of the elaborate codes of conduct when one is going to defecate in the principle Hindu text. Only the upper classes can follow all these recommendations, but most of the Hindus at least use water for cleaning the anal region. Although it would be better for primary treatment of faeces to use no water, it should be noted water is unavoidable in Indian context; purity and cleanliness is valued highly. Culturally they wash and any system proposed should take this practice into account. A small percentage of the population has installed a western style toilet and prefers cleaning with paper.

Caste system
The Indian social structure is a unique social system. Nowhere is caste better exemplified by degree of complexity and systematic operation than in India. A caste is a closed group whose members are severely restricted in their choice of occupation and degree of social participation. Social status is determined by the caste of one's birth and may only rarely be transcended. Nowadays there are thousands of such castes. Each has its distinctive rules and customs and is graded on a scale of purity with Brahmin (priestly and learned class) at the top and Dalit (oppressed) or untouchables at the bottom. The Dalits are considered polluted and often have to live outside the village, using a separate well for their water and doing the most dirty work such as cleaning or sweeping of streets, drains and sewers and removal of human and animal excreta. They often do this in very degrading and unhealthy conditions (piling the excrement into baskets and carry those on the head to a distant location during which the contents of the basket drips onto a scavenger's hair, clothes and body, especially during the rainy season, causing malicious forms of infections, which affect among others their skin, eyes and limbs).

The caste system, and with this the practice of “untouchability”, was declared illegal in 1949 in the constitution, but the caste system continues to be influential and resistance to change has remained strong, especially in rural areas (more information on the history and initiatives taken by the government: Srivastava, 1997).

For this research this means that handling is still only permitted by Dalits. Even when working conditions are improved considerably and the income is satisfactory other castes will not engage in handling of excreta, because of fear of social repercussions within their community.

The presence of the caste system with its social issues and the strong attitude of impurity of excreta means that there is high degree of disapproval and scepticism on the transportation of excreta in India. It is felt as a step back into the past that India is trying to leave behind (based on many interviews with Indian people (of which many have work in the field of sanitation)). This goes further than general sceptics towards a system that one is unfamiliar with. Experts in ecological sanitation note that when people see for themselves how a well-managed system works, most of their reservations about handling human waste disappear (Warner, 1990).

Political/Legal

Although the political/legal aspects are not a part of this research, there is a specific law directly related to this research. There are several domestic and international laws forbidding the current treatment of the Dalits, because the Dalits work in conditions that are degrading and a serious risk to their health as explained above. Under the Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act (1993) it is now forbidden, among other things, to engage in or be employed for manually carrying human excreta and constructing or maintaining a dry latrine (by forbidding a dry latrine and compelling water-seal latrines one advocates sewers and septic tanks. However, these are not only cleaned in mechanised ways; manual cleaning also occurs for these systems). The United Nations Commission on Human Rights (2002) and The Hindu (2003) point out this law remains only on paper and manual scavenging continues in virtually every State.

This law has influence on both the type of toilet and the way of handling. By enforcing water-seal latrines, one advocates sewers and septic tanks. This could pose a problem as these options are not first choices for EcoSan. As all dry latrines (a latrine other than a water-seal latrine) have to be replaced by water-seal latrines (a (pour-) flush latrine, with a minimum water-seal of 20 mm diameter in which human excreta is pushed in or flushed by water), the construction of dry “ecological sanitation” latrines without water-seals is forbidden. Furthermore, the Act does not specify what is manually carrying human excreta and under what conditions it is allowed. Apart from the fact whether or not a water-seal has been added to the construction, it remains unclear whether the handling of *dried* faeces and urine is forbidden. Dried faeces are very distinct from fresh faeces, because the number of pathogens in dried faeces is considerably less, there is no bad smell anymore and it looks like soil.

This law is formulated to stop practices of removing fresh faeces or as Leelaben, a safai karamchari (a person engaged in sanitation work) in Gujarat, illustrates: "In the rainy season, water mixes with the faeces that we carry in baskets on our heads, it drips onto our clothes, our faces... When I return home, I find it difficult to eat food. The smell never leaves my clothes, my hair. But in summer there is often no water to wash your hands before eating. It is difficult to say which is worse." (Thekaekara, 1997). For this research it is assumed that when the handling and transport of faeces and urine is designed in such a way that the dignity and health of the worker is not harmed it is allowed, although strictly seen it is forbidden by the law. In the perception of the scavengers the collection of dried faeces is favourable as explained in Box 5.1 in Section 5.3.3.

Environmental and economic

The Green Revolution, spreading over the world in the 1960s and 1970s, changed India’s status from a food-deficient country to one of the world's leading agricultural nations. The Green Revolution was a technology package comprising material components of improved high yielding varieties, irrigation or controlled water supply and improved moisture utilisation, fertilizers, and pesticides, and associated management skills. India is one of the countries where it was most successful, building substantial buffer stocks of food grains, in spite of increasing demand due to rising population. However, critics argue the Green Revolution has thrown up its own set of problems. The Green Revolution is destroying soil quality over the long term as a result of a variety of factors, including prolonged and heavy use of chemical fertilizers and increased soil salinity, because of heavy irrigation (Good News India, 2002). These factors can lead to increased reliance on chemical inputs to compensate for deteriorating soil quality, a process which may ultimately fail, as the chemical fertilizer e.g. does not substitute the organic material and kills off beneficial soil microbes and other organisms. Restoring soil quality is one reason to include more sustainable agriculture. A second reason is the increasing scarcity of phosphorous. It is especially important for India to find alternatives to chemical fertilizers, because it is the largest importer of phosphate and phosphoric acid and completely dependent on foreign sources (Rosemarin, 2004). Furthermore, the FAO (2005) reports that despite its success at increasing aggregate food supply, the Green Revolution has not necessarily translated into benefits for the lower strata of the rural poor in terms of greater food security or greater economic opportunity and well-being. Small-scale farmers for example did not always have the capital to invest in the new technologies. Human excreta might provide a fertilizer and soil improver at lower costs.

As for water supply, Delhi gets almost 90% of its water supply from surface water through the Yamuna river. During its passage into the Delhi, the quality is heavily deteriorated, mostly due to very poor sewage treatment facilities (more in Section 3.1). Furthermore, many places and people in India starve for water, especially in summer. The level of water provision in Delhi is also inadequate in the city and in every type of settlement. Water supply is intermittent in most zones and water pressure is low. As a consequence, households have to invest in compensatory strategies such as private boreholes or hand pumps, electric motors, water filters (Ruet, 2002). EcoSan systems could lower the water demand for toilet use (flush water) and could lower pollution and contamination levels of the water.

Technical

From a technical point of view India does not impose specific characteristics in addition to the general characteristics of low-income areas in developing countries, such as bad road conditions and frequent lack of electricity. The general technical criteria as formulated in the next section in Table 2.4 apply.

Table 2.4 Set of policy and design criteria for a good transport system

Aspect	**Policy criteria**	**Design criteria for storage, handling and transport**
Health and environmental	- The occupational and public health is safeguarded - Faeces and urine do not enter the direct living environment - Valuable resources are reused to the maximum extent	*General* - Spillage consequences of failures should be limited and easily cleanable - Container and equipment is cleanable - The container content is not easily reachable for unauthorized people and not reachable for rodents and insects - In- and outlet of storage container above maximum rainfall level *Urine storage and handling* - No direct contact of workers with urine - Storage and transport container is watertight - Inlet of storage container is small - No use of vent pipe - No or small occurrence of spillage during handling - Prevent contact with eyes *Faeces storage and handling* - No direct contact of workers with fresh faeces - No or minimal occurrence of fresh faeces spillage during handling - In case of fresh faeces collection the storage and transport container is watertight - In case of drying of the faeces a double vault pit latrine is used

Technical	- The system is easy to construct and maintain in the local context - The system is robust enough to meet the exigencies of normal use - The system is safe, user friendly and reliable - The system is as cost efficient as possible	*General* - Suitable to the physical conditions of the area - Rely on locally widely available knowledge, skills, spare parts and materials for operation and maintenance - Critical sections are easily reachable and replaceable - Vehicles and equipment are available on the local market and safe to use - Handling is easy and quick - Service is performed in the way and at the time that is agreed upon - Scheduling of operation is efficient - The total weight of vehicles does not exceed the maximum allowed axle weight *Urine storage and handling* - Use of stainless steel, plastics or concrete (concrete needs to be rubbed down) - Urine storage excluded, places where urine stands still are minimized (because of crystallising of urine) *Faeces storage and handling* - Use of vent pipe
Financial	- The system is affordable to all households in the community - The costs are affordable for the community as a whole - Economic use of scare resource such as money, energy, space, land and water	- Reasonable price for the service performance (price/quality performance) - Affordable price for the users - Affordable costs and reasonable benefits for the community (municipal) - Reasonable income for the employees - The advantages of the service should be competitive with existing practices
Social/Cultural	- The system is consistent with cultural and social values - The system is aesthetically inoffensive - The system meets the needs of all household members and workers considering gender, age and social status and caste - The system is acceptable to the users and waste workers	*General* - The fee for the service fits within the expenditure pattern of households - Potential users have identified the sanitation service as a necessity - Potential users are involved in selecting the option most appropriate for their community - Users feel responsibility to manage and maintain their toilet and corresponding storage - Everybody has access to the service and feels safe using it - A complaint mechanism is present - Operation is done in a way that preserves the dignity of the workers *Urine storage and handling* - Storage and transport container is watertight - Sealing is watertight or movement of the urine is minimized *Faeces storage and handling* - Storage of anal cleansing water in storage container - Watertight closure - Vent pipe that causes an upward airflow through the vent pipe - Situating the pit not directly under squatting hole - Addition of ash or paper

Institutional	The system operates within the settings of the local institutional framework	- The different responsibilities and tasks have to be clear to the involved stakeholders - There has to be a sense of ownership and commitment from the involved stakeholders, preferably by contracts and terms of references - The structure for the institutional framework is a proven structure or is in line with a proven structure - Needed institutional capacity for purchase, planning, operation and maintenance is available - Misuse of the system should not be possible (e.g. giving a fee for the quantity delivered could encourage addition of water to the urine)
Political/Legal	The system fits within existing or planned legal and regulatory framework and political priorities and decision making processes	- The manual handling of excreta is avoided or minimized or the law is adjusted to the needs of the sanitation service (Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act)

2.4 Criteria logistics system

A logistic service of excreta management performs two essential functions:
1. The service collects excreta from the urban areas where residents live and work (collection);
2. The service takes excreta to areas for treatment and/or reuse (transport).

These two logistic functions are part of a total sanitation service that address the following urban needs:

- the health of the people is protected from contaminants in excreta (see Annex 4 (hygiene);
- the environment is not polluted and the aesthetic conditions of the living environment are not impaired by the excreta (environment);
- the capture and reuse of valuable resources (such as nutrients and water) (ecology).

Based on the general framework of ISWM and the specific characteristics discussed in the previous two section, Table 2.4 on the next page gives a set of policy and design criteria to assess what a good transport system is in order to fulfil the above urban needs. Although the institutional and political/legal aspects are not part of this research an attempt has been made to avoid the impression that these are less important.

3 CURRENT SANITATION AND SOLID WASTE COLLECTION PRACTICES AND LOGISTIC ORGANISATION

This chapter will describe the current sanitation and solid waste practices and their logistic organisation in Delhi or in India in general. Knowledge of the current methods gives ideas for possible options for EcoSan. The solid waste practices are interesting in this respect, because the collection and transport of solid waste has many similarities to the manner in which excreta might have to be removed when an ecological point of view is taken. The transport of excreta through sewer systems is e.g. not appropriate, necessitating possibly transport by road, which is common in the solid waste field.

3.1 Current sanitation practices

This section will give an overview of the general sanitation methods present in India. First an indication is given of the current status of the provisions in India and the organisational structure in Delhi.

3.1.1 Current status and organisational structure

India is a country with one of the lowest coverage levels of sanitation in the world. The United Nations Statistics Division points out only 15% of the rural population and 61% of the urban population had access to improved sanitation[1] in 2000. Faced with growing pollution problems, Indian cities are not able to provide services that are adequate, neither quantitatively nor qualitatively. Of the ± 4000 towns and cities in India, 300 have a sewerage system and only 70 of them have treatment facilities (Ruet, 2002). This means a lot of untreated, raw sewage finds it way to low-lying areas and natural watercourses such as the river Yamuna flowing through Delhi. The result is that many water bodies have become open sewers polluting not only their surroundings, but also causing serious health and environmental problems to towns and cities downstream. With the continuing urban growth it is unlikely that the present gap between demand and supply of essential services and infrastructure will be met in the nearby future leading to further deterioration of the physical environment and quality of life (the Indian urban population has increased more than five times since Independence in 1947; the decadal growth rate is ± 40%).

Ruet (2002) describes some of the major institutional actors in the water supply and sanitation sector in Delhi. The Delhi Water Board (DWB) is responsible for the production and distribution of drinking water, treatment and disposal of wastewater as well as water quality control and water pollution monitoring in the Municipal Corporation of Delhi (MCD). However, sanitation falls under the direct responsibility of the MCD indicating the lack of coordination that can and is occurring. The situation in Delhi is quite complex as it is the National Capital Region and there is often confrontation between the State's legislators and the Central Government that tries to keep a control over the Capital. Within the MCD, the Slum Wing Department is in charge of squatter settlements, notified slum areas and pavement dwellers. The Delhi Development Authority (DDA) is in charge of preparing the Delhi Master Plan, but it also acts as an implementing agency and is, therefore, responsible for the development of new housing projects in Delhi. An example of the lack of coordination with the DDA and DWB is the Dwarka housing project. Only a small number of people have shifted to the newly constructed high quality houses in Dwarka (accommodations for 1.4 million people in total), because there is almost no water provided. The DDA is the planning agency for Delhi but there is also the National Capital Region Board. There is also the Central Ground Water Authority (under the Ministry of Water Resources) and the Delhi Pollution Control Board (under the Ministry of Environment and Forest) who play a part in the water and sanitation scene. Another "external" factor that currently plays a role is the Supreme Court that has summoned the DWB to build a wastewater treatment plant to reduce the pollution levels. As can be seen from the rapid description of some of the major institutional actors in the water supply and sanitation sector, the situation in Delhi is complex and the lack of coordination leads to

[1] 'Improved' sanitation technologies are: connection to a public sewer or septic system, simple or pour-flush latrine and ventilated improved pit latrine. The excreta disposal system is considered adequate if it is private or shared (but not public) and if it hygienically separates human excreta from human contact. 'Not improved' are: service or bucket latrines (where excreta are manually removed), public latrines, latrines with an open pit.

situations where the judiciary needs to intervene. A large number of NGOs and lobbying groups are also involved in the sector. They have various roles: contractor for the Corporation, a voluntary action role to provide services to selected settlements, a lobbying role and a strong opposition role to influence the policies of the government.

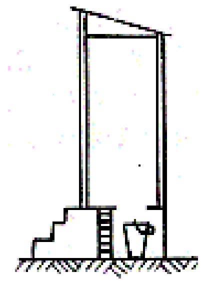

Figure 3.1 A bucket latrine (Agarwal, 1993)

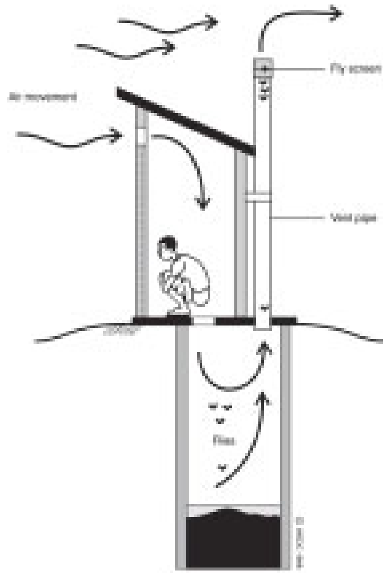

Figure 3.2 A pit latrine with vent pipe (Harvey, 2002)

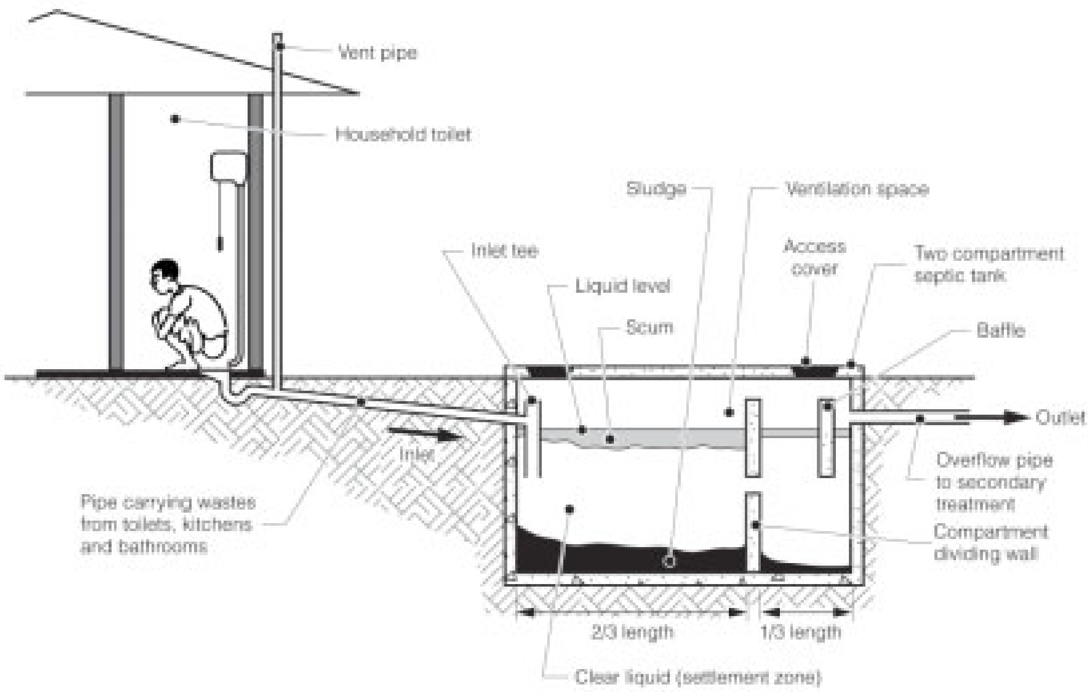

Figure 3.3 A septic tank (Harvey, 2002)

3.1.2 Current methods

Several sanitation methods with their collection and emptying activities are discussed below. More technical information on the different systems can be found in e.g. Mare (1996) and Feachem (1978).

Bucket latrine

In a bucket latrine the excreta is collected in a bucket or other receptacle that is placed directly under the toilet (Figure 3.1). Once or several times a week a scavenger goes from house to house and empties the buckets. Usually a small door is present on the outside of the house giving access to the bucket. The collector empties the bucket in some kind of drum and places the empty bucket back under the toilet. The collectors carry the drums on their head or on a cart and empty it in the nearest sewer or storm drain manhole or some other place, because disposal sites are often not available or far away. As everything is done manually and they have little to no equipment they come into contact with the excreta very often and suffer from many infections. Today, many of these bucket latrines have been converted into pour flush latrines, which has put an end to this kind of scavenging. However, full pits are not always emptied mechanically which means manual emptying still takes place with the collector physically going into the pit and using buckets to get the faecal matter out.

Pit latrine

Pit latrines are the most common and simple sanitation system. They are widely used in rural and urban areas, but in a highly populated area pits are less suitable. A pit latrine consists of a large hole in the ground, whether or not reinforced with e.g. open-joint brickwork, with on top a cover slab. The liquids percolate into the surrounding soil and the faecal solids accumulate slowly in the pit where they are digested anaerobically. By adding a well-designed vent pipe odours and flies are eliminated (Figure 3.2). When the pit is almost full it can either be emptied or closed off. When the pit is emptied this is usually done with a vacuum tanker, but manual emptying also occurs as explained above (with the excreta at the top of the pit still being fresh, this poses great health risks). The content is deposited at the nearest possible place, as explained for the bucket latrine. When the pit is closed off on the other hand, one has to make a new pit and rebuild the slab and superstructure on top of the new pit. Two pits can also be used in alternation. As it takes one or more years to fill one pit, the excreta are digested by that time, and are safe to remove. During the raining period the pits can easily become overloaded with storm water causing overflows into the streets giving a sharp rise of e.g. cholera in the monsoon months (Agarwal, 1983).

Septic tank

Septic tanks are mostly used for houses in relatively high-income, low-density areas, which are not covered by a sewer system. Septic tanks are rectangular chambers, usually placed just below ground level, in which household wastewater is retained for 1-3 days (Figure 3.3). During this time solids settle to the bottom of the tank where they are digested anaerobically. The liquids undergo some natural purification, but the process is not complete. The final effluent will contain pathogenic organisms such as roundworm and hookworm eggs and must therefore be diverted to e.g. a sewer system or soak-away. As some sludge accumulates, the tank must be desludged, usually once every few years. This can be done with a vacuum tanker, but this again is done manually as well. Cleaning is often not done regularly causing the treatment performance to drop and finally overflowing of the tank.

Sewer system

Conventional sewerage has large diameter pipes in which flush water and possibly kitchen, bathroom and storm water transport the excreta and other waste. The sewer transports the black water to a treatment facility or takes it directly to rivers or other water bodies. Often little to no maintenance is performed on the pipe system, which has lead to many leakages and blockages. The leakages cause sullage to enter the groundwater and leaky water distribution system. Blockages cause overflows in streets. During the rainy period, the situation is aggravated. The number of connections is small in India as construction and maintenance of the system is extremely costly. It also requires a regular supply of water for flushing which many parts of India do not have.

Public toilet

In slums one can find public toilets where people do not have space or money to have their own toilet. Often a few toilets are situated together. The public toilets are either connected to a nearby sewer or vacuum tankers empty it. The toilets are often not managed well; they are not cleaned regularly and blockages are not removed. Instead, people go to defecate in the open at a place outside the settlement.

Open air defecation

Often more than half of the slum population does not use any kind of toilet facilities. This is the case even when there are public facilities available. The main reasons are the distance to the facilities, the payment and the lack of cleanliness in a large number of toilet complexes. In this case defecation takes place in the open. There are no transport activities as the excreta is left openly on the field.

3.2 Current solid waste collection practices

This section will give an overview of the solid waste collection methods in Delhi. First an indication is given of the current status of the provisions and the organisational structure in Delhi.

3.2.1 Current status and organisational structure

Solid waste collection and disposal is under the responsibility of the Municipal Corporation of Delhi (MCD). The MCD daily collects 6000-6500 tonnes of waste in their 1400 km^2 working area. To realise this, the MCD employs 50.000 workers that are supervised by 1000 sanitary inspectors. The MCD equips its people with 25.000 wheelbarrows, over 2000 handcarts, animal carts and tricycles and almost 1000 motorised vehicles, mostly tipper trucks. This waste is transported to one of the three active sanitary landfill sites and to two compost plants (Sandhu, 2004). As there is a significant level of waste sorting that occurs at the street level, by the time the waste is transported to disposal, it has very little plastic, paper, cardboard, glass or metal remaining. Mostly, it is rotten organic material and fines such as soil and ash.

However, with the limited capacity of the MCD not the whole city is cleaned. In 1996, it was estimated around 30% remained uncollected (Ruet, 2002). The problem of uncollected waste is most prevalent in low-income neighbourhoods. Uncollected wastes accumulate on open lands, are piled along streets, fill drains and clog sewers. These uncollected wastes provide ample habitat for flies, cockroaches, rats and other disease vectors; and the stagnant waters in the clogged drains provide habitat for mosquitoes. During flooding, the health consequences are enormous. Middle-income and high-income neighbours tend to take matters into their own hands and hire their own neighbourhood pushcart collector who brings their waste to a transfer location. Solid

A B C

Photo 3.1 Street sweeping and primary collection

A and B: Street sweeper collecting the swept up waste in a wheelbarrow by picking up the waste between two pieces of e.g. cardboard (Photos: Surinder Pal);

C: Filled tricycle of waste collector who goes house-by-house everyday to collect the waste, mostly supplied by households in plastic bags.

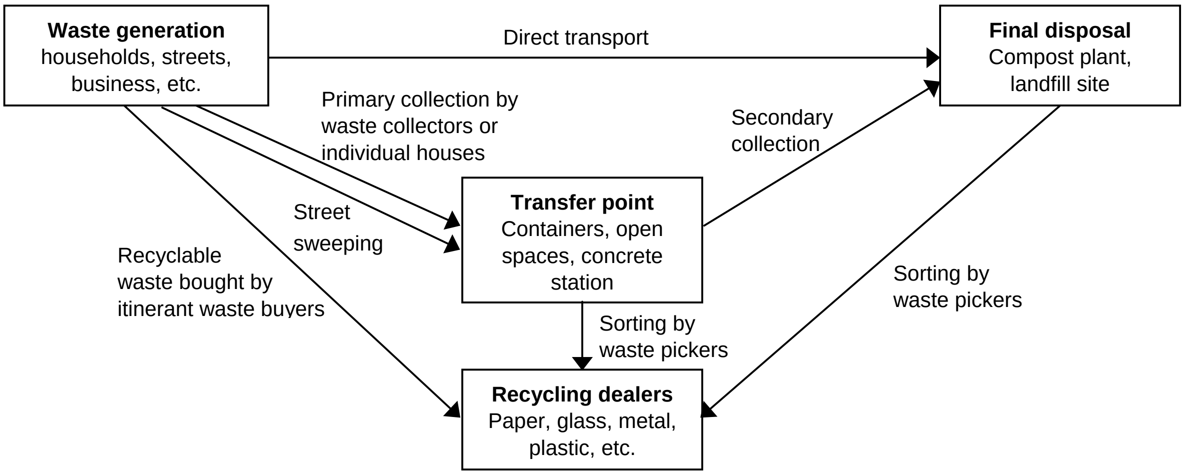

Figure 3.4 The solid waste collection process (adapted from Rouse (2002)).

In many low-income countries it is the responsibility of waste generator (households, etc) to get their waste to a transfer point. Many do this themselves, but households who can afford this often employ a waste collector. This stage is called ‘primary collection’ in Figure 3.4. The households hand over their waste in plastic bags or their waste bin is emptied in the collection vehicle. Collectors have a bell or shout to make people aware that they can bring their waste. The waste collected during the sweeping of the streets is also taken to a transfer point. The government or Residence Welfare Associations employ people for a specific area. Many collectors use small vehicles to transport the waste, typically handcarts or tricycle carts such as in Photo 3.1A en C. These small vehicles are emptied in general by tilting the vehicles and depositing the waste on the ground.

A B C

Photo 3.1 Street sweeping and primary collection
A and B: Street sweeper collecting the swept up waste in a wheelbarrow by picking up the waste between two pieces of e.g. cardboard (Photos: Surinder Pal);
C: Filled tricycle of waste collector who goes house-by-house everyday to collect the waste, mostly supplied by households in plastic bags.

In many low-income countries the local authority's responsibility for waste begins at a 'transfer point'. A transfer point is an intermediate place where waste is deposited and stored before being transported to the final disposal site. This can be anything from a plastic bin (Photo 3.2B, emerging in Delhi) to a concrete construction (Photo 3.2A and Photo 3.3B, typical in Delhi) or an unplanned open site when the distance to a planned transfer point is too long (Photo 3.2C). Photo 3.2 also shows how the waste is handled at these different types of transfer points. The stage in which the local authorities collect the waste from the transfer point and convey it to the final disposal site is called 'secondary collection' in Figure 3.4. Sometimes primary collectors meet at an arranged location and time to empty their vehicles directly into the secondary collection truck. In that case the primary collection vehicles are lifted into the truck to empty them or the waste is transferred via baskets, like is done in Photo 3.2C. Only a few cities have ramps or bins in the primarily collection vehicles to enable the collectors to discharge the waste in the trucks without double handling, that is unloading to the ground and scraping or shovelling into the truck from the ground.

A B C

Photo 3.2 Different types of transfer points in Delhi and their handling methods
A: A bulldozer picking up the waste from a transfer station and throwing it in a truck (Photos: Surinder Pal);
B: Waste collected in the community bins (green for biodegradable material and blue for other wastes) is picked up
mechanically (Photos: Surinder Pal);
C: Manual loading of the waste lying at open dump sites or at transfer stations by scraping the waste in a

The recycling industry also plays a significant part in waste management in low-income countries. Itinerant waste buyers or collectors collect recyclable materials (e.g. glass, paper, metal) directly from households who set this aside, and waste pickers sort through waste on the streets, at transfer points and at final disposal sites. Some pictures of this are displayed in Photo 3.3. Once collected, the waste is sorted into different materials and into different grades. Sometimes value is added by e.g. pounding the metal flat. After this, it is taken to a dealer or wholesaler who again sells it to specialised wholesalers and/or factories.

A B C

Photo 3.3 Sorting by waste pickers
A: Waste picker that is bringing his collected recyclables to a dealer;
B: Waste pickers going through the dumped waste at a transfer location (Photo: Surinder Pal);
C: Waste pickers waiting for a new truck to be unloaded at the landfill site to collect more recyclables (Photo: Surinder Pal).

4 MAIN LOGISTIC SYSTEMS

There are many different concrete transport systems possibilities. In order not to disappear in all the possible options this chapter will focus on the identification of a few main systems. These main systems can be seen as basic systems in which there has not been a choice yet for the particular handling and transport equipment. This can be filled in more concretely in a later design stage together with the assessment of different (equipment) options. The concepts are identified in the first section and the second section determines the appropriateness of each concept for urine and faeces transport. Based on this, one main system is chosen which will be worked out in detail further in this research. Section 4.3 will look into this main system from a logistic point of view to gain more understanding of the dimensions of the system by identifying the parameters of the system. The parameters of design will give information on the variations and choices that have to be made within the main system. Next, Section 4.4 will focus on one of the most important choices, the selection of the type of collection vehicle. A list of factors will be presented with some of the factors that should be considered in selecting the most appropriate type of waste collection vehicle.

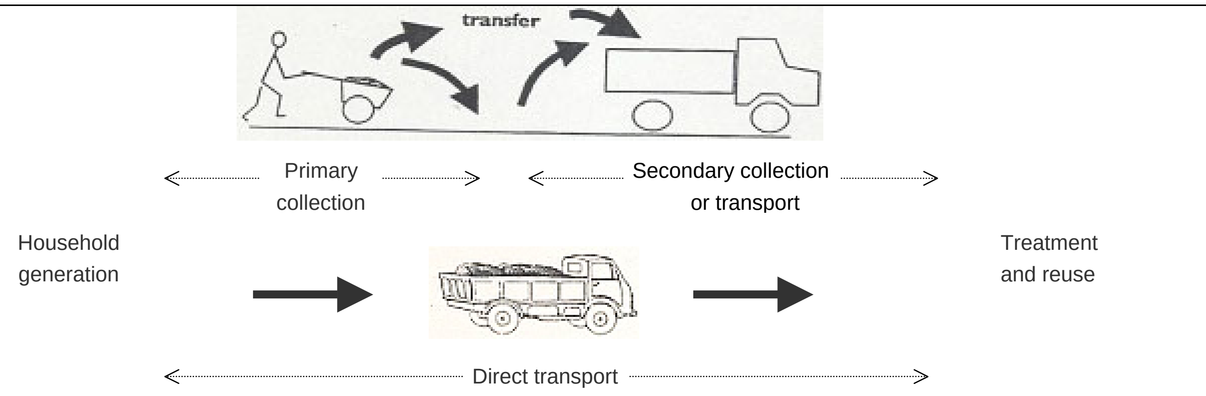

Figure 4.1 Distinction between direct transport and transport with a transfer

Table 4.1 Overview of main logistic systems

Main logistic system	Operator of primary collection	Means of collection	Analogy with existing collection systems
Public toilets	Household-member	Inside the body of household member.	Communal collection (households discharge their waste at predetermined locations. Refuse-collection vehicles visit these sites at frequent intervals to remove waste (secondary collection))
Household member brings urine and/or faeces to a collection point	Household-member	Household containers	
Collection vehicles collect urine and/or faeces at each household	Collection service	Household container is switched for empty container or household container is emptied into collection vehicle	Door-to-door collection service
Piping system on street/block level	Automatic (collection service)	Small diameter pipes from households to a large collection tank	Small bore sewerage (small diameter sewers laid at shallow gradients to convey sewage)

4.1 Overview main logistic systems

On a high level basic logistic systems can be distinguished depending on how the collection and transport takes place and is organised. The first division can be made between direct transport and transport with transfer operations. This difference is depicted in Figure 4.1. Transfer becomes a necessity when haul distances increase to such a distance that direct transport is no longer economically feasible or when the destination can only be reached with a different means of transport. It is cheaper to haul a large volume of waste in large increments over a long distance than it is to haul a large volume of waste in small increments over a long distance (Tchobanoglous, 1993). Depending on the size of the collection vehicles transfer might be cheaper.

The second division that can be made is the means of transport. With regard to the secondary collection or transport basic differences can be made between transport by road, rail, water, air or pipes. In this research only road transport is relevant. Transport by rail, water or air is not relevant due to the limited distance that has to be bridged, ± 10-20 km; the destination (farmers or a treatment facility) is located near the rim of the city. Concerning a pipe system, large-scale pipe infrastructures lie outside the scope of this research. This leaves only transport by road for secondary collection.

With regard to the primary collection, transport by road and small-scale pipe systems are possibilities. Basic distinctions can be made in who does the primary collection and the means of collection. This affects the service level for the household and the complexity of the organisation from a logistic point of view. Different systems are listed in Table 4.1. The first three basic possibilities are derived from the different collection methods used for solid waste collection (Coffey, 1996a), Cointreau (1989), UNCHS (Habitat), 1988) and the fourth in the list has an analogy with small bore sewerage (Mara, 1996). The four systems are clarified below.

Public toilets

In case of using public toilets instead of individual toilets the logistics is very simple and straightforward. In that case, the primary collection does not need to be arranged by a logistic service, because people themselves walk to the toilet carrying the excreta inside their bodies to the collection point: the public toilet. The public toilet can be designed to divert urine and to store the urine and faeces in two separate tanks e.g. under the toilet complex.

It might be impossible to perform primary treatment of the faeces under the toilet complex, because the quantity of faeces collected each day is large and the time required for primary treatment is months. In that case a truck could collect the faeces each day and transport it to a treatment facility, like is done in the Bangalore project described in Section 2.2.

Household member brings urine and/or faeces to a collection point

Under this system the inhabitants bring the urine or dry faeces collected from their household collection container to a collection point nearby. This collection point could be a public toilet, a collection station with storage or a mobile collection container that is present at predetermined times. This is also a relatively simple system, because the people still carry out the primary collection. This reduces the number of locations from where the excreta has to be collected by a logistic service considerably. However, it is a little more difficult than a system of public toilets. Household containers have to be designed and maintained and these containers need to be easy to decouple and to carry for the household members.

Collection vehicles collect urine and/or faeces at each household

Under this system the household members no longer carry the excreta to a collection point. A collection service, with collectors having (small) collection vehicles, collects the excreta door-to-door. With regard to the previous system the walking distance for the inhabitant is now much smaller or zero. An aspect that should not be overlooked in this system is how the container becomes accessible for the collector: can the collector take the excreta himself or does a household member first have to take the household container to the outside of the house where the collector has access to take the container with him. In the latter case, there is still some degree of user involvement required.

Piping system on street/block level

A very different system is the partial transport by pipes. Small diameter pipes laid at shallow gradients can be used to convey the urine and/or faeces from multiple households to a large collection tank. From the collection tank it can be emptied with a tank truck. By laying the pipes at shallow excavation depths and using small diameter pipes requiring only small inspection holes the costs of such a system can be considerably lower than sewers. The initial investments needed for a piping system might be higher compared to a collection system with vehicles. On the other hand the operational costs can be considerably lower, because less personnel and vehicles are needed.

4.2 Appropriateness of main systems and choice for system

One of the above systems will be chosen to be worked in detail; not all systems can be worked out, because of the time limitations of this research. Based on the context of the specific area, the expertise of the researcher and the knowledge gaps in research, the logistic system that has the most potential usage will be chosen. The appropriateness of each concept for urine and faeces transport in the context of the specific area will first be determined (see for a description of the Indian and EcoSan context Section 2.2 and 2.3).

Appropriateness of systems for urine and faeces collection

The appropriateness of the different systems for urine and faeces collection is considered for each system.

Public toilets

Public toilets provide less convenience for the household members than an individual toilet. It takes more time to go to a public toilet, because it is further away and there can be queues. Furthermore, public toilets tend to be dirty and women often do not feel safe visiting the toilets, especially when it is dark. Most people in Saboli are able to and have constructed individual toilets. Having to go to a public toilet would be a step back for them. This system is therefore not appropriate for most people in Saboli. Another reason not to choose a system of public toilets is that the focus on public toilets might carry out the message that ecological sanitation is only for the poor.

Household member brings urine and/or faeces to a collection point

As explained in Section 2.3, people who do not have the profession of excreta removal do not want to be engaged in the handling of excreta. Although this system could mean the household members can bring the urine and/or faeces free of charge or even receive some money for it at the collection point instead of having to pay a collection fee to a collector, it is unlikely the inhabitants of Saboli will go for a system where they themselves bring the urine and/or faeces to a collection point. Even though urine is technically clean, it is associated with excreta/faeces and not perceived as something that they could be seen with from a social point of view. However, when the system is in operation for a certain amount of time and people see what a urine diverting toilet and urine collection is about and see what faeces look like when it has undergone primary treatment, people might start to change their opposition to handling the excreta themselves and feel comfortable to bring it to a collection point if this saves money. They could also start to use it for own purposes as fertilizer if they start a small garden on their roofs.

Collection vehicles collect urine and/or faeces at each household

It is acceptable for people to hire a person who collects the urine and faeces. There is no cultural opposition against this and therefore this system is likely to be acceptable for the community members.

Piping system on street/block level

In this case a distinction has to be made between urine and faeces collection. A piping system for faeces is not considered appropriate, because it needs water to transport the faeces through the pipes. This is against the principle of EcoSan of using/polluting no or very little water. Furthermore, the faeces have to be collected untreated in this case. This is against the principle of providing safe sanitation, because of inevitable leakages in the pipes and the invisibility of the leakages under the ground, which lowers chance of repairs.

A pipe system for urine collection could be appropriate, because urine is not (very) hazardous and does not need flushing water. Furthermore, a piping system is very convenient for the household members as the collection does not need any user involvement and the collection becomes less visible. It is also likely that people want to be associated with a pipe system more than with a door-to-door collection service, because a pipe system looks more like the sewers the well-off and western world has.

The above is summarised in Table 4.2.

Table 4.2 Appropriateness of main logistic systems

Main logistic system	Appropriateness		Explanation
	Urine	Faeces	
Public toilets	X	X	- Public toilets are regarded as a step back as most people already have individual toilets. - Focus on public toilets might carry out the message that EcoSan is only for the poor.
Household member brings urine and/or faeces to a collection point	X	X	People do not want to be associated with the handling of excreta from a social point of view.
Collection vehicles collect urine and/or faeces at each household	√	√	It is acceptable for people to hire a person who collects the urine and faeces.
Piping system on street/block level	√	X	A piping system for faeces is not appropriate, because flushing water is needed and the faeces are not treated. For urine no flushing water is needed and urine is not hazardous. A piping system also makes the collection less visible and it is associated with western systems.

Choice for main system

For faeces collection there is only one system that is likely to be appropriate in the context of India and EcoSan: collection vehicles collecting the faeces door-to-door. Therefore, this system is chosen to be worked out in detail in this research. For urine collection the same system of door-to-door collection with a collection vehicle is likely to be appropriate and the pipe system is also a promising system. For this research the system using collection vehicles is chosen, because the institutional capacity required for construction and maintenance of pipe systems is often a problem in developing countries. With the crystallisation characteristic of urine, maintenance is very important. Another reason not to choose a system of public toilets or household members bringing the excreta to a collection point is that the logistics of these systems are relatively simple compared to collection from individual households, because the primary collection step is skipped in these cases. For the research to be more informative, the collection from individual toilets is preferred. The results of this research could be used as input for research on the other systems.

4.3 Parameters of the chosen system

In order to gain more insight into the dimensions of the chosen main logistic system this section focuses on the design parameters. Choosing different parameter settings, such as the type of vehicle, allows creating variations on the main system. The parameters should be chosen in such a way that it creates an efficient and effective system in the situation on hand. To determine the parameters, an overview of a basic logistic chain to transport goods from A to B is drawn in Figure 4.2. In this research, the sources are the toilets in the houses and the destination is the treatment facility or farmers nearby. Depending on the size of the collection vehicle, the distance to the treatment facility and the size of the community, no or several transfer stations are necessary in order to minimise required resources.

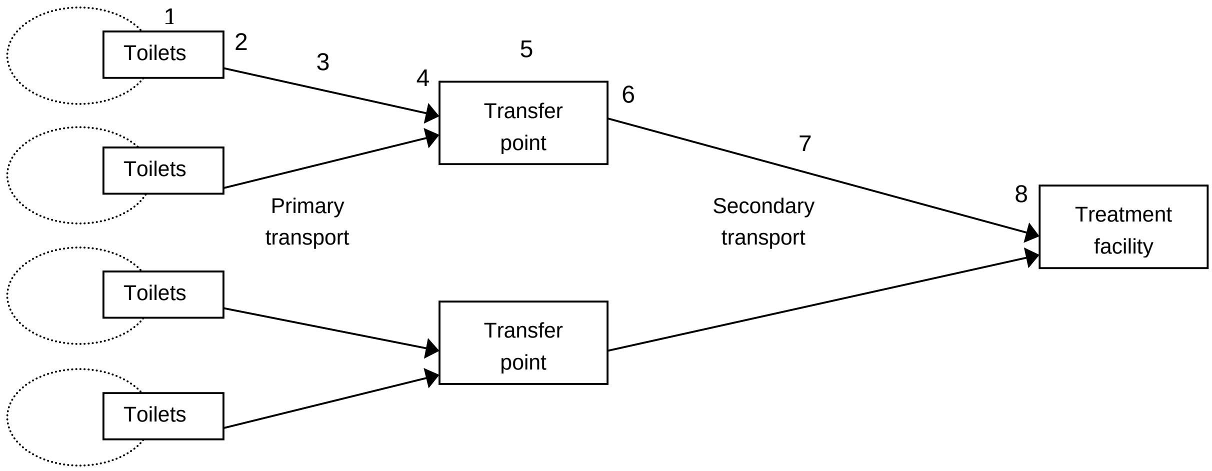

Figure 4.2 Overview of logistic chain with primary and secondary collection
The general logistic chain is the same for urine and faeces, although the handling method and type of vehicles might be different for the two streams.

Figure 4.2 makes it clearer what the parameters are: each line, block and transition represents an aspect that needs to be looked at when determining all the parameters. From the household toilets, with a certain type of container and storage capacity (1), the excreta is handled in a certain way (2) to undergo primary transport with a certain type of vehicle (3). When arrived at the transfer point, the container is emptied in a certain way (4) into a certain type of larger collection medium (5). From the transfer point the excreta has to be loaded (6) into a secondary transport vehicle (7) to be unloaded again at the destination (8).

Table 4.3 Basic parameters of logistic system

Primary transport	**Transfer point**	**Secondary transport**
1a. Selection type of household storage 1b. Capacity household storage 2,4. Selection handling method at household and transfer point 3a. Selection type of collection vehicle 3b. Capacity of collection vehicle 3c. Number of collection vehicles and personnel	5a. Selection of type of transfer station 5b. Capacity of transfer station 5c. Number of transfer points and personnel needed	6,8. Selection handling method at transfer station and destination 7a. Selection type of vehicle 7b. Capacity of transport vehicle 7c. Number of transport vehicles and personnel

Table 4.3 lists for the basic system the design parameters that can be recognised. All parameters are considered part of this research. Although parameter 1a/b theoretically fall outside the scope of this research, these cannot be seen separately from the handling method at the household and the type and number of collection vehicles required.

Table 4.4 Factors affecting vehicle selection

Situational factors	**Area of influence**	**Explanation**
Housing density	Capacity of vehicle Reach of vehicle	Housing density is an important factor in determining how far vehicles have to travel. If housing density is high, a smaller low-range vehicle may be appropriate unless transfer or destination points are distant. Low-density areas will generally require larger capacity, longer-range vehicles.
Waste generation per household per period	Handling mechanism Capacity of vehicle	If the waste generation per household is large a high capacity vehicle may be more appropriate.
Waste density	Handling mechanism Capacity of vehicle	If the waste density per household is high a high capacity vehicle may be more appropriate.
Haul distance	Capacity of vehicle Reach and speed of vehicle	Small vehicles may be cost efficient where there are short haul distances and larger vehicles will be needed where there are long haul distances.
Road surface (muddy, sandy, stony, firm)	Wheel size Rate of wear	On very poor road conditions, larger wheeled vehicles perform better, though cycle carts do not operate well.
Road widths	Vehicle size	In the case of very narrow alleys, only small and narrow vehicles physically fit.
Road gradient	Propulsion, brakes, gearing	Steeply sloping roads may need chassis with special gearing and braking systems.
Traffic type and density	Operating speed Manoeuvrability	In congested areas a slow-moving vehicle may be adequate.
Waste corrosiveness and abrasiveness	Material of body Rate of wear	If it is more expensive to use the material that can withstand the contact the rate of wear should be weight against the higher purchase costs.
Waste hazardousness	Handling mechanism	The degree of physical contact is determined by the handling mechanism.
Labour and fuel cost	Propulsion vehicle Motorized or non-motorized equipment	If vehicle and fuel cost are high and labour is cheap, labour-intensive methods are preferred or vehicle productivity should be high, at the expense of reduced labour productivity.
Available capital	Limits capacity and degree of mechanisation of vehicle	For purchase of a vehicle a certain amount of capital is necessary. If interest rates are high it is cost effective to buy the lower cost vehicle with a shorter life expectancy.
Strength of user in case propulsion is (partly) manually	Payload	If the strength of the user is limited the payload has to be lowered.
Risk of theft, damage and abuse	Material choice Storage area	Separate containers for example are easy to steel and have value to use for other purposes or to sell.
Availability of spare parts and service	Type of propulsion and other parts	Spare parts and service for a vehicle should be widely available.

In the case of public toilets, the transfer points take the place of public toilets and the toilets take the place of the houses of the inhabitants who use the public toilet: the public toilets are the collection points where the inhabitants bring the excreta. For the system in which pipes are used to do the primary transport, the basic logistic schedule is the same. Different is only the way in which the primary transport is performed: through pipes with the help of gravity instead of the use of vehicles and people.

Not present in the picture is the time parameter or, in other words, the frequency of collection and transport. The frequency is a derivative of the chosen storage quantity and the given generation quantity. Therefore, it is not a parameter, but more a result of a choice for a certain system.

In the science of operation research (a scientific approach to decision making, which seeks to determine how best to design and operate a system, usually under conditions requiring the allocation of scarce resources) this system can be analysed by means of a network representation. The system can be translated into a minimum-cost network flow problem and solved with the network simplex (Winston, 1993). Input for this problem is, among other things, the cost of transporting one litre of urine and faeces from one point to the other. However, none of the parameters to estimate these costs are known and the different options have not even been identified yet. Formulating a mathematical model of this problem is not yet under discussion. However, different options will be roughly analysed later in this research. As the number of options that will be looked into will be limited and the analyses can be rather straightforward at this stage, the translation into a minimum-cost network flow problem is not appropriate.

4.4 Factors to consider when selecting a collection and transportation vehicle

The selection of a specific type of collection and transportation vehicle is a very important decision. Waste collection vehicles might be very efficient and effective in one part of town or for transport of a certain type of waste, but might be totally unsuitable to work under different conditions. Waste collection vehicles designed to operate in low-density urban areas with well-paved roads might be totally unsuitable to handle high-density areas with poor access, although the two areas might be in the same city. Table 4.4 suggests some of the factors that should be considered in selecting the most appropriate type of waste collection system. Sources that have been consulted are Esrey (1998), Rouse (2002), Coad (1997), Coffey (1996a), UNCHS (Habitat) (1988), Muller (1997), Muller (1994), Cointreau, (1989) and Klundert (2001).

5 SOURCE OF URINE AND FAECES – HOUSEHOLDS IN SABOLI COMMUNITY

The Saboli community is the focus area of this research, acting as the source of the urine and faeces to be transported in the EcoSan project. As such, it gives the setting of the collection system, making it very important to know the situation and dynamics in this area. This whole chapter focuses on Saboli to give a broad picture of the situation. The first section describes the context of Saboli: Delhi, the history, the economical and physical situation and the degree of development. Particular focus on the sanitation, solid waste disposal and health situation is giving in Section 5.2. Section 5.3 gives insight into the viewpoints of the community on EcoSan, in particular the concerns and criteria about the storage and collection of the urine and faeces in their houses and community.

Figure 5.1 Location of Saboli within the State Delhi

5.1 Context of Saboli

Delhi

From a population of 700.000 in 1947, today Delhi's population has grown to 14 million (Census of India, 2001). The National Capital Territory of Delhi comprises 1486 km^2 of which 93% has already been urbanised, making the Delhi population density the highest in the country (Planning Department, 2004). This means the decadal growth in Delhi has been around 50% in the last two decades (Census of India, 2001), resulting in phenomenal pressures on urban administration, land and infrastructure services.

Due to the lack of adequate developed land at affordable prices to different categories of residents, a considerable percentage of the population in Delhi lives in unplanned settlements and slums. As per Census of

India (2001) 18% of the population in Delhi lives in slums. The Planning Department (2004) shows a higher percentage of at least 34% (see Annex 5). Their greatest concentration is found in the northeast and east of Delhi, across the river Yamuna, where Saboli can also be found.

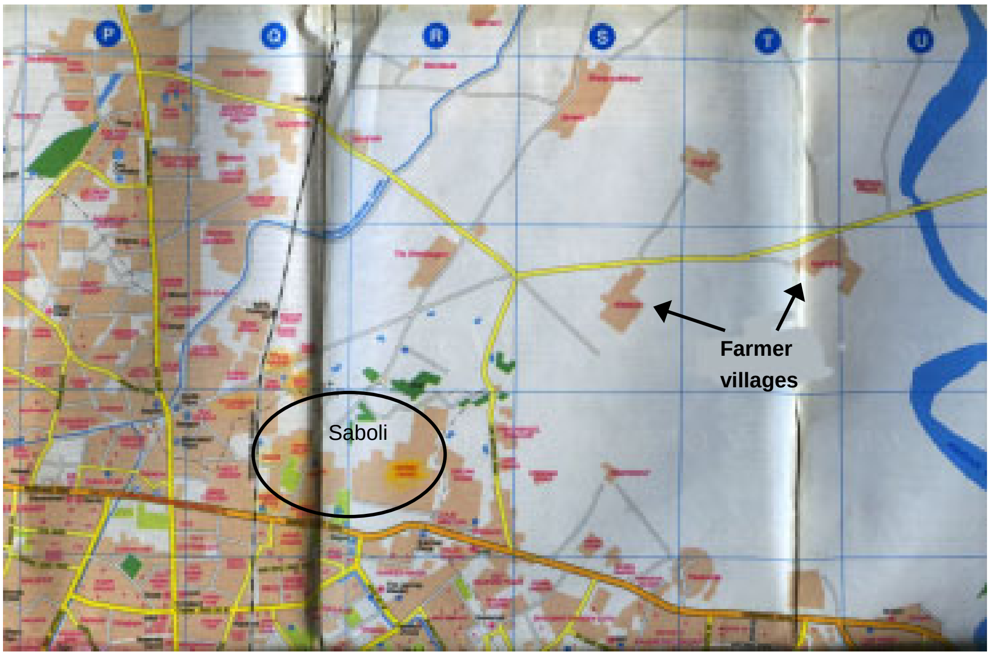

Figure 5.2 Location of Saboli at edge of the city Delhi with farmland nearby

History and characteristics

At first, Saboli was a village with agricultural land surrounding it. Fifteen years ago, with the growth of Delhi, the landowners of the village started to sell small plots of land on basis of monthly and quarterly instalments. It slowly became an urban area. There are still vacant plots and some agricultural fields left in the area, but these plots are disappearing fast with a new influx of migrants each year. The majority of the residents are migrants from the neighbouring state of Uttar Pradesh in search of work. The employment opportunities offered by the city, even though mainly in the informal sector, ad hoc and unstable, are attractive given the bleak employment opportunities in rural areas.

Focus area of this research are the adjoining clusters[2] to Saboli Village, in Nand Nagri Block, located in northeast of Delhi (see Figure 5.1). It is located at the outskirts of Delhi, next to the border with the state Uttar Pradesh where agricultural fields start (see Figure 5.2). The area is approximately 2-3 km by 2-3 km in size and an approximate 8.000 households live there at the moment. Two to three years back this figure was 5000 households and in 2 years this probably will grow to 10.000 households. The director of FODRA estimates that in the coming years the number of people in the area will grow to a maximum of 100.000 when people start to build an extra floor to rent out to the ongoing stream of people wanting to come to Delhi. Table 5.1 on the next page summarises some general figures about Saboli.

Economic situation

Most of the men are daily labourers working in small factories nearby or work e.g. as rickshaw pullers in adjoining areas or they have their own small shop. In recent months nearby small factories are being closed, because of the pollution they cause. If these factories have not been closed, they have become illegal. For this reason it has

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[2] Anoop Vihar, Harsh Vihar, Pratap Nagar, Prem Nagar, Radha Vihar, Saboli Gadha, Santosh Vihar. This comprises the programme area of FODRA, the local NGO (See Annex 1 for description on FODRA and Annex 6 for a map of the clusters).

become more difficult for the men to find work every day. This sometimes means families go without a meal on days no income is generated. The women also try to earn money if they can and if allowed by their husband by making things at home such as toys, bindies, scarves, or do some embroidery and sowing. Table 5.2 shows the

Table 5.1 Saboli community: general figures (source: GIS database)

Indicator	Amount
Number of households	8000 (an estimate of the employees of FODRA)
Family size average	6,1 persons (derived from EcoSan database)
Population	Nearly 50.000
Plot size average	45 m^2 (ranging from 25-90 m^2)
Property ownership	80% Owner 20% Rented
Literacy level	70% Men (estimation director and programme coordinator of FODRA) 50% Women
Religion	98% Hindu 2% Muslims
Caste	21% Brahmins & Kshatrivas 62% Vaisyas & Sudras 17% Untouchables/Dalits (derived from database by director of FODRA; see section 2.3 for an explanation on the caste system)


Photo 5.1 The open drains in Saboli
Majority of the roads are sand roads with a lot of holes and bumps due to the lack of proper constructed drains.

income level in Saboli as answered by a large number of individuals in a survey. The average income comes to 2500 rs (€ 47) per month in the GIS database after removal of extreme numbers. FODRA expects that the actual income level is higher. This is supported by the 2885 rs that Ruet (2002) indicates as the average monthly income of households in slums, which is a figure of before the year 1999.

Table 5.2 Saboli community: income level (source: GIS database)

Income (in rs. per month)	**Number of households**
500-999	2 %
1000-1999	18 %
2000-2999	45 %
3000-3999	24 %
>=4000	11 %
Average Income Saboli	2500 rs (most likely an underestimation, see text above)
Average Income Delhi	47.477 rs (2002-2003; Planning Department, 2004)

Development situation

Saboli is an unregistered colony. These clusters have come up in agriculture land without proper approval of the settlements. This means there is no proper local governing structure due to the lack of official recognition by the urban authorities. Politicians and the concerned development authorities act according to their will. This leaves the people without basic facilities such as potable water, drainage, waste collection, paved roads and schools most of the time. At the moment Saboli has applied for registration. If this will be accepted, the government might provide some services to the area in the future. The health care, water supply and waste management situation is discussed in the next section.

Almost all people have built permanent houses constructed with bricks and mortar (pucca) having two floors. This is an indication, together with the large percentage of ownership of the plots that the perspective of the people is to stay here (this is often a condition for people to be willing to make investments for improvements in their homes. Some investments might be needed for e.g. a urine diverting toilet). Only small parts of the houses are semi-constructed, e.g. the toilet not having a proper door or roof. The small plots are completely built. There is no open space or garden around the house, the houses are built attached to each other. From the door one is standing immediately on the road.

The majority of the roads are sand roads with a lot of holes and bumps due to the lack of proper constructed drains (see Photo 5.1). There are a few brick roads, laid recently during election time by the government, but because there is no maintenance these roads are deteriorating already.

There are no government schools in the area itself, for that one has to go to an adjoining cluster. There are a few small private schools and a small school set up by FODRA. A large percentage of the children do not attend school, because going to school costs money: instead, when the children do some work, some money is raised. Looking at the GIS database 70% has an electricity connection, almost all illegal connections with very irregular supply. Nowadays people are taking more metered connections. The level of organisation in the community is very low. Recently a Residence Welfare Association has been set up, because this is required for registration, but the organisation is not organised very well yet. Other than this, there are only the small micro-credit groups who are well organised.

Saboli is still a male oriented community. Women are often not allowed to take something up, like work or attend meetings. But with the years this is improving now. The male-orientation in decision-making can also be read from the GIS database. It shows that 60% of the decisions are taken by both female and male, but in 35% of the decisions to be taken the male decides alone against 5% in which only the female decides. This distribution is also true for health related issues.

Physical characteristics

Saboli is a low-lying area with small elevation differences within the area. This means that in the raining season, two months a year, some parts of the area get flooded. The majority of the houses are built somewhat higher than ground level to prevent water from coming in the house most of the time. The roads on the other hand do become flooded. There are several places where the elevation difference is large and in these places the water rises to more than a meter making these places temporary lakes. In these severely flooded areas most people return to their village to resume cultivation in the rainy period.

Table 5.3 Saboli community: sanitation figures (source: EcoSan database)

Characteristic	Amount
Individual toilet in house	90%
Place of defecation in case no toilet is available	Nearby open plots or railway track
Place where children defecate	3% Drains 12% Open plots 85% Toilet
Users of toilet	Only family members
Toilet condition	56% Pucca (fully constructed) 44% Kucha (e.g. no roof or cloth as door)
Location of Individual Toilets	20% on ground floor parallel to land level 50% on ground floor elevated 30% 1st floor/Top of house
Way of emptying	No household has emptied their pit yet, because the pits have not been filled yet. The water is over flown into open drains.
Individual hand pump	85% (source: GIS database)
Hand pump within 10 metres of pit	95%
Water used for drinking	93% Hand pumps (no government water supply available) 7% Government supplied water 0% Chlorinated water or boiled water
Depth of hand pump	28% <49 feet (<15 meter) 20% 50-74 feet (15-23 meter) 23% 75-99 feet (23-30 meter) 27% 100-124 feet (30-38 meter) 2% 125-149 feet (38-45 meter) 0% >= 150 feet (45 meter)
Knowledge of urine and faeces containing pathogens that can cause diseases	77% Yes 23% No
Knowledge that leakage of pit can contaminate water of nearby hand pump and can cause diseases	64% Yes 36% No
Knowledge of waterborne diseases	40% Yes (source: GIS database) 60% No

5.2 Current sanitation, solid waste disposal and health situation

Due to lack of any local governing body, the community development in terms of hygiene and sanitation is totally neglected. This section will first give a picture of the sanitation and solid waste situation and will finish with the health situation, because this a consequence (partly) of the first two practices.

Sanitation and drains

There is no sewer laid in the area. 90% of the households have an individual toilet in their homes as can be read from Table 5.3. As there are no community toilets in the area, the families who have no toilet defecate in the open fields. The reason why they do not have an individual toilet or hand pump are financial problems or that they rent a house in which it is not provided. The individual toilets are often single pits with brick or semi-septic tank constructions. Almost nobody has ever cleaned the pit or tank as long as they live there. During the meetings with the women groups, it became clear that the pits or semi-septic tanks are not watertight and that the wastewater is being over flown in the drains when they start to become full. This last practice is a big health hazard, because the drains are not covered and are often all over the road where the children play freely (see Photo 5.1 on the previous page). These open and informal drains are also a breeding place for mosquitoes. Wastewater is thrown in the drains or in the open plots when these are nearby. Photo 5.2 shows the situation that arises because of this.

Concerning the seepage into the ground, the water is contaminated with pathogens. Several water samples have been tested by FODRA in a laboratory. These tests showed that the water has to be pumped from more than 180 feet to be potable. The majority of the households drink water that comes from a depth of less than 100 feet, because there is no provision of potable water to the community from the government, also not with water tankers. This is why the majority of the people have installed their own water pumps. However, almost all hand pumps are constructed at a limited depth, close to the pits and the ground water is often only 10 feet under the pits. The water is also contaminated from nearby metal factories. Table 5.3 gives more insight into the sanitation practices and knowledge.

Photo 5.2 Throwing of the waste and wastewater in nearby open plots (middle of picture). These plots where wastewater gathers all year are breeding places for mosquitoes.

People do not take measures to treat the water, such as boiling the water or using chlorine tablets that are supplied for free. Most women know more or less that the water they drink makes them sick, but they feel that in their village they used to drink their own water and then there was nothing wrong with it, so why should it be wrong now. Another reason is the taste and smell of chlorinated water.

Solid waste collection

There is no solid waste collection taken up by the government in the area. Recently FODRA has set up a community waste collection system in which now approximately 250 households participate. Other than this there is no community collection system. In the system of FODRA a sweeper is paid 10 rs per month per household to collect the waste 6 days a week (see Photo 5.3 on the next page). There are also no disposal sites constructed by the government where the sweepers can bring the waste. They have to take this to surrounding areas where are transfer points are constructed. The number of participants decreased considerably after the initial phase, because not all the people in the neighbourhood were participating and the open drains still cause a lot of mess. Furthermore, the sweeper does not come regularly, because he also works as a sweeper for the municipal in another area. He comes as he pleases, but FODRA cannot appoint another sweeper. Sweepers are powerful in this area, because their territories are all family bound and the union of the sweepers is very strong. Bringing in another person means the existing sweepers in that area will throw out the new sweeper, by force.

The number of participants of the community waste collection of FODRA is picking up again after further awareness building and every now and then FODRA organises a day that a sweeper is hired to clean open plots and streets in specific areas (paid half by the community and half by FODRA). The majority of the household waste is still thrown in the open plots or in the streets. Most people are not interested to join the community waste collection programme, because it is easier to throw the waste in the nearby open plots (see Photo 5.2). The cleanness of the public domain is much less important compared to the cleanness of the house. There are waste pickers in the area, but most of the households take out the valuable materials themselves, leaving not much for the waste pickers. This means they don't come regularly or not at all.

Photo 5.3 Collection vehicle of solid waste collector

Table 5.4 Saboli community: water use for toilet related activities

Activity	Amount of water used (in litres)	Number of times per day	Total water usage per person per day (in litres)
Washing after defecation	2	1	2
Flushing after defecation	5-10	1	7
Flushing after urinating	1-2	3-5	4
Cleaning of toilet	10-30	Once a week	2
Total			15

Health situation

There are no healthcare facilities provided by the government. The nearest government hospital is approximately 4 km away. This means that the women are afraid to go by themselves and that their husband has to accompany them, making it difficult to go. FODRA has set up a small clinic in which a doctor is present two mornings a week with around 50 consultations per visit. She explains that most people wait too long to see a doctor in case of problems, which makes it worse, or they go to nearby private doctors. These private doctors do not have official training and charge a lot of money. Looking at the GIS database the total health expenditure comes to almost 2200 rs per year, after removal of extreme numbers.

In Saboli the children and adults suffer much from malnutrition, anaemia, diarrhoea, vomiting, fever, jaundice and skin diseases. Cholera is also present in the raining season. There are a lot of cases of worm infections, especially among children, causing anaemia and loss of appetite, and by that malnutrition. The worm infections are caused by poor hygiene, such as the use of contaminated water, walking barefoot on places where open defecation takes place (and think of the open drains all over the roads) and touching of the mouth with dirty hands. The women also suffer from vaginal infections, causing the reproductive rate to be very low in this area: 25-30% of the women do not bear children automatically. After a few years of waiting they go see the doctor and are treated for infections or blockages in the tubes. After treatment they are able to get pregnant most of the time. A woman not bearing children at first brings a lot of tension in the family, up to the point of divorce.

As the doctor indicates, treating the people does not solve the problem. The worms, infections and so on come back each time, over and over again. To stop this cycle a better toilet system is necessary, water should be treated, the children should wear shoes, hands should be washed, etc.

5.3 Constraints and viewpoints of the Saboli community on EcoSan

This section gives insight into the viewpoints of the community on EcoSan and the concerns and criteria that they have in particular about the storage, collection and transfer of the urine and faeces in their houses and community. Another important aspect that is discussed is an indication of the amount of water that they will be using in the new system. See the methodology section in Chapter 1 for an explanation how the information in this section has been obtained. Annex 7 discusses the general response to the meetings and the general response to EcoSan.

5.3.1 Toilet and water use

People use water to the wash the anal region after defecation, for flushing and for cleaning the toilet. No other water for e.g. cleaning other parts of the house or other things are thrown into the toilet. Throwing other things than water could clog the toilet and it is felt that only clean water should go into the toilet, otherwise the toilet will become dirty or the septic tank will not function properly anymore. Table 5.4 summarises the responses concerning the amount of water used for the separate activities as well as the number of occurrences per day. From this the total amount of water that goes into the toilet can be estimated.

The total usage of water comes around 15 litres per person a day and with an average family size of 6 this means more than 90 litres of water disappears into the toilet per day. Important to note is that most people commented that if more water would be available, they would add more: “the more water, the cleaner we feel and that is very important”. Other reasons mentioned to use much water are to prevent smell from coming and preventing the faeces from getting clogged into the pipe or in the water seal.

The community women realise that they must use less water in order for the new toilet system to work. The general feeling is that they can agree to use less water if the toilet will not start to smell. They only need clean houses and if that is also possible with less water than that is acceptable to them. In one group the persons without a hand pump said this would save their energy, because they need to carry the water from outside (people who do have an individual hand pump do not see fetching the water as much effort). Also, one group started to calculate how much water they are currently using and that if they would have to pay for the water they would not use this much. They also realised themselves that water will start to get scarce in time, another reason to agree with a system in which less water is or can be used.

The general feeling is that they can reduce their current water use to half. This is their limit they indicate. In the beginning this will be difficult for them, because they will feel less clean, but if others can do it they can also do this. In time it will become a new habit and if awareness is raised and others start doing it, they feel people will start to copy it. No adding of water after urinating is not acceptable, otherwise smell will come they feel.

5.3.2 Storage

For the storage of faeces there are two main options:
- the double pit system to facilitate the drying of the faeces before emptying or
- the collection of the faeces in one chamber and emptying while it is still wet.

The community women prefer the dry system, because it will be cheaper as no vacuum tanker is needed and fertilizer is produced directly. On the other hand, one group commented that they see the emptying with a vacuum tanker as more clean, because the faeces are invisible to them as it goes through a pipe and they do not think there will be any spillage. The dried faeces emptying on the other hand will be visible, but they will tolerate this, because it is beneficiary to the fields. Fertilizer is being seen as very valuable, because they all come from villages with agriculture. If fertilizer can be produced with this system then that is very good. The concerns that they have about the double pit system are that they are afraid the vent pipes will smell and that the faeces might not dry quickly enough.

As for the size of the system, they prefer a system that needs to be emptied less frequent and has higher initial costs over a system that has lower initial costs that needs emptying more often. A bigger vault means less hassle of finding a sweeper.

They felt that they could not afford to have their pit emptied every year. They feel this way, because they relate to the wet pit emptying, which is very costly, either done by vacuum tanker or manually. After explaining the dry pit empting will be less costly, because the volume is much less and no vacuum tanker is needed, they felt they could bear the emptying costs e.g. once a year. Concerning the construction and design of the double vault containers no specific demands or concerns were raised. When the time is there, they will see what is a convenient way for them to build and construct it.

Concerning the urine collection, they do not relate to that so much, because they have not seen in their villages that urine is a good fertilizer. They believe it is a good fertilizer, but they are not so eager as with the dried faeces collection. They feel it will require extra effort of them. However, they are willing to separate the urine if that is necessary for the whole system to work and for them to get the benefits of better health. They indicated that their criteria for acceptance are:
- it must not smell
- it can not be stored inside the house
- and an outside storage container must not be not be very visible, but be covered somewhat

Ideas generated by them to realise the storage container not being visible are putting it under a bench or making a bench over it or putting the container into a hole in the ground with a cover. If it is covered properly, they will not feel awkward walking down the road. Another concern one group raised was that children and animals could damage the storage containers and that they cannot afford to buy a new container each time. The response from one person in the group was that they would find solutions themselves to problems as they arise. Once they would adopt this system, they would have to continue with it.

Concerning the size of the storage containers for the urine, the same goes as with the faeces collection. They are willing to spend some extra money initially to have less tension about the collection each time. For all of them the storage is not a big problem, because for faeces this is under the ground and for the urine it can be covered and they do not have to touch it themselves. Their biggest concern is the collection part, because if the sweeper does not show at the agreed times or is not willing to do it, this means hassle and tension for them. In addition to having to empty a smaller container more frequent, a smaller container is more prone to overflow when the collector does not show. The women indicated this was a problem that they have to solve in practice. The men said it was the sweepers problem to solve.

Box 5.1 General reactions of sweepers to EcoSan

The sweepers very much preferred EcoSan in comparison to the current toilet systems. Two of the sweepers present had manually cleaned wet pits and told how humiliating this made them feel: the dirtiness and despise from the surrounding people. Also, some boys and men died empting these latrines. Sometimes the whole road was dirty from their vehicle. The dried faeces collection was much better these two men said:

- "we won't get dirty and it doesn't smell. We can just wipe the dried stuff of our clothes;
- it is much quicker and easier to clean; a wet latrine could take four days and it means lifting heavy buckets";

In the beginning of the meeting the sweepers who did not clean toilets, said they would not clean these toilets and were annoyed that they were in this meeting. Later in the meeting when they understood better what this new collection system would entail, they said out of themselves they could also take up this work.

Photo 5.4 The solid waste collector using a fawari to pick up some waste from the street. On the left is his collection vehicle.

5.3.3 Collection

The household members themselves cannot do the collection they explained. That is socially unacceptable for them for both the faeces and urine collection. They cannot touch it with their own hands, not even if they could make money with it. Paying a person to do the collection is no problem. In big families a sweeper cleans the toilet slabs (for payment) instead of a family member, because cleaning the toilet used by others than close family makes them feel comfortable.

The leaders indicated the collection vehicle for the faeces has to be closed to avoid spillage on the road. The sweepers also prefer to close the collection vehicle in such a way that the faeces are not visible. Then the people cannot see what they are collecting, because they are afraid that people might despise them again for cleaning of toilet waste. However, they are in favour of the dried faeces collection. See Box 5.1 for an illustration of their feelings on the clearing a conventional toilet system and an EcoSan toilet system.

The sweepers indicated that for the faeces collection they would build a small engine on their simple tricycle. This could move everywhere and would be much quicker than with an ordinary tricycle. They would clean the faeces with a fawari (see Photo 5.4). When asking how they felt about collecting the faeces into small containers, which can be loaded directly into their vehicle and taken off again to speed up the handling activity they said they would not prefer such a system. Without the extra containers, transferring the faeces is also easy by digging and the containers take extra money.

During the meeting with the sweepers two options to collect the urine were discussed: the urine could be pumped into a large tank, pulled behind a tractor, through a hosepipe with a pump attached to the tank or the urine container at the houses could be poured manually into a small tank on a tricycle. The sweepers preferred a pump system, because this would take less effort and they would be able to do more houses in a day. However, to buy a tractor on their own is not affordable for them, but they proposed that they could unite with other sweepers to do this. On the other hand, putting the small tank on the tricycle that they would use for the faeces would be easy and if it was heavier or smelled more they could bear that, this was their job. But if they could afford the better option, the pump system, they would go for that option.

In the light of this meeting an in between option was formed afterwards: attaching a hand pump on a small tank and putting this on a tricycle. This could unite the wish of less effort, less smell and less heavy work with an affordable system. Unfortunately, in this research it was not possible anymore to arrange a consultation with the sweepers about this option due to a personal loss in their family.

About the urine transport the leaders commented that it might smell a little, but this would be acceptable. It would not smell that much, just like the kitchen waste collection.

5.3.4 Transfer

The first reaction of the leaders was that the locations where the transfer could take place from one vehicle into another had to be far away from the residential area. After realising that was too far for the transfer to be sensible and that the dried faeces would not smell, nearby was also acceptable, as long as it was not next to houses. An empty parking area would be an option for example. If no smell comes off, then the transfer location does not need to be a closed place.

5.3.5 Financial aspect

In the women groups the financial aspect is also discussed briefly, because this is again an indication of the degree of acceptance. Concerning the initial investment costs, they say they willing to pay a little more for the construction of a new EcoSan toilet in comparison to the normal built toilets, because of the increased health benefits. Most women indicated they spent 10.000 rs (€ 200) on their pit latrine, but this figure is probably a little lower as FODRA indicated the usual loan amount to build a toilet is 5000-7000 rs (see Table 5.2 for height of income level). The costs to change their current toilet into a urine-diverting toilet is estimated to 3000 rs in Section 7.5. The costs to (re)construct the faeces chamber is unknown. However, most women indicate that they cannot change their already built toilet into EcoSan toilet, because in that case their earlier spent money goes waste (partially) and their financial position does not allow that. When they would have to build a new toilet somewhere, the EcoSan toilet could be a good option.

Table 5.5 Saboli community: **s**ummary of viewpoints, concerns and criteria for EcoSan

General response to EcoSan	
Double pit system and dried faeces collection	Easily acceptable, because it doesn’t smell and they can relate to the production of fertilizer easily as people come from villages
Urine separation	Not easily acceptable, because they can’t relate to (separate) urine as a good fertilizer, looks like more effort in general and don’t exactly know how to relieve oneself on urine separation toilet slab. But urine separation can be tolerated to make double vault system possible.
Implementing EcoSan toilet	Already built a toilet and changing the systems takes extra money again. Maybe when building a new house. Changing the toilet into a urine separation toilet also requires money and sanitation is not the first priority.

Toilet and water use	- Current amount of water use for toilet related activities is 15 litres per person a day. - Prepared to reduce this to half the amount.
Storage	- Prefer dry system over wet system, because it will be cheaper and fertilizer is produced directly - Concerns are smell of vent pipe and that the faeces might not dry quickly enough - Prefer system that needs to be emptied less frequent and has higher initial costs over system that has lower initial costs that needs emptying more often, because want to be troubled with the collection as least as possible. - Criteria for urine storage: - it must not smell - storage can not be inside the house - outside storage container must not be not be very visible, but be covered somewhat collection must not create tension and hassle
Collection	- Emptying and collecting one self is socially unacceptable. Paying person to do this is no problem. - The collection vehicle must be closed to avoid spillage and to hide from the public what work is being done. - Collector prefers using current cycle tricycle where an engine is put onto it to minimize investment needed and to increase number of houses covered. - Collector prefers using a mechanism that requires less effort, such as no heavy lifting or less smell if affordable to them
Transfer	- Acceptable to have a location in the community, but not next to house. - Covering of the place is not necessary if it doesn't smell.
Financial aspect	- Willing to pay a little more for the construction of a new EcoSan toilet in comparison to the normal build toilets, because of the increased health benefits. - However, rebuilding their current toilet into an EcoSan toilet is felt to be impossible. Their financial position doesn't allow earlier spent money going waste (partially). When building a new toilet the EcoSan toilet is a good option. - They feel they should get money for the collection, because the farmers benefit from their supply very much, but they also understand transport and treatment takes money and it also gives them benefits. Are willing to pay a little fee for the collection. - For regularly urine collection 10 or 20 rs per month is acceptable. For the faeces collection they have no idea, because they have never done that before. But the fee for vacuum tankers is much too high: that would be 600-1000 rs.

In the beginning of the meeting, after realising the value of this new fertilizer, the women mostly felt that they should get money for the supply of their manure and urine, because the farmers would benefit from their supply very much. After explaining that the farmers would not get it for free, that the collection and transportation takes money and that it would also give them (financial) benefits, at the end of the meeting when the financial aspect was discussed there was no need to receive money anymore and they were willing to pay a little fee themselves. They feel they should get money for it, but they also understand it takes money to transport and treat it. Maybe in the future when a lot of people participate, the yield is higher than the costs.

For urine collection, which has to be collected regularly, 10 to 20 rs per month is acceptable for them, like the kitchen waste collection fee. For the faeces collection they have no idea what they are willing to pay for it, because they have never done that before. But the fee for a vacuum tanker is much too high: they indicated that the fee is around 600-1000 rs per household per time the pit is emptied.

After explaining that the collection costs would be much less if they brought it themselves to a collection point and that they could even get a little money for it, carrying it themselves was still not an option (not even for the women who brought up the idea that they could sell the matter themselves and make money with it). They fear people will socially reject them for doing that.

5.3.6 Summary

Table 5.5 gives a summary of the whole section.

As this chapter focussed on the source of the urine and faeces to be transported, the next chapter focus on the destination: the nearby farmers.

6 DESTINATION OF URINE AND FAECES - FARMERS NEARBY SABOLI COMMUNITY

The most obvious destination of the urine and the faeces of Saboli are the farmers nearby Saboli. In the community little agricultural fields are left and people do not have space to have gardens. This chapter focuses on these farmers nearby Saboli even though the scope of this research is defined until the delivery at the gate of the treatment location of the urine and faeces (this treatment location can be at the farmers itself or in another location, e.g. a central treatment facility). During the research it became clear that understanding of the destination and the way the excreta will be reused also defines what is a good logistic system. Looking at the whole chain reduces sub-optimisation of the separate steps in this chain and makes sure delivery is useful to the next party. Next to this, looking beyond the borders of this research to the destination also provides more insight into the whole chain that needs to be set up. This makes the purpose of the transport, the actual topic of this research, more understandable for the readers and gives it purpose. This means at the same time that this chapter's depth is limited.

Photo 6.1 To irrigate the land, the land is divided in small plots separated by small earthen border ridges. During irrigation the small plots are filled with the desired amount of water; the water remains within the small plot until it infiltrates into the soil.

The first section gives a general picture of the context of the farmers such as their location in relation to Saboli, the type of crops the farmers grow, irrigation, the size of their land and the future perspective. The next section focuses in particular on the current use of fertilizer and current application and storage methods, because the urine and faeces will be alternatives to the currently used fertilizers and can be applied in the same way perhaps. To be able to obtain viewpoints of the farmers on storage and application the researcher has to share and have knowledge of possible application and storage methods and provide information on application time and amount. Therefore, in Section 6.3, basic knowledge is given on how much excreta can be applied on the field and on the current guidelines for safe use of urine and faeces, both factors determine what sensible application and storage options are. The section finishes with some concrete possibilities for storage and application. The last section then gives the viewpoints, concerns and criteria of the farmers on EcoSan.

6.1 Context of nearby farmers

Adjoining to Saboli are villages with far stretching agricultural fields in the state of Utter Pradesh. The distance to the nearby villages is around 12 km, half an hour drive by car (see Figure 5.2 in the previous chapter). The villages included in this research are Afzalpur and Asalpur, each comprising two separate village parts. The road from Saboli to these villages is a dirt road that quickly becomes muddy with large water pools.

In this area the big farmers have around 5½ - 6½ ha (hectares)[3] of land and the small farmers around 1½ - 2 ha of land on average. Each of the "four" villages has around 30 big farmers and 40 small farmers. Multiplying these figures gives a total field area of around 1000 ha (10 km^2) for these four villages.

The farmers grow wheat, all kinds of vegetables, such as carrots, tomatoes and potatoes, and fodder is grown for their animals. The crops are firstly used for own consumption; the rest is sold to middlemen. Per year one or two crops of wheat are grown and two to five crops of vegetables, depending on the vegetable and the farmer. Vegetables are grown in larger quantities than the wheat, because there is more demand for vegetables and profit margins are higher. The selling of the crops and milk from their cattle is their only income. Not many cattle are kept. They have no other option for work in the village. For most farmers their income is just enough to pay electricity and other daily needs. Only a few farmers have tractors. Other farmers hire these tractors to plough their land e.g.

The land is irrigated to meet the crops water needs. For this, the land is divided in small plots separated by small earthen border ridges (see Photo 6.1). During irrigation the small plots are filled with the desired amount of water; the water remains within the small plot until it infiltrates into the soil. The irrigation water is pumped up from the groundwater and supplied through a network of unlined canals.

Concerning the future of the farmers, a threat and at the same time an opportunity are the brick factories in the area. The brick factories pay a farmer a high amount to rent a piece of land for 5 years to take off the top layer of the soil. This is an opportunity for the individual farmer, because it gives him a reliable income without having to do investments with associated risks. On the other hand, it makes his land unsuitable for agriculture afterwards; it takes many years for the soil to recover. The surrounding fields of other farmers are affected as well due to the heat that comes from the ovens. More and more land slowly becomes unsuitable for agriculture, although the number of offers from the brick factories is limited.

Table 6.1 Fertilizer usage of farmers

Type of fertilizer	Main nutrient content	Application time	Reason for usage
Animal manure (organic)	Nitrogen (N) Phosphorous (P) Potassium (K) Organic matter	Before sowing	The manure from their bullocks is freely available to them. It is firstly used for fuel purposes. The rest is used as fertilizer.
NPK fertilizer (chemical)	Nitrogen (N) Phosphorous (P) Potassium (K)	Before sowing	In addition to the animal manure NPK fertilizer is used, because they don't have enough animal manure to fertilize everything.
Urea fertilizer (chemical)	Nitrogen (N)	When crops have grown a little	To give growing boost

[3] The local farmers use bigha as unit of measure and indicated 7,5 bighas is equal to 1 hectares (the size varies per region). 1 ha = 10,000 km2

Photo 6.2 Animal drawn cart that is used to apply the animal manure on the field.
In the cart the fawari used to spread the manure onto the field while standing in the cart.

Another threat is the expansion of cities. For one village this is very real already. Nowadays, their fields come under the development plan of Gaziabad: “They can snatch the land when they want to”. Land has already been taken to build an airport. The head of that village fears that the farmers will disappear. 50% of the people already have other jobs than farming. In the other villages it has not come this far yet: the majority are still farmers. Although the farmers did not indicate this, this threat from the city could also be a reason for hesitation to invest in new equipment for excreta reuse (Section 6.3.3 will given some low cost options).

6.2 Current type of fertilizer usage, storage and application method

Type of fertilizer usage
All the farmers in the four villages use three types of fertilizer (source: four local farmers groups, see Section 1.4). The type of fertilizer and their application time and reason for usage is summarised in Table 6.1. Fertilizer is used for every crop.

Storage method
The manure is collected from the animals by emptying out the yards with a shovel and/or digging out the top layer of the earth where the animals mostly stand. The animal manure is mixed with household garbage and straw to help the decomposing process. After 6 months of storage in heaps, plastered over with dung/earth slurry, it is ready to be applied on the fields. These heaps are situated in the village on the yard or around the village in the field. The chemical fertilizer is bought in bags from a nearby wholesaler and is stored in a shed.

Application method
The men bring the manure to the land on a bullock cart and throw the manure, while standing on the cart, on certain places on the field with a fawari (see Photo 6.2). After this, a tractor ploughs the heaps into the ground. The ploughing will spread the manure on the field. If they do not have a tractor themselves, they will hire one for

750 rs per hectare. If the tractors are all taken, they arrange a tractor from somewhere else. The men spread the chemical fertilizer by walking in the field with a basket and manually throwing it.

6.3 Basic research needed to be able to interview farmers

In order to ensure continuing harvests, the soil needs to be replenished with nutrients and soil-improving material. Currently the farmers do this mainly by the application of chemical fertilizers, a nitrogen-fertilizer and a NPK-fertilizer (see Table 6.1). Urine and faeces can replace these fertilizers very well, because they contain the same, and more, nutrients and in addition faeces contains organic matter.

6.3.1 Amount of urine and faeces to apply to the field

It is essential one has an indication of the amount of urine and faeces one has to apply to the field to be able to think about application and storage options. To calculate how much urine and faeces a farmer can or has to apply, one needs to know:

- the nutrient concentration in the urine and faeces and
- the fertilizer requirement (the amount of fertilizer required for the crops to grown)[4];

The nutrient concentration in urine and faeces can vary widely between different regions and population strata as explained in Annex 3 . Analysing the actual figures for Saboli lies outside the scope of this research, as well as obtaining the fertilizer requirements. However, the WHO guidelines (2005) and Schönning (2004) give a rule of thumb that can be used in case the specific data is unavailable or cannot be obtained:

- For urine: '*the urine from one person in a year is enough to fertilize 0.03-0.04 ha*[5] '
- For faeces '*the faecal matter from one person in a year is enough to fertilize 0.02-0.03 ha of wheat at a yield of 3000 kg/ha*' based on the recommendations for the use of phosphorous-based fertilizers[6].

Based on these general rules the calculations in Table 6.2 try to give some indication of the amount one has to deal with during application. This gives an indication which application methods could be applicable and how much storage is needed. This will be further discussed in the next section. Added to this is a calculation of the area needed to apply the excreta of the whole Saboli community and the number of people needed to supply one farmer. Important to note when reading these figures is that the used application rates for these calculations are based on very general assumptions. These can differ much per region, depending on e.g. soil conditions, climate conditions and type of crops. Subsequently, storage and application amount varies accordingly. Local investigations and experiments (trial and error) should be encouraged to find appropriate application levels. As stated above, the volume of the urine and faeces are also assumptions that differ per region (Jönsson; 2004).

From Table 6.2 can be read that a farmer needs to apply around 1-5 m^3 of faeces per crop. This is a fairly manageable amount and is probably no problem to apply or store. Section 6.3.3 will talk further about this. On the other hand, for urine a small farmer has to apply around 23 m^3 per crop and a big farmer has to deal with around 77 m^3 per crop. To illustrate, an 80-m^3 big container with a height of 2 meters and a width of 2 meters is 20 meters long in size. Note that when the people in Saboli add water after urination, the amount will double or more! It is impossible to apply this amount manually, like is possible with chemical fertilizer which is much more concentrated.

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[4] Local recommendations for commercial mineral fertilizers or the estimate of the amounts of nutrients removed by the crop can give an indication for this. One farmer group also told the government (for free) or private persons could examine the NPK need of the soil.

[5] This is a low level of application. Up to tree or four times this level may be a probable application strategy. For most crops, the maximum application rate before risking toxic effects is at least four times this dosage.

[6] In many places, the soil is so devoid of phosphorous that the recommended application rate of the fertilizer is much higher. At this high application rate, most of the P will remain in the soil, which will then noticeably improve the structure and water-holding capacity of the soil.

Table 6.2 Figures on the amount of urine, faeces and land required. Annex 8 lists the assumptions that have been made.

	Small farmer (1,75 ha)	**Big farmer (6 ha)**	**Calculation** (Given is the calculation for a small farmer. For a big farmer replace the size of land of 1,75 ha with 6 ha)
Urine			
Amount of urine a farmer has to apply per crop	23 m^3 [7]	77 m^3	(1,75 ha land / 0,035 ha fertilized per person per year) x 450 litre excreted per person per year
Total field area needed for urine reuse of whole Saboli community (40.000 people)	467 hectares		40.000 people x 0,035 ha fertilized per person per year / 3 crops per year
Number of people needed to supply the urine for one farmer	150 people	510 people	(1,75 ha land / 0,035 ha fertilized per person per year) x 3 crops per year
Faeces			
Amount of faeces a farmer has to apply per crop	1,3 m^3	4,5 m^3	(1,75 ha land / 0,02 ha fertilized per person per year) x 15 litre excreted per person per year
Total area needed for faeces reuse of whole Saboli community (48.000 people)	960 hectares		48.000 people x 0,02 ha fertilized per person per year / 1 crop of wheat per year
Number of people needed to supply the faeces for one farmer	88 people	300 people	(1,75 ha land / 0,02 ha fertilized per person per year) x 1 crop of wheat per year

Table 6.2 also shows that almost 500 ha are needed to reuse all the urine excreted in Saboli. The total area of the farmers interviewed during this research is 1000 ha. For the faeces almost 1000 ha is needed, but not all the available land can be used for faeces application, because faeces should not be applied on vegetables that are eaten raw (see Section 6.3.2). Most probably however, the local application rates can be much higher and in India most food is cooked.

6.3.2 Guidelines for (safe) use of excreta in agriculture

Several measures to protect public and occupational health can and should be implemented, some of which at the farmer level.

Treatment

The greatest pathogenic risk from source-separated urine is a result of cross contamination with faecal material. The most obvious treatment option for urine is: storage for a certain period of time[8]. During this storage, no fresh urine should be added. The required length of storage depends on the temperature (climate conditions) and the ph level reached. For large-scale systems the storage time should be at least two months (note that WHO guidelines (2005) not clear on this), unless good protective measures and other barriers are applied (see text below).

[7] 1 m^3 = 1000 litre

[8] Work is also being carried out on other methods of nutrient recovery, including nutrient concentration through the controlled evaporation of urine, the precipitation of magnesium ammonium phosphate (struvite, MgNH4PO4), freeze concentration and the use of membrane technologies.

Table 6.3 Practical handling guidelines for reuse in agriculture

Both urine and faeces
• During application to the soil precautions related to the handling of potentially infectious material should be taken. These precautions should include personal protection such as wearing gloves, washing used equipment and hygiene. Hand washing should naturally be done.
• A withholding period of at least one month should be applied between fertilisation and harvest. This will allow further reduction of pathogens due to ambient factors such as microbial activity, UV-light and desiccation.
Urine
• The urine should preferably not be diluted. Concentrated urine provides a harsher environment for microorganisms, increases the die-off rate of pathogens and prevents breeding of mosquitoes.
• During storage the urine should be contained in a sealed tank or container. This prevents humans and animals to come in contact with the urine and hinders evaporation of ammonia decreasing the risk of odour and loss of plant available nitrogen.
• For the above reasons urine should also be incorporated into the soil. This could in practise be done mechanically or it can be watered into the soil with e.g. irrigation water.
• Urine should be applied close to ground to minimise aerosol formation.
• In areas where Schistosoma haematobium is endemic, urine should not be used nearby freshwater sources.
• As a rule of thumb, fertilization should stop after between 2/3 and 3/4 of the time between sowing and harvest. Once the crop enters its reproductive stage it hardly takes up any more nutrients.
Faeces
• Equipment used for un-sanitised faeces should not be used for the treated (sanitised) product.
• Treated faeces should be worked into the soil as soon as possible and not be left on the soil surface to minimize further human or animal exposure and will decrease the risk for pathogen run-off to nearby waters.
• Improperly sanitised faeces should not be used for vegetables, fruits or root crops that will be consumed raw, excluding fruit trees[9].
• Faeces should be applied prior to sowing or planting, because the faeces contain large amounts of P and the availability of P is very important for good development of small plants and of roots and in order not to disturb the small plants.
• The faecal fertilizer product should be applied at such a depth and in such a way that it is well covered by the upper layer of the soil and where the soil stays moist to make full use of the P and organic matter. However, the application depth should not exceed the rooting depth, otherwise the plant nutrients will not be available to the plants.

For faeces more treatment options are available. Deciding what treatment option is the most appropriate lies outside the scope of this research. However, the simplest forms of secondary treatment include a certain storage period. Since simple methods are preferable in developing countries the assumption is made that storage is required. After primary treatment of about one year at the households in Saboli faeces cannot be regarded as hygienically safe. The WHO (2005) states there are currently few studies indicating the pathogen die-off rate in dehydrating toilets, although those available indicate that Ascaris eggs have proven to be particularly resilient to dehydration. Therefore some degree of secondary storage might be is necessary.

The specific recommendations for large-scale systems, such as the two-month retention time for urine, need to be adapted to local conditions such as behavioural factors and the chosen technical system. If a system is clearly mismanaged, i.e. faeces can be seen in the urine bowl or other routes of cross-contamination are envisaged, special precautions are needed. On the other hand, less stringent guidelines for developing countries may be rectified based on the actual disease rates in the population, because of e.g. other water-, sanitation- and food-related exposures.

More on how and where storage for secondary treatment can take place in the next subsection.

[9] In the same chapter of the WHO guidelines also the more stringent advice is written “Faeces should not be used for fertilisation of vegetables, fruits or root crops that are to be consumed raw, excluding fruit trees.”

'Multiple barrier' approach
The focus in the guidelines and recommendations for the reuse of excreta has been on treatment. However, even if treatment is aimed at elimination of the risk of pathogen transmission and its potential has been proven in experiments, process steps may malfunction, resulting in a fertilizer product that is not completely hygienically safe. Furthermore, in small-scale systems in developing countries it is impractical or even impossible to relate performance of treatment to actual numeric values, mainly due to limitations in performing microbiological analyses. Therefore, additional measures should be taken to further minimise the risk for disease transmission. As the WHO (2005) states, "Different subsequent treatment steps of the human excreta and other barriers against human exposure are considered the most important precautions against the transmission. Sometimes, partial treatment to a less demanding standard may be sufficient if combined with other measures". Table 6.3 gives simple design and handling practices for urine and faeces as advised in WHO (2005), Schönning (2004) and Jönsson (2004). Refer also to Carr (2004) for an illustration of creating multiple barriers.

6.3.3 Options for application and storage

The above listed handling guidelines assisted in the design and selection of appropriate storage and application methods.

Storage at individual farmer level or central level
As explained in Section 6.3.2 urine and faeces most probably have to be stored for a certain period of time for secondary treatment. This section will draw some conclusions about the required storage size at the individual farmer level. This is done even though Section 6.3.1 showed that urine has to be applied in very large quantities on the field making it almost impossible for an individual farmer to create the required storage facilities. Local government or cooperative ventures among the farmers are more likely to be able to facilitate this at a (more) central level. However, to speak with the words of Mr Sharatchandra (Environmental Management Specialist) in an interview with the researcher: "…if we keep waiting for the local governments to act, then the programme may not take off at all." Also, it will probably take a long time before the farmers will actually unite, as the most common line of thought is 'first seeing then believing'. This implicates that first a few farmers have to be willing to take a risk and start individually on a small scale and then 'seeing is believing' might start to motivate farmers to demand infrastructure either from the local government or to create cooperative ventures.

Need for batch storage
The storage of faeces and urine at the farmers has to be done in batches, because during the required treatment period no new material is allowed to be added to the collected material to make sure all the material is stored for the minimum required period. When the supply of the material is not stopped a certain time, the material that was added last might not be stored long enough before it is handled again.

When one focuses on one batch one can see that the material in a batch undergoes a number of processes in time. First new material is added to the batch. When enough material is collected, supply is stopped and the storage period (retention time) sets in. Once the required storage period is over, and the pathogens have been eliminated, the material in the batch is ready-to-use and the farmer can remove the material to utilize it on his field (see Figure 6.1). Each of these processes take time and during this time the batch is occupied and not ready to receive additional material.

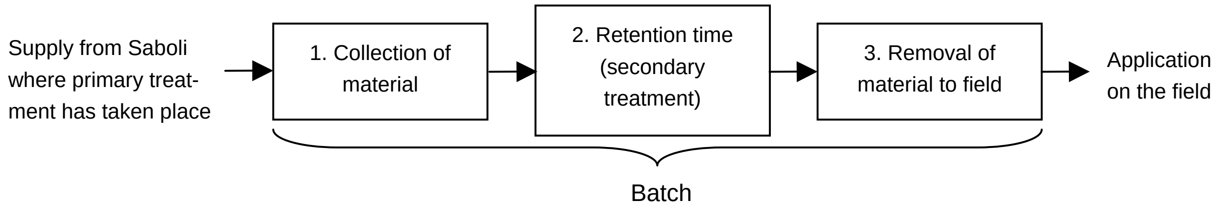

Fig 6.1 Different processes in a batch

Each batch needs a certain infrastructure to enable the processes to function, such as a storage space/tank, airtight storage and a pump for urine and ventilation for faeces. To minimize the investment and operational costs a small number of batches is preferred.

Required number of batches

The question in this section is whether a farmer can suffice with one batch or whether he needs two or more batches to realise his fertilizer requirement. The required number of batches depends on three variables:

- the minimum period between two fertilizations[10] (or more accurately: the period between the start of the first fertilization with the batch to the start of the fertilization with a new batch)
- the minimum batch period: the minimum required period to perform the three processes in a batch (Fig 6.1)
- the period in a year collection can/needs to take place

This can be illustrated in different schemes: Figure 6.2 and 6.3 on the next page. Figure 6.2 represents the situation in which the minimum batch period is shorter than or equal to the period between two fertilizations and Figure 6.3 covers the situation in which the minimum batch period is longer than the period between two fertilizations. The number of batches required is different for both cases. Note that the sowing moments and batch periods in these figures are chosen fictionally, because these are not clear yet and need further investigation. Therefore the figures might not represent reality, but it illustrates the principles.

Figure 6.2: Minimum batch period is shorter than or equal to the period between two fertilizations

In Figure 6.2 sowing takes place every 4 months: in the beginning of May, September and January. Before sowing fertilization has to be finished[11]. For the material to be ready as fertilizer is has to be stored for a certain period of time. In this figure the minimum batch period is said to be 2½ months, e.g. one week collection, two months secondary treatment and one week to work it into the field. This means that to be able to sow in the beginning of e.g. May the farmer has to start to collect the faecal matter at least mid February, 2½ months earlier. However, during mid February to the end of April the farmer cannot receive new faecal matter from Saboli for that batch; during the period of secondary treatment one should not add new faecal matter. By constructing a second storage location one can receive new faecal matter during that period. This means that the number of storage locations and the storage size at each farmer determines the period in which collection in Saboli can take place during the year. One can distinguish three options:

[10] In reality when more crops are grown during a year these are often not spread evenly during the year. Many regions have a dry or wet period during which cultivation does not take place. This means when three crops a year are grown, the minimum period between two fertilizations is smaller than four months.

[11] This is true for faeces, because this is a NPK fertilizer that needs to be applied prior to sowing. Urine will probably be applied after sowing when the crops have grown a little. However, the principle remains the same apart from a shift in time.

Figure 6.2: Option 1 One full sized storage location

In the first part of Figure 6.2 the farmer has only one storage location with the size of the amount of fertilizer that needs to be applied per crop. As calculated in Section 6.3.1 this will be around 1-5 m^3 for faeces and around 20-80 m^3 for urine.

From the moment the farmer has fertilized his field his batch is empty, ready to receive new material. This gives the farmer a longer period than the 1st week of the minimum batch period to collect new material (or to treat it for a longer period than 2 months when he has collected enough material). As can be seen in Figure 6.2 in the row for Option 1 before each batch period there is a 1½-month slack period.

Having only one batch has the consequence that collection/supply can take place only during these slack periods and the first small part at the start of a batch. In the fictional situation in Figure 6.2 collection in Saboli can take place only 3 times ±1½ months a year: less than half the year. In the start when not many people participate and the amount to be collected is manageable this is doable. However, as the amount to be collected increases, it becomes more difficult to handle these collection peaks and there will be more need to evenly spread the workload in the year to minimise the necessary *peak capacity*.

Solely delivering the material at different times to different farmers cannot solve this issue, because the farmers all need fertilizer at the same moments in time in general. Delivering material to the farmer in e.g. March or April, within the batch period before sowing, means the farmer cannot add it to the batch he has already created for the coming sowing moment. To make supply during the whole year possible or a larger part of the year, the farmer needs to make a second storage place

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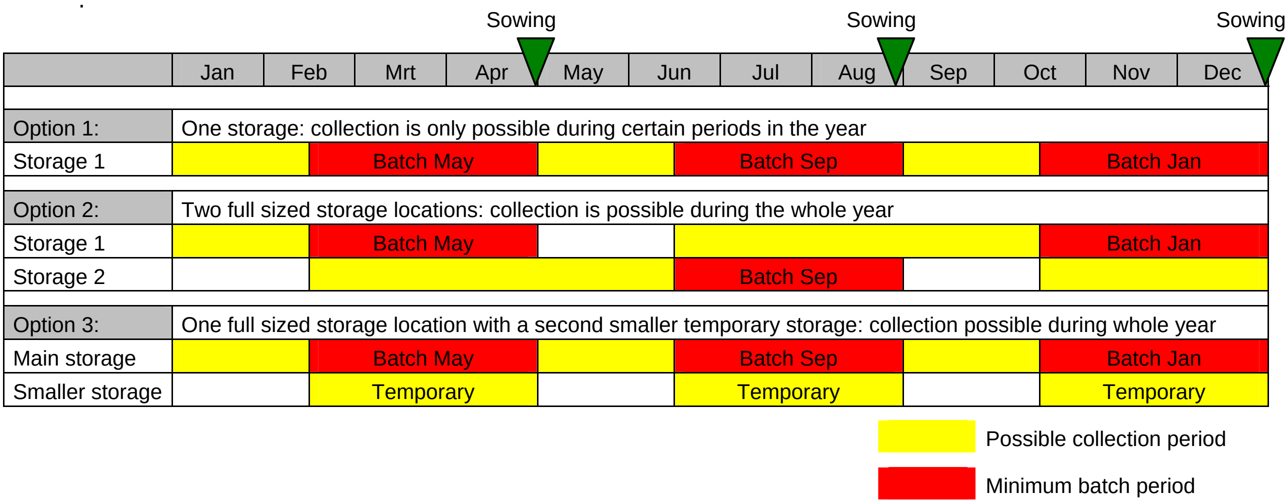

Figure 6.2 Situation: Minimum batch period is shorter than or equal to period between two fertilizations

Table 6.4 Relation between number of batches and possible periods of supply in case the minimum batch period is shorter than or equal to period between two fertilizations

Number of batches	**Possible period of supply**	**Need to handle potentially hazardous material**
One (full sized)	Limited periods a year[12]	No
Two (full sized)	Whole year	No
One full size and one smaller sized	Whole year	Yes

12 Percentage of year during which supply can take place = (Period between two fertilizations – Minimum batch period) / Period between two fertilizations (During the minimum batch period also a small supply period is included, but this is relatively small and for simplicity is neglected in this formula.)

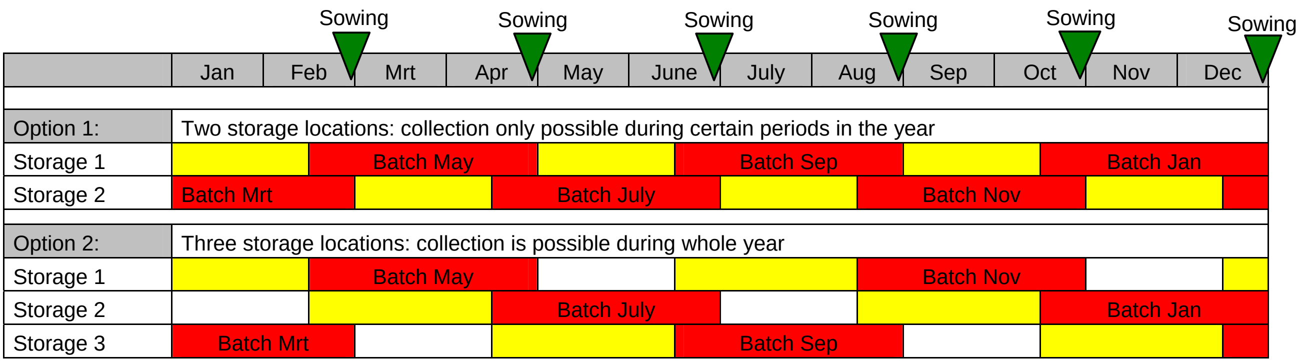

Figure 6.3 Situation: Minimum batch period is longer than period between two fertilizations and shorter than two times the period between two fertilizations

Table 6.5 Relation between number of batches and possible periods of supply in case the minimum batch period is longer than period between two fertilizations and smaller than two times the period between two fertilizations

Number of batches	Possible period of supply	Need to handle potentially hazardous material
Two (full sized)	Limited periods a year[13]	No
Three (full sized)	Whole year	No

Figure 6.2: Option 2 Two full sized storage locations
When the farmer creates a second similar storage facility he can store the material there when the other batch is occupied. As depicted in Option 2 in Figure 6.2 the storage locations are then used in alternation making it always possible to receive new material.

Figure 6.2: Option 3 One full sized storage location and a second smaller sized temporary location
In Option 2 two full-sized storage location are necessary. Instead, it is also possible to create a second smaller storage facility. This facility is then used only temporarily for when the main storage facility is occupied. As this second facility has to receive material for a shorter period of time, it can be smaller. Drawback of this temporary storage option is that the farmer needs to relocate the material from the temporary storage to the main storage again once the main storage is empty again. As the material that the farmer needs to relocate has not undergone the complete treatment period yet, he has to handle potentially hazardous material.

The above is summarised in Table 6.4.

<u>Figure 6.3: Minimum batch period is larger than the period between two fertilizations</u>
When the minimum batch period is larger than the period between two fertilizations there is a different situation. In that case one storage facility at the farmer is never sufficient, because it is not possible to complete and empty the batch before the farmer needs to receive the next batch already to have it ready in time for the next fertilization. This can be read from Option 1 in Figure 6.3. As can be seen also from this row, collection is not possible during the whole year. In the period right before fertilization there is an overlap between the batch that is not yet emptied for the next batch and the batch period that has already started to be ready for the next fertilization. In order to be able to supply the farmers the whole year round a third storage facility has to be created. This is depicted in Option 2 in Figure 6.3. The above is summarised in Table 6.5.

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13 Percentage of year during which supply can take place = ((Period between two fertilizations x 2) – Minimum batch period)) / (2 x Period between two fertilizations) (During the minimum batch period also a small supply period is included, but this is relatively small and for simplicity is neglected in this formula.)

Continuing on this line of thought, in the situation in which the batch period is longer than two times the period between fertilizations, an extra storage needs to be added again (and so on). This situation is less realistic, as the number of sowing periods within a year are limited.
Instead of creating these extra storage facilities at the farmer level to enable collect during the whole year, this can also be done by creating a central storage facility where it can be stored temporarily or treated completely. As it is unlikely that these facilities are provided in the near future, the next subsections discus how the individual farmers could create storage in a low-cost way and how they can apply the amount to the fields.

Storage of faeces

When storing the faeces it is important that the material stays dry and airy to aid further die-off of pathogens. To keep it dry it could be stored a little elevated and it could be covered with e.g. plastic sheets or a simple shed. To keep it ventilated pipes could be inserted to prevent development of anaerobic processes. This can all be done in a very low-cost way. A farmer can make it as sophisticated as he likes, e.g. with concrete underground and walls. Furthermore, animals and children should not be able to come into contact with the material to prevent disease transmission. This can be realised by adding a fence or a locked storage place.

Application of faeces

Jönsson (2004) reports of four methods to apply faeces, depending on the desired application rate. These are listed below from a high application rate in a large scale setting to a low application rate in a small-scale setting:

- Ploughing with a tractor or animal drawn;
- Digging the faeces into the soil in a layer and covering it with soil not mixed with faecal matter, forming a bed;
- Digging furrows and covering it after application with unmixed soil;
- Application in holes close to where the plants will be growing and covered again with soil.

Urine storage

As shown in Section 6.3.1 urine has be applied in large quantities and together with the fact that possibly two or three times this amount has to be stored (see the batches explanation earlier), some very low-cost but practical solutions have to be found to make urine reuse possible. No low-cost alternatives for urine storage were found in the EcoSan literature. The researcher, together with a farmer from Holland and Mr Sharatchandra (Environmental Management Specialist), has put the following options together:

- Big canvas/rubber bags for storage of watery manure are nowadays available in the Western world and are a better alternative than the construction of concrete cellars. In India these canvas/rubber bags are most probably too expensive and/or not easily available.
- Making a concrete basin is a very expensive option and it may also not last long, because of the aggressive nature of urine. Instead, plastic drums are readily available nowadays in India for water storage. These could very well be used for urine storage as well. They will last long without leaks and might be more economical, but still a large investment is needed given the large capacities that are needed.
- A very low-cost and simply solution that might work well is digging a hole in the ground and covering the ground with polythene sheets (farm-/agricultural plastic) to create a basin. It can be covered with polythene sheets as well to prevent evaporation of the urine and rain from coming in. The sheet to cover the top and the sheet from the basin itself can be pressed together on the sides by throwing soil on it to keep it in place and let the condensed urine flow back into the basin. Wood can e.g. first be laid over the basin at a little slope to prevent that the cover plastic collapses in the rainy season. A fence should be made around the basin to keep children and animals from trying to walk on it and rodents from damaging the plastic. As inlet/outlet a simple permanent hose can be laid into the basin. With a pump it can be pumped out.

Application of urine

There is little written on actual application methods for urine. The following list is composed by the researcher with the general comments of the Jönsson report (2004) and talking to a farmer in Holland and Mr Sharatchandra:

- Let the urine flow along with the irrigation water through the channels or drains to flood the field. To regulate the quantity a tap can be added in the supply pipe of the urine. Uniformity or evenness might be a concern, but as the urine flows along with the water and gets diluted, it is likely the urine will spread evenly if the water normally also spreads evenly.
- Drip irrigation using diluted urine. Measures must be taken to avoid blockages due to precipitation of salts.

Box 6.1 Willingness of farmers to apply excreta
A good indication for their willingness comes from the group that FODRA already had contact with. Earlier, FODRA discussed with them whether FODRA could use some of their land for demonstration purposes. They have agreed to give their land for this and now, in the two meetings, the farmers asked when the urine starts to come and remarked several times that it is taking very long.

A tractor with a tank trolley and a spreader with several hoses next to each other applying it directly to the ground, much like injection slurry spreaders.

- A low-cost version of the previous option could also be constructed by local people: the spreader device could be constructed with simple hosepipes and a simple tap and instead of using a tractor and tank trolley a bullock cart with a tank put on it.
- A sprayer that is used to spread liquid. There are very simple and robust spreaders that work on centrifugal force. However, spraying urine could lead to loss of nitrogen through gaseous emissions of ammonia and there could be a hygiene risk through aerosols.
- Spreading the urine by hand with a jerry can or an ordinary watering can used for gardens. This is only an option for very small-scale fields, because it is very time consuming and it is heavy.

6.4 Constraints and viewpoints of the farmers on EcoSan

This section gives insight into the viewpoints of the farmers on EcoSan: what is their general response to EcoSan and what are their concerns and criteria, in particular about the application, storage and transport of the urine and faeces. See the methodology section in Chapter 1 for an explanation how the information in this section has been obtained. Annex 9 discusses the general response to the meetings and to EcoSan. Although applying human excreta will be a little awkward to apply in the beginning, the farmers are anxious to try this new fertilizer on small pieces of their land to see what the results are. Box 6.1 illustrates this.

6.4.1 Application

The human manure can be applied in the same way as the animal manure: putting it on a bullock cart, throwing it on the field with a fawari and then ploughing it with a tractor. This is no problem. They say: “It will be a little awkward, but if it is dried than there is nothing dirty about it anymore”. They comment that they do not even feel the need to wear gloves.

The simplest way to apply the large quantity of urine is to mix it with the irrigation water. The other methods are always more expensive than the mixing with the irrigation water. All the farmer groups have faith that the urine will spread evenly and that it will work very well. The land is divided into small pieces of land (see Photo 6.1) and the water spreads evenly. They foresee no problems. One group explained that during irrigation they stand next to the field to see if everything goes right and to see when it is full. The fields are flooded one by one.

One group commented that they did not want to use the spreader (see Section 6.3.3) for urine, because then they would have to walk more on the fields to relocate the spreader, which will harm the field.

The Muslim leader indicated he prefers not to store the urine somewhere. They are not willing to appoint land for storage, because they do not have so much land (the storage of faecal matter is acceptable, because it is a smaller amount). It is more convenient if they apply the urine directly on the land when the trolley from the community arrives. The trolley can go directly to the field and then someone can apply the urine immediately with a pesticide spreader (in that case the urine is not covered with soil, but a solution can possibly be found). He responded they could make a continuous supply pipe from the trolley to the pesticide spreader on the back of the person. That is a better option then the flooding with the irrigation water, because no storage is needed in that case. As can be read in Annex 9 the Muslims farmers have strong feeling towards the uncleanness of urine (unlike the Hindu farmers). This could be a (partial) reason why they do not want to store the urine on their land and mix the urine into the clean irrigation water next or instead of the reasons given above.

6.4.2 Storage

The manure can be stored in the field; in the village space is limited and in the field there is enough space. To keep it dry it can be elevated a bit and e.g. covered with plastic sheets. That is no problem. One group added that they could dig a hole and make cemented walls and cover it with metal sheets. If the human manure is less expensive than the chemical fertilizer, than they can afford to make an investment for this.

The Muslim leader explicitly said it was not acceptable to store the human manure in the village itself. They would do this in the field, 100 metres away. They will arrange some cover, like building a brick storage shed.

For the storage of urine they prefer to dig a hole that is completely covered with plastic sheets (they thought of themselves to make a fixed pipe in it as inlet/outlet). In the field there is enough space to do this. That option is much cheaper than purchasing plastic water tanks. One farmer responded in the following way: “We will look at all the options and see what is best for us. If a more expensive option works better, then we can afford to spend a little more on an expensive option. But I do not see any harm in digging a hole and cover it with plastic sheets” (the village of this farmer is richer than the other villages and have more land). He also commented on the fact that the urine was far more voluminous than the urea fertilizer, which probably meant more effort and money to store and apply it: “We are not afraid of hard work, hard work is our duty. It just has to be beneficial and cheaper”. As explained in the previous subsection the Muslim community preferred not to store the urine.

Table 6.6 Farmers: summary of viewpoints, concerns and criteria for EcoSan

General response to EcoSan	
General	- Prefer organic fertilizer over chemical fertilizer. - Their concern is that they do not how to process and how to apply the urine and faeces. - Their criteria for using is that costs of the new fertilizer are lower in relation to the price of chemical fertilizer and/or the increase in yield achieved. All farmers first want to experiment with the new fertilizer on a small piece of land before they make any investments. - Although the Muslim farmers stronger perceive excreta as unclean in comparison to the Hindu farmers, the Muslim farmers can accept to reuse excreta if it is beneficial, because nothing is written in the Koran about this. - Farmers communities who only had small pieces of land were not interested in EcoSan
Urine	- Hindu farmers perceive urine as clean - Muslim farmers perceive urine as very dirty: it should not be visible or touched.
Faeces	- It will be a little awkward to use the faeces as it is regarded as unclean, but if it is dried and cheaper than there is nothing dirty about it anymore and they will start rushing for it.
Storage	- Faeces - Hindu farmers: The faeces can be stored in the field; space in the village is limited. To keep it dry storage can be elevated a bit and e.g. covered with plastic sheets. - Faeces - Muslim farmers: It is not acceptable to store the human manure in the village itself. They would do this in the field, away from the village. - Urine - Hindu farmers: Can be stored in a hole that is completely covered with plastic sheets and with a fixed pipe in it. In the field there is enough space to do this and it is a cheap option. - Urine - Muslim farmers: They are not willing to appoint space for storage, because they do not have much land (storage of faecal matter is acceptable, as it is a smaller amount). They want to apply urine directly on the field when the supply trolley comes. The strong feelings towards the uncleanness of urine could be a (partial) reason why they do not want to store the urine.

Application	- Faeces: Can be applied in the same way as animal manure: putting it on a bullock cart and throwing it on the field with a fawari and then ploughing it with a tractor. - Urine - Hindu farmers: Mix it with the irrigation water: the simplest and cheapest way. As the land is divided into small pieces of land, the “urine-water” will spread evenly. - Urine - Muslim farmers: As they do not want to store urine, the trolley can go directly to the field where someone applies the urine immediately with a pesticide spreader with a continuous supply pipe from the trolley. This option was given instead of the mixing with irrigation water, as no storage is needed in this case. The strong feeling towards the uncleanness of urine could be a (partial) reason why they do not want to mix urine with clean irrigation water.
Transport	The farmers indicated they could organise a tractor and trolley for secondary transport themselves, as this would be much cheaper than a government tanker delivering it.
Financial aspect	If the costs of the new fertilizer are lower in relation to the price of chemical fertilizer and/or the increase in yield achieved they are willing to make necessary investments and to buy the human manure.

Box 6.2 Financially deprived

At the end of the meeting with the ‘Farmer of the year’ farmer (see Annex 9), after discussing the situation for farmers in Holland, he explained that Indian farmers are financially deprived and cannot afford to take any risks. They cannot afford to switch to new techniques like farmers can in the Western world. He agreed to the response of the researcher that this is why it is very important that they experimented with it themselves on small pieces of land and that we have come up with options to do EcoSan in a very simple and low-cost way during the meeting, with materials and equipment that they already have. That was true he said.

6.4.3 Transport

The question was put to the farmers whether they want to collect the urine and faeces themselves with a tractor from the transfer points in the community and pay a lower price for the urine and faeces or that they prefer that it is brought to them. The farmers indicated they could organise to get it themselves. If a tanker from the government has to come it will be expensive one group explained. If the prices are cheaper than the chemical fertilizer than they are willing to pay transportation costs.

6.4.4 Summary

Table 6.6 gives a summary of the whole section.

Box 6.2 illustrates the concern of farmers that they cannot afford to take the risk of switching to a new technique and how this can be tackled.

7 LOGISTICS - URINE COLLECTION AND TRANSPORT

This chapter addresses the question how the urine collection in Saboli and the transport to the nearby farmers could be designed effectively and efficiently. The next chapter will deal with the collection and transport of faeces. Urine and faeces are substances with very different characteristics. Urine is a liquid that is generated in relatively large quantities and therefore needs to be collected weekly or monthly and faeces can look like soil and needs to be collected only once a year in that case. Because of these differences different handling and transport options might be appropriate and other dynamics might play a role. Therefore, separate chapters deal with the collection and transport of urine and with that of faeces.

Photo 7.1 Constraining road conditions in Saboli
On the left: small streets where a large vehicle like a tractor cannot go.
On the right: bumpy and muddy roads where small vehicles have difficulty moving with a full load or where it is impossible for small vehicles to move during the rainy season.

To start with, the first section defines four scenarios of different ways for the households in Saboli to offer the urine to the collector. These choices have a strong impact on the collection possibilities and costs. The second section presents possible collection and transport options followed by a comparison between these different options in the third section. The assessment will give insight into the strong and weak points of each option from a health, technical and social/cultural point of view. With the results of this assessment a choice will be made which options are acceptable; these will be further analysed on investment and costs level in the fourth section. Some suggestions for the actual design of the household containers will be given in the Section 5 and the chapter will conclude with some remarks on several social and technical issues that should not be overlooked before implementation.

7.1 Different scenarios of collection situation

Addition of flush water

The first important option that household members have that has a large impact on the urine collection is whether or not to throw some water in the toilet bowl after urination. By flushing with some water after each urination the amount to be collected is increased considerably and with this the collection costs are increased considerably as well. Currently, people add 1-2 litres of water after urination and feel this is necessary to avoid smell (see Section 5.3.1). The people interviewed indicated this amount of water could be reduced, but not flushing at all is not acceptable to them, because of fear of smell. However, when the toilet is constructed properly smell will not occur (see Section 7.5). Sensitising the users about this is very important to limit the costs of the system. The impact of only adding ½ litre of flush water is calculated in Table 7.1. Addition of ½ litre of water after urination already more than doubles the amount to be collected. This has the consequence that the workload and the costs involved in the collection and transport system will also double.

Table 7.1 Calculation of amount to be collected per day

Amount of water added after urination	Total generation amount per person per day	Assumptions
0 litre	1,23 litre	On average an excretion of 450 litre urine per year = 450 / 365
½ litre	2,73 litre	On average 3 times urination per day[14] = (450 / 365) + 0,5 x 3

Connection of several houses with small pipes

Another option that has an impact on the way collection can take place and the costs involved is whether or not houses are connected together with small pipes e.g. on street level. During the research it was found that using pipes (on street or community level) would be a good alternative for the small and bumpy streets off the main roads where access by a (loaded) vehicle is a problem (see Photo 7.1 for an illustration). Although a pipe system concept is not chosen to be worked out in this research (see Section 4.2) it is felt this option has to be mentioned, because of the difficulties imposed by the road conditions for vehicles. By using pipes directed to the main road, collection can take place by staying on the main road, which makes accessing these small and bumpy streets unnecessary any longer.

Table 7.2 Possible scenarios for collection situation

	No Connection of houses	Connection of houses
No addition of water	No Connection + No Water added	Connection + No Water added
Addition of water	No Connection + Water added	Connection + Water added

Another advantage of connecting several houses via a system of pipes is also that it considerably decreases the number of collection points. This has an impact on the total collection time and thereby on the costs of the system. It also reduces the health risks for the collection personnel and the occurrences of spillages in the community, because the number of times of handling is decreased. Some suggestions on how to connect the houses, how to keep the construction costs incremental to the number of people participating and how blockages might be minimised can be found in Section 7.5.

Table 7.2 summarises the four scenarios on how the urine is offered to the collector as a result of these two choices.

[14] Women more often and men less often in general as men are also out of the house more. Further research is needed to obtain a more accurate number, because the number of people asked is limited and people might have a wrong picture in their mind of how many times the toilet is used.

Photo 7.2 Example of tricycle with engine

Photo 7.3 Example of hand pump (semi-rotary pump) suitable for this situation:
small and light with a suction depth of more than 5 meters and an acceptable capacity of
25-50 litre/minute (depending on the type of the pump and strength of operator)
(Right photo: Peter Ball)

7.2 Possible collection and transport options

Given the characteristics of Saboli as described in Chapter 5 and the different scenarios, this section will list the possible means how to collect and transport the urine from the houses to the farmers. This section is based on researcher's observations on available vehicles and equipment in Delhi and on interviews with engineers and other people with experience in waste collection.

7.2.1 Handling options

A liquid can be transferred from one container to another in three ways:

- by hand, through pouring
- by pump, through a pipe or hose
- by gravity, through a pipe or hose

Each of these handling options involve certain equipment to transport it over a certain distance.

7.2.2 Collection and transport means

The following collection and transport means with the related way of handling can be considered for Saboli:

- *Pouring the household containers into a collection container on a small vehicle*
  In this option households have a small container outside the house. The collector can disconnect and pick up this container and pour the urine manually into a larger tank on his collection vehicle, a tricycle. Considering that the collector has to be able to lift the container at each house, collection has to take place every day. With an average household size of six persons, the weight per day will come to ± 16 kg if people add ½ litre of water after urination. This will be higher for larger households. The storage container of households that have constructed their toilet at ground level, instead of on e.g. the first floor, will be extra heavy to lift, because these containers will be located (partially) under street level to let the urine be able to flow from the toilet to the container. Mechanisation could solve the problem of bad ergonomics. However, this will increase the costs of the equipment considerably and as this equipment is not readily available, it is not a suitable option. A collection frequency of once a day results in a high frequency of handling and subsequent high collection costs[15].
  If the collector is not able to drive the tricycle into a street, because of bumps and drains across the road or mud in the rainy season, the collector can take less load and/or carry a container to the vehicle.
- *Switching the full household container for an empty one and emptying them at a transfer station*
  Another obvious possibility is that the container is not emptied on the spot, but that the full container is lifted onto the vehicle and exchanged by an empty container. At the end of the trip the containers can be emptied at a transfer station. This option is not preferred over the option of emptying at the spot for several reasons. More on this in Annex 10
- *Pumping the urine with a hand pump from the household container into a collection container on small vehicle*
  When pumping the liquid out of the household containers into a larger collection container on a vehicle there is no heavy lifting involved. A small and light hand pump could be fixed onto a tricycle. The solid waste collectors of Saboli suggested using a tricycle with an engine (see Photo 7.2), because it can take more load than a tricycle without an engine. A small electric pump is not an option as electricity supply is limited in Saboli. A small sized hand pump (see Photo 7.3) cannot pump much liquid per minute, but the tank on the small vehicle is also small. When it takes a few minutes longer to fill this tank this is not a problem, the costs of the whole vehicle is relatively small compared to a larger vehicle with a heavier pump. Collection does not need to take place everyday, because the collector does not have to lift the collection containers.
  If the collector is not able to drive the tricycle into a street, because of bumps and drains across the road or mud in the rainy season, the collector can take less load and/or the collector can attach a longer hose to the

[15] An illustration of the impact on the number of vehicles needed in case a frequency of only one or three days is chosen can be found in the frequency analysis in Section 7.4.2 for a comparable vehicle (the tricycle where handling takes place by pumping).

pump to limit the distance the vehicle has to go into a street. However, the length of the hose will not be sufficient to cover a whole street.

- *Using a centrifugal pump mounted on a tractor-driven trolley with a plastic tank on it*
  Using larger capacity vehicles could be more cost-efficient, because the number of trips is reduced linear with the increased capacity. Time-and-motion studies can give insight whether the time savings offset the larger expenses for the vehicle (see Section 7.4). A tractor is the most appropriate vehicle in Saboli to pull a large tank of e.g. 3000 litres, because a tractor is able to move in very bumpy roads (most roads in Saboli). A truck is not as stable and manoeuvrable as a tractor. Another advantage of tractors is that they are very robust vehicles and maintenance knowledge is less complicated and more readily available compared to that of trucks. When large transport distances are involved a truck can prove to be a better option, because higher speeds can be reached on good roads. This is not the case here; the distance to the farmers is only ± 10 km on dirt roads.

Photo 7.4 Example of tractor with trolley
On the trolley a big square plastic tank can be fixed (a square tank has a lower centre of gravity than the standard round water tanks). A generator with inbuilt pump also needs to be added to the construction.
(picture tank: www.sintex-plastics.com; picture generator: www.honda.com)

A suitable pump could be a self-priming centrifugal pump, because there are no solid parts in the liquid and the viscosity is low. A self-priming pump is easy to operate, as it is automatically in working order. The material for the tank can be of plastic, because there is no pressure build-up in the tank. Plastic tanks are readily available in all kinds of capacities. The tank can be mounted on a widely available standard trolley (see Photo 7.4). The centrifugal pump can be directly driven by the power take-off (PTO) of the tractor. However, it might be better to use a generator for driving the pump. Not every tractor has a PTO or a sufficient PTO speed and if the tractor driver does not regulate the speed correctly the pump is damaged. A generator with an inbuilt centrifugal pump is tuned to the capacity of the pump. Generators are readily available and operation and maintenance knowledge is widely available in Delhi. It is assumed a generator is necessary when calculating the costs later in this chapter.

A tractor cannot move in every small street of Saboli. Electrical poles often block the way and/or make it impossible to make turns. Narrow streets with dead ends are also problematic. To reach the non-accessible houses the hose of the pump can be increased in length. However, in this case the pump has to be taken close to the house as well, because the suction hose cannot be much longer than 10 metres, otherwise the pump will have difficulty pumping. Also, the longer the hose, the more difficult the hose will be to handle, because the suction hose needs to be reinforced to prevent it from collapsing. The discharge line can be lengthened without a problem, because pushing is much easier than suction for the pump and the discharge line does not need reinforcement. To make the pump moveable it can be loaded on some kind of wheelbarrow.

- *Using a vacuum pump mounted on a tractor driven trolley with a vacuum tank*
  A vacuum pump construction is very expensive and not cost-efficient compared to the previous option. Therefore this option is discarded. An explanation is found in Annex 10
- *Using gravity by constructing the containers at a high level*
  If the household containers are constructed higher than the vehicle, the containers can be emptied by gravity. By fixing a tap to the household container a hose can be attached to let the urine flow into the vehicle. However, only 30% of the households have constructed their toilet at the first or top floor. Constructing the container right under the first floor on the outside of the house makes the containers visible to the eye. As concluded in Chapter 5 this is not acceptable for the inhabitants of Saboli, as well as storage of the urine inside. Therefore, this option is discarded. However, if one wants to implement this option (at suitable houses and the containers attached and finished off in such a way that people are not offended by it) the results of the costs calculation of the tricycle option with a hand pump in Section 7.4.3 is comparable to this. The cost of the hand pump contributes only little to the total collection costs. Whether handling will be quicker is unclear, as this depends on the hand pump used, the strength of the collector and the size of the hoses. Beware that spillage can occur easily as the tap has to be closed before the container is full, otherwise the collection container will overflow with what is left in the hose. This is not an easy thing to do when the collector is alone.

None of the above means can cope very well with the road conditions in Saboli; the tractor mostly because roads are too narrow and have dead ends and the tricycle because it does not have power to go over drains and bumps and to move in muddy areas. Solutions can be found for this, such as reducing the load and lengthening the hose in case of using pumps. The employment of both vehicles might also be necessary in the specific areas where the tricycle or tractor cannot cope. However, in these physical conditions the laying of small-bore pipes as introduced in Section 7.1 maybe the only long-term solution (some thoughts on the actual design are given in Section 7.5).

7.2.3 Transfer options

Transfer means extra handling and the construction/purchase and maintenance of equipment and the obtaining of a location for it. Therefore, transfer is only sensible when savings in the transport costs offset the costs of the station. For the tractor pulled constructions not much saving can be gained by transferring the urine into a higher speed vehicle or a larger capacity vehicle. The distance is manageable with a tractor and speeds cannot be high. Furthermore, the road conditions to and in the village are more or less the same as in Saboli, demanding equipment of limited size as well. This gives no reason for transfer for the tractor pulled collection options.

The situation is different for the (motorised) tricycles. The maximum quantity they can carry is ± 100-300 litres. Transferring the urine in 3000 litre tanks, pulled by a tractor, reduces the number of trips to the farmers ten to thirty fold. The average speed of the tractor on the road to the farmers will also be higher compared to a small tricycle (with an engine). In the rainy season it will also be very difficult to go by tricycle. Furthermore, the farmers will most likely prefer delivery with a tractor; in case of the tricycle, the number of deliveries to each farmer will be much higher. Therefore, in case of collection with a tricycle transfer into a larger tank pulled by a tractor for secondary transport is considered necessary.

There are two options how this transfer from a tricycle into a larger sized tank can be organised:

- *Transfer directly in the transport vehicle*

The simplest way is to directly pump the contents of the tricycle into the transport vehicle, a tank trolley. A generator could be used for this. Generators are widely available and a cheaper and a more flexible option than constructing a reinforced platform with a (long) ramp to be able to empty the tricycles by gravity. When the trolley is full the tractor can pick it up, deliver it to the farmer and return the trolley again to the transfer site. To let the operation run smoothly at least two extra trolleys are needed to allow for the tricycles to continue working when the tractor is on its way and to allow for delays of vehicles and vehicles arriving early[16]. When the tricycles and tractors will have to wait for each other, the required total number of vehicles increases.

- *Transfer in an intermediate storage tank*
  Instead of emptying the tricycles directly into the trolley it can be emptied in an intermediate storage tank. This can be a large plastic tank, placed into the ground. By parking the tricycle next to the storage tank and coupling the hose from the storage tank to the opening of the tricycle tank, sealed with a tap at the bottom, the urine flows into the storage tank. When the storage tank is almost full the tractor can come and load his tank trolley with a pump, generator driven. The size of the plastic tank has to be at least the size of two tank trolley loads, similar to the previous option to avoid vehicles waiting.

The transfer site itself can be very basic: only a tank into the ground with a few pipes out of the ground for inlet(s) and outlet(s) or a marked out area for the trolleys with a generator for transferring the urine and a hand pump for e.g. washing hands. This way construction can be very cheap. Please note that money has to be reserved for strengthening the transfer area and access roads when vehicle movement increases. Later, when collection is taking place on a larger scale the transfer site could be expanded with additional facilities such as a more elaborate cleaning site, an office for a supervisor with additional shelter for breaks of the collectors, a space for the vehicles to park and to perform simple repairs. This can be as simple or refined as one chooses.

Partial comparison and assessment
Which of the two transfer options is preferable will already be assessed in this subsection while the two options are still in mind. The two options do not differ much in regard to expenses. A plastic tank is cheaper than a plastic tank on a trolley, making the transfer station with an intermediate storage tank cheaper. On the other hand, in the option where the urine is transferred directly into the trolley, the tractor does not have to wait anymore at the transfer station to load his tank. This increases the number of trips the tractor can make on a day, decreasing the required number of tractors. When 8000 households participate this saves ½ to 1½ tractors for secondary collection, depending on the amount of water added[17]. When the number of participants is still limited and these savings cannot be achieved fully yet, a transfer station with an intermediate storage tank might be cheaper than hiring or purchasing several tank trolleys[18]. A social/cultural advantage of the intermediate tank is that it can be placed under the ground making the urine storage invisible. People will prefer this. From a health point of view there is no difference as in both options the transfer takes place through hoses that can be coupled to the tanks instead of inserting the hoses into the urine. This decreases spillage and dirtying of the hoses.

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[16] The exact number can be determined with a simulation program, which takes into account the distribution of the time which handling and transport take. This is outside the scope of this research. However, two extra trolleys are proposed, because one extra trolley does not allow for any margin.

[17] The required number of tractors needed for secondary collection is analysed in Section 7.4.2. In this analysis the time reserved during a trip for loading at the transfer station can be omitted to determine the reduction in the number of vehicles.

[18] Purchasing a large plastic tank of 6000 litres will come to ± 20.000 rs and purchasing two trolleys of both 3000 litres will come to ± 70.000 rs, making a saving possible in the beginning of 50.000 rs However, when the number of participants increases and with this the number of tractors for secondary collection, a significant reduction in the number of tractors can be achieved by not having to wait at the transfer station. The extra costs of the trolley can then be easily offset by the yearly costs to operate a tractor (± 240.000 rs). The mentioned investment and yearly costs can be found in Annex 13 .

In the costs calculation it is assumed the transfer station will have an intermediate storage tank, because this makes the transfer less visible and keeps investments down in the beginning. As to how people feel about the two options, further research need because this is not researched thoroughly. Tolerance of the transfer station is very important. If the transfer station has to be located further away the costs for primary collection will increase substantially.

7.2.4 Putting the options together - Summary

The previous subsections introduced several options. Of the six possible options for collection and transport three options have been discarded immediately and three options remain to be investigated. Table 7.3 shortly characterises the three remaining options together with the transfer and secondary transport, if necessary, to carry the urine to its destination, the farmers.

Table 7.3 Characterization of remaining options for assessment

<table>
<tr><th></th><th colspan="2">Primary transport</th><th>Transfer</th><th>Secondary transport</th></tr>
<tr><td rowspan="3">Option 1 Pouring in tricycle</td><td>Handling</td><td>Pouring contents of small household container in tank on vehicle</td><td rowspan="6">Transfer directly in the transport vehicle with a generator
- or -
Transfer in an intermediate storage tank (in by gravity, out by generator pump)</td><td rowspan="6">Tractor with trolley</td></tr>
<tr><td>Vehicle</td><td>Tricycle</td></tr>
<tr><td>Equipment</td><td>Disconnectable containers</td></tr>
<tr><td rowspan="3">Option 2 Tricycle & hand pump</td><td>Handling</td><td>Pumping contents of small household container in tank on vehicle</td></tr>
<tr><td>Vehicle</td><td>Tricycle (with/without engine)</td></tr>
<tr><td>Equipment</td><td>Hand pump with hose</td></tr>
<tr><td rowspan="3">Option 3 Tractor & pump</td><td>Handling</td><td>Pumping contents of small household container in tank on vehicle</td><td rowspan="3" colspan="2">No transfer - Direct transport to destination</td></tr>
<tr><td>Vehicle</td><td>Tractor with trolley</td></tr>
<tr><td>Equipment</td><td>Generator with inbuilt centrifugal pump with hose</td></tr>
</table>

7.3 Comparison of the different options for collection and transport

This section will assess the remaining three options as characterised in Table 7.3 on the criteria for a good logistical system that have been drawn up in Section 0 (the two transfer options are already (partially) compared and assessed in the previous section). This assessment will give insight into the strong and weak points of each option. Based on this assessment a choice can be made which options are acceptable and need to be further analysed on costs implications. The criteria on the financial aspects will not be considered at this stage, but will follow after the analysis on the costs consequences in Section 7.4.4, as more information is available then. The institutional and political/legal aspects lie outside the scope of this research. However, some comments are made on this in the financial and social assessment.

Some criteria have been omitted from the list developed before the field research, because these have more reference to the design of the storage containers at the household. Section 7.5 returns to the design of the storage containers. Also, some criteria have been added to the list in response to the meetings held with the potential users and collectors in Saboli (discussed in Section 5.3).

Assessment

Table 7.4 on the next page assesses respectively the health and environmental, technical, social/cultural aspects one by one. This is done by giving a rating in the form of +, +/- and - where a '+' means that the design criteria is met and a '-' that the design criteria is not met. An explanation for the rating is given in Annex 11 .

Table 7.4 Assessment of remaining options

	Option 1 Pouring in tricycle	Option 2 Tricycle & hand pump	Option 3 Tractor & pump
Health and environmental assessment - Policy criteria • The occupational and public health is safeguarded • Faeces and urine do not enter the direct living environment • Valuable resources are reused to the maximum extent			
Health and environmental assessment - Design criteria			
No direct contact of workers with urine	-	+	+
Prevent contact with eyes	-	+/-	+/-
No or small occurrence of spillage during handling	-	+	+
Spillage consequences of failures should be limited and easily cleanable	+/-	+	+/-
Container and equipment is cleanable	+	+	+
Transport container is airtight	-	+	+
Technical assessment - Policy criteria • The system is easy to construct and maintain in the local context • The system is robust enough to meet the exigencies of normal use • The system is safe, user friendly and reliable • The system is as cost efficient as possible			
Technical assessment - Design criteria			
Suitable to the physical conditions of the area	+/-	+/-	+/-
Vehicles and equipment are available on the local market and safe to use	+	+	+
Rely on locally widely available knowledge, skills, spare parts and materials for operation and maintenance	+	+	+
Handling is easy and quick	+	+/-	+/-
Service is performed in the way and at the time that is agreed upon	-	+	+
The total weight of vehicles does not exceed the maximum allowed axle weight	+	+	+
Use of stainless steel, plastics or concrete (concrete needs to be rubbed down)	+	+	+
Urine storage excluded, places where urine stands still are minimized (because of crystallising of urine)	+	+	+
Critical sections are easy reachable and replaceable	+	+	+
Social/Cultural Assessment - Policy criteria • The system is consistent with cultural and social values • The system is aesthetically inoffensive • The system meets the needs of all household members and workers considering gender, age and social status and caste • The system is acceptable to the users and waste workers			
Social/Cultural Assessment - Design criteria			
Everybody has access to the service and feels safe using it	+	+/-	+/-
The fee for the service fits within the expenditure pattern of the households	See section 7.4.3		
Potential users have identified the sanitation service as a necessity	+/-	+/-	+/-
Potential users are involved in selecting the option most appropriate for their community	+	+	+
Users feel responsibility to manage and maintain their toilet and corresponding storage	+/-	+	+
A complaint mechanism is present	Unclear yet		
Operation is done in a way that preserves the dignity of the workers	-	+	+
No association with manual scavenging	-	+/-	+
Storage container must be located outside the house and not visible to the eye	+/-	+	+
Collection vehicle is closed to avoid spillage and to hide the urine from the public eye	-	+	+
The users can not handling the urine themselves in any way	+	+	+
Collection must not create tension and hassle	-	+/-	+

Conclusion

Option 1 '*Pouring in tricycle*' scores lower or equal to the other two options on most points. Many of the criteria are not met, due to the way the urine is handled: pouring. It makes the option socially and culturally less acceptable:

- It is associated with manual scavenging;
- The dignity of the workers is affected, because of smell and larger chances of spillages over the worker, as the containers can be heavy and slippery;
- During the pouring the urine is visible to the public eye and during collection the tank is most likely not closed. With the necessary high collection frequency the collection system is strongly present in the community;
- The collection service is prone to create tension and hassle for the users as frequency of emptying has to be very high. There is also little space for a safety margin as the container has to stay manageable for the collector during lifting. This can create problems if the collector does not show up at the agreed times.

The other two options are socially and culturally (more) acceptable, because the use of a hose and pump make a "closed circuit". This minimises visibility, spillage, smell and it has a more mechanised charm around it. This increases the dignity of the collector and this way of handling escapes the strong association with manual scavenging. The invisibility and lower frequency of collection makes the collection services less present in the community. The fact that the container can be as big as the user wants in these two options allows for a larger safety margin, minimising tension and hassle for the user with regard to the service performance.

Technically all three options will perform fine, but from a health and environmental point of view Option 1 scores lower than the other options. The collectors will have more direct contact with the urine than when pumps are used. The container can easily slip out of the hands of the collector during the lifting and pouring of the heavy containers. Also, when pouring too fast, the urine can spill on hands, body and ground. Handlebars can make the containers more manageable. However, these mistakes will most likely still occur, especially when people get tired or when the containers or hands are wet from e.g. rain or wiping the containers clean. When using pumps spillage can be reduced to a minimum level with the help of simple technical additions.
Option 1 will be discarded for the above reasons.

7.4 Cost calculation acceptable options

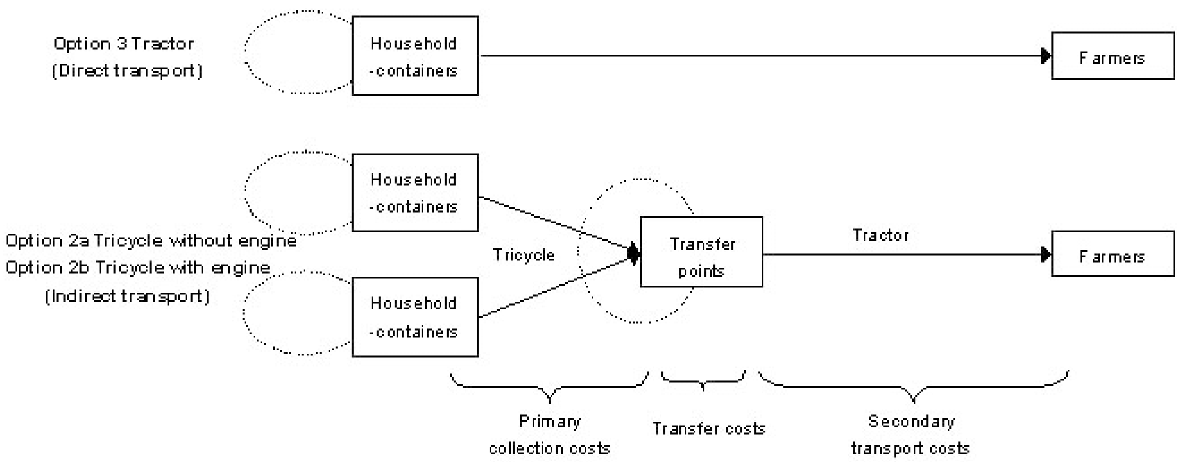

Fig 7.1 Overview of collection and transport chain for the tractor and tricycle options

This section will calculate the costs to collect the urine in Saboli and to transport it to the farmers nearby Saboli for the remaining options in which a tricycle is used (Option 2a Tricycle without engine, Option 2b Tricycle with engine) and Option 3 in which a tractor is used. In case of the transport by tractor direct transport is possible.

There is no need for transfer as explained in Section 7.2.3. In case of the tricycle, transfer into a tractor trolley is neccessary. An overview of this and the breakdown into the primary collection, transfer and secondary transport is given in Figure 7.1. Table 7.3 described the handling mode and the equipment used. The following subsections will calculate the costs for each step and compare the options on the total costs involved.

Table 7.5 Input assumptions for costs calculations

Quantities generated per day	**Value**	**Remarks**
Number of households	8000 Households	See Table 5.1
Average household size	5 Persons	The average household size is 6.1 (see Table 5.1). A lower average is used for calculation purposes, because especially men and children often urinate in the open.
Scenario No water added: Generation per person per day	1,23 Litre	See Table 7.1
Scenario Water added: Generation per person per day	2,73 Litre	See Table 7.1
Capacity of vehicle		
Option 2a Tricycle without engine	100 Litre	In reality, the actual load has to be reduced during the rainy season. In the calculation it is assumed that this is dealt with by working longer or working in shifts in order to collect the same quantity per day.
Option 2b Tricycle with engine	300 Litre	
Option 3 Tractor	3000 Litre	
Duration of one trip and workday		
Duration of one trip depends on scenario and frequency. See Annex 12 for assumptions and calculations.		
Duration of workday	7 hours	A workday of 8 hours is assumed with one hour allowing for breaks
Capacity factors		
Workday factor	7/6	Work is performed 6 out of 7 days in a week
Efficiency factor	1,25	An overall efficiency of 80% is assumed

Table 7.6 Overview of investment and yearly costs of the different vehicle combinations and transfer stations (in rs)[19]

Annex 13 lists what equipment is needed in addition to the vehicle itself.

Option 2 Primary collection with tricycle – Secondary collection by tractor								
Vehicle	*Tricycle without engine*		*Tricycle with engine*		*Tractor*		*Transfer station*	
Investment costs per vehicle/station	8.600		15.300		111.200		42.000	
Yearly capital costs	2.752	5%	4.896	3%	24.464	10%	9.240	35%
Yearly operational and maintenance costs	2.200	4%	103.360	66%	165.935	70%	17.085	65%
Yearly labour costs	48.000	91%	48.000	31%	48.000	20%	0	0%
Total yearly costs per vehicle/station	52.952	100%	156.256	100%	238.399	100%	26.325	100%

Option 3 Collection by tractor - Direct transport				
Scenario	*Houses connected - One operator*		*Individual collection - Two operators*[20]	
Investment costs per vehicle	121.200		121.200	
Yearly capital costs	26.664	11%	26.664	9%
Yearly operational and Maintenance costs	176.325	70%	176.325	59%
Yearly labour costs	48.000	19%	96.000	32%
Total yearly costs per vehicle	250.989	100%	298.989	100%

[19] 53 rupees equals 1 euro (July 2005).

[20] A second operator is advisable when each house has to be covered individually to reduce the handling time per house. The first operator could handle the house and the second operator could handle the pump and e.g. close and open the containers.

7.4.1 Input

To be able to calculate the collection and transport costs several inputs have to be determined:

- Quantities generated per day
- Capacity of the vehicle combination
- Duration of one trip and workday
- Capacity factors
- Investment and yearly costs of vehicle combinations and transfer stations

These inputs are summarised in Table 7.5 and Table 7.6 and will be covered one by one below.

Quantities generated per day

The first part of Table 7.5 gives an overview of the quantities generated per day and the number of houses to be covered.

Capacity of the vehicle combination

The weight loads which the tricycle, without and with engine, and the tractor can carry in one trip are respectively around 100, 300 litres and 3000 litres. The weight load of the tricycle is limited to 100 and 300 litres, because there are many deep drains across the streets and slopes (see Photo 5.1 and Photo 7.1). For a tricycle with regular cycle wheels this means that the collector has to push the tricycle across these holes and bumps all the time. Attaching broader wheels helps in this respect, but these are also more expensive[21].

Regarding the tractor, the common tractors in the area (40-50 HP) can transport 3000 litres on these streets without difficulty. The size of the common trolleys are ± 1,5 meter wide and ± 2,5 meter in length. With these dimensions a rectangular 3000-litre tank is less than a meter high making the construction very stable.

In the rainy season the capacity of the vehicles is a different story. Several parts in Saboli are low-lying areas where much water is gathered from the surrounding areas, making the roads very muddy and/or flooded with water. Then the capacity of the vehicles needs to be reduced by around half, depending on the specific condition of the road that the collector has to take. This varies e.g. with the level of maintenance of the road and the weather conditions of the previous days. The tractor can better cope with these conditions, because the underlying layer of the road is hard; often the big tractor wheels are still able to find grip. During the rainy season the tractor will have to be driven with reduced loads compared to the loads during the dry season. The tricycle also has to reduce its load during the rainy season, but it might not be able to go into several areas it previously was able to enter, depending on the severity of the conditions.

Reducing the load during the rainy season increases the required number of trips and with this the workload. It is assumed this can be dealt with by working longer or working in two shifts on a day to get the work done during this period. By working longer or by working in two shifts, investments can be kept to a minimum. On the other hand, a lot of people in the severely affected areas move to their home villages during the raining season, which reduces the workload for the collectors.

Duration of one trip and workday

The time one trips takes is also an input to the calculation of the collection and transportation costs. It determines the possible number of trips per day. Annex 12 lists the assumptions that have been made. These assumptions are based on a combination of talking to several operators of tractors and tricycles and on the researcher's observation of these vehicles in Delhi and Saboli in particular. A workday of eight hours is assumed with an effective work time of seven hours i.e. one hour is reserved for breaks.

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[21] For a sweeper making this extra investment is a risk he is not willing or able to take normally, although he knows this increases the number of houses he can cover in one day, and by that, the money he can make. This is especially the case when the roads start to get muddy and the collector has to reduce his load to be able to move on.

Capacity factors

Two factors have been assumed that lower the capacity of the whole operation:

Table 7.7 Analysis of required number of vehicles for collection from individual houses to cover a certain number of households
Case: Option 2b Tricycle with engine – Scenario: No connection + No water added

1. Quantity to be collected	**Value**	**Unit**	**Remarks**
Number of households	8000	Households	
Household size (average)	5	Persons	
Generation per person per day (average)	1,23	Litre	Depends on the scenario chosen (see Table 7.5)
Workday factor	7/6		In a week 6 out of 7 days work is preformed
Quantity to be collected per day (incl. workday factor)	*57534*	*Litre*	= # Households x Households size x Generation p.p.p.d x Workday factor
2. Analysis of required number of vehicles	**Value**	**Unit**	**Remarks**
Capacity of collection vehicle	300	Litre	
# Trips needed per day	*191,8*	*Trips per day*	= Quantity to be collected per day / Capacity collection vehicle
# Trips possible per day	*8,6*	*Trips per day*	See for assumption Annex 12
Collection frequency (every # days)	14	Days	
Collection quantity per household	86	Litre	= Household size x Generation p.p.p.d x Collection frequency
# Households covered in one trip	3,5	Households	= Capacity of vehicle / Collection quantity per household
# Vehicles required (excl. efficiency factor)	22,4	Vehicles	= # Trips needed per day / # Trips possible per day
Efficiency factor	1,25		An overall efficiency of 80% is assumed (= 100 / 80)
# Vehicles required (incl. workday and efficiency factor)	*28,0*	*Vehicles*	= # Vehicles required x Efficiency factor
3. Analysis of frequency of collection			
Change the frequency of collection to analyse the impact on the required number of vehicles and the size of the household storage containers. See Table 7.8 for the worked out results.			

Calculation of number of trips possible per day	
Activity	*Minutes*
Driving to first house	10
Handling per house + driving to next house	12 (4 houses x 3 min)
Total filling time of tank (= 300 litre/ 25 litre per minute)	12
Driving to transfer point	10
Unloading	5
Total duration of one trip	*49 min*
Working hours per day (7 hours)	420 min
# Trips possible per day (= Total duration of one trip / working hours)	*8,6 Trips*

- *Workday factor:* It is assumed the collectors work six days a week. Six workdays per week is the standard in Delhi, as well as for the current solid waste collectors in Saboli. However, urine generation continues everyday. Therefore the quantity that needs to be collected per day needs to be increased by a factor 7/6: the urine generated during seven days needs to be collected within six days.

- *Efficiency factor:* No fleet can operate at 100%. Coad (1997) generally uses an efficiency factor of ± 80% to allow for breakdowns, maintenance and the number of trips made per day. Therefore, an overall efficiency of 80% is assumed in the calculation. This percentage might not be achieved in the beginning of the project due to inexperience and starting errors, but with time efficiency will pick up.

One can adjust these capacity reduction factors as one sees fit or add factors to it. One can for example add a factor for the fact that the solid waste collectors might not show up every day, because this is the reality for the solid waste collection. In this study this is not incorporated in the calculations. It is assumed that when a collector does not show up, he will work more hours the next day. This is the normal procedure for the solid waste collection: on e.g. the religious day of the week collection does not take place, which means they (have to) collect much more waste the next day; on these days the collectors work until they have finished their round of houses.

Investment and yearly costs of vehicle combinations and transfer stations

Table 7.6 on the previous page gives an overview of the investment costs and yearly costs. The yearly costs include capital costs (depreciation and interest), operation, maintenance and labour costs, but excludes overhead costs. A more detailed break-up of the costs can be found in Annex 13 . The numbers are an average of figures received during several inquires by the researcher on local markets and from operators.

7.4.2 Analysis

The investment and operational costs per vehicle were determined in the previous subsection. One further needs to know the required number of vehicles to calculate the total investment and operational costs for the urine collection. This section will explain how the number of vehicles can be calculated for a certain number of houses.

The calculations for the collection at the individual houses are different from the collection at one spot per trip in case houses are connected and the transport from the transfer station. Therefore these two types of calculations will be dealt with one after the other. The required number of transfer stations will be explained after that.

Collection at the individual houses

The tricycle with engine will be used in this subsection as an illustration of the calculation. Table 7.7 gives an overview of the complete calculation. The only differences with the tricycle without engine and the tractor for direct transport are the values for the load capacity and duration of one trip. The calculation is divided into three steps:

Step 1 - Quantity to be collected

First one needs to decide on the quantity to be collected per day. This is the multiplication of the number of households participating, the household size, the generation quantity per person per day and the workday factor. When 8000 households participate and an average family consist of 5 persons and each person generates 1.23 litre per day, with collection taking place 6 days a week, a total amount of 57.534 litres has to be collected per day (=8000 x 5 x 1,23 x 7/6).

By varying the number of households one can obtain an overview in time when the number of participants increases gradually. By varying the generation quantity per person per day one gains insight into the impact of certain amounts of flush water. In this report two scenarios with 1,23 litres and 2,73 litres of total volume per person per day are included.

Step 2 - Analysis of number of vehicles required

This step calculates the required number of vehicles given a certain collection frequency. With 57.534 litres to be collected per day as calculated in Step 1 and a 300-litre collection vehicle one needs to make 192 trips per day (=57.534 litres to be collected per day / 300 litres per trip). How many trips can be made per day depends on the collection frequency, because the duration of one trip depends on the number of households that the collector covers in one trip (each house takes 3 minutes). When in Table 7.7 a collection frequency of e.g. 14 days is chosen, the quantity to collect per house is 86 litres after 14 days (= 5 persons x 1,23 litre x 14 days) which means the collector can cover 3,5 houses before his 300-litre vehicle is full (=300 litre / 86 litre). With 4 houses to cover, one trip takes 49 minutes and makes 8,6 trips possible on a day on average (= 7 hours per day x 60 minutes / 49 minutes per trip).

There was a requirement for 192 trips per day calculated above. As one vehicle can make 8,6 trips per day on average, 22 vehicles are needed to operate all day (= 192 trips required per day / 8,6 trips possible per day). When the efficiency factor is included the required number of vehicles increases to 28 vehicles (= 22 vehicles x 1,25).

The question left is now what collection frequency is best; in the example a random collection frequency of 14 days was chosen.

Step 3 - Analysis of frequency of collection

When deciding on the collection frequency it is useful to know that the trade-off for the collection frequency consists mainly of the initial investments costs for the storage household container and the total costs for the collection service. With a high collection frequency just a small household container needs to be purchased, but the costs per ton-collected material will be higher in comparison to a lower collection frequency[22]. A lower collection frequency is not only preferable in view of the collection costs. It also reduces the health risks for the collection personnel and the occurrences of spillages in the community, because the number of times of handling is decreased. The inhabitants of Saboli also indicated that they preferred to spend more on their household containers to reduce the frequency of collection and thereby reduce the tension and hassle of collection. However, one needs to keep in mind that the ability and willingness to invest in ecological sanitation is limited.

The price of the household container is determined by its size and the required size (or capacity) is determined by the quantity generated per household during the period between two collection events. When collection takes place every e.g. 14 days, 86 litres have to be collected per household and a storage container of ± 150 litres would be adequate (for an explanation see Table 7.8). As an indication of the total costs for the collection service the required number of vehicles as calculated in Table 7.7 is used.

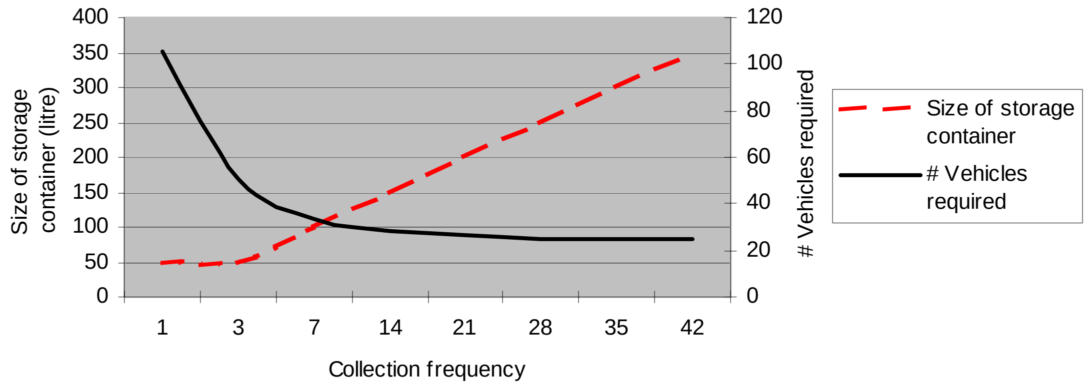
[22] With a higher collection frequency the collected quantity per trip is the same as with a lower collection frequency (the vehicle is loaded to its maximum), but a trip takes more time with a higher collection frequency, because the collector has to make more stops per trip to fill its vehicle. The longer the duration of the trips, the less trips can be made on a day (see the illustration in Table 7.8), the less urine the collector can collect per day; this increases the costs per litre urine collected.

Table 7.8 Analysis frequency of collection in case of individual house collection (in the example a participation level of 8000 households is taken)

Case: Option 2b Tricycle with engine – Scenario: No connection + No water added

Collection frequency (days)	Collection quantity per household (litre)	Storage container (litre)	# Houses per trip	# Trips possible per day	# Vehicles required (incl. workday and efficiency factor) [23]
1	6 – 12[24]	50	49	2.3	105
3	18 - 25	50	17	4.8	50,3
7	43	100	7	7.2	33,1
14	86	150	4	8.6	28,0
21	129	200	3	9.1	26,3
28	173	250	2	9.8	24,5
35	216	300	2	9.8	24,5
42	259	350	2	9.8	24,5
Collection quantity per household	= Household size x Generation p.p.p.d x Collection frequency				
Storage container	The capacity of the household container needs to be bigger than the collection quantity; it should include a safety margin to compensate for the periods in which relatively more urine or water is generated and for times when the collector is delayed. The lower the frequency the lower the safety margin can be, because fluctuations are levelled out over time. The size of the safety margin is not determined exactly, but based on a rough assessment of the researcher.				
# Houses per trip	= Capacity of vehicle / Collection quantity per household				
# Trips possible per day	See Table 7.7 for calculation				
# Vehicles required (incl. workday and efficiency factor)	See Table 7.7 for calculation				

Fig 7.2 Trade-off for collection frequency in case of individual houses collection: size of storage container and number of vehicles required



[23] In the example a participation level of 8000 households is taken for illustration purposes. However, when fewer households participate, fewer vehicles are also required. For the trade-off this makes no difference, because the collection costs per household remain the same; the ratio # Vehicles required : # Households participating remains equal.

[24] If one works six days per week, the workload on the day after the day-off is higher than on the other days when the collection frequency is less than seven days. This is especially the case when the collection frequency is one day. In that case a workweek of seven days might be advisable to spread the workload evenly during the week. However, in all calculations a workday of six days is assumed to make the different frequencies better comparable and currently, the solid waste collectors also work longer to collect the waste after a day-off.

Table 7.8 and Figure 7.2 provide insight into the trade-off in the choice of the frequency of collection: the bigger the storage container at the household, the fewer vehicles for collection are required. With a collection frequency of three days for example a household generates 18-25 litre of urine (= 1,23 litre per day x 5 persons x 3 days and 4 days; collection will take place every 3 and 4 days, because one day per week collection does not take place) and a container of 50 litres would have to be purchased. 50 vehicles would be required for the collection at 8000 households, because the possible number of trips is relatively low as many stops have to be made per trip; 17 houses need to be emptied per trip to fill the 300-litre vehicle (= 300 litre / 18 litre). With a collection frequency of 28 days on the other hand, a large household container of 250 litres would be needed, but only a minimal number of 25 vehicles would be required. As can be read from Table 7.8 and Figure 7.2 a collection frequency of 14 days might be the most appropriate choice for the tricycle with engine for the scenario in which no water is added. The required number of vehicles is already considerably reduced and the size of the storage container is still limited: a household container of 150 litre and 28 collection vehicles. Choosing a lower frequency lowers the transportation costs only marginally, but the storage container that needs to be purchased for this will have to be almost twice as large.

For every scenario and vehicle combination this has to be analysed separately. The results have been summarised in Table 7.11 at the end of this subsection.

Table 7.9 Analysis of required number of vehicles for collection at one spot to cover a certain number of households
Option 2 - Secondary collection - Scenario: No water added

1. Quantity to be collected	**Value**	**Unit**	**Remarks**
Number of households	8000	Households	
Household size (average)	5	Persons	
Generation per person per day (average)	1,23	Litre	Depends on the scenario chosen (see Table 7.5)
Workday factor	7/6		In a week 6 out of 7 days work is preformed
Quantity to be collected per day	57.534	Litre	= # Households x Households size x Generation p.p.p.d x Workday factor
2. Analysis of required number of vehicles	**Value**	**Unit**	**Remarks**
Capacity of collection vehicle	3000	Litre	
# Trips needed per day	19,2	Trips per day	= Quantity to be collected per day / Capacity collection vehicle
# Trips possible per day	3.9	Trips per day	= See for calculation Annex 12
# Vehicles required (excl. efficiency factor)	4,9	Vehicles	= # Trips needed per day / # Trips possible per day
Efficiency factor	1,25		An overall efficiency of 80% is assumed
# Vehicles required (incl. workday and efficiency factor)	6,2	Vehicles	= # Vehicles required x Efficiency factor

Calculation number of trips possible per day	
Activity	*Minutes*
Handling at transfer station	4
Filling of tank	12
Driving to farmers	40
Unloading	12
Returning to transfer station	40
Duration of one trip	*108 min*
Working day 7 hours	420 min
# Trips possible per day (= Total duration of one trip / working hours)	*3,9 Trips*

Collection at one spot (individual houses are connected or transport from transfer station)
The calculation of the required number of vehicles when collection takes place at one spot is basically the same as for the collection at individual houses, only simplified. Now the collectors of the tricycles for primary collection or of the tractor for secondary transport have to only stop once per trip to fill their vehicle completely. This means every trip takes the same amount of time, as 'the number of households covered' is always one. The number of trips the vehicle can make on a day is therefore always the same; the required number of vehicles only depends on the number of households participating. There is no question of analysing the frequency of collection like has to be done for the collection at the individual house collection. The simplified calculation of the required number of vehicles is illustrated in Table 7.9 in which the tractor for secondary collection is used as subject.

Step 1 and 2 - Quantity to be collected and analysis of number of vehicles required
The first step is again to determine the quantity that needs to be transported per day. This is done exactly the same as in Table 7.7, the situation is which collection takes place at individual houses; 57.534 litre per day. Next, the required number of tractors can be calculated. The 57.534 litres that need to be transported to the farmers each day are collected with a 3000-litre tank in the example. This means 19,2 trips need to be made per day (= 57.534 litre per day / 3000 litre per trip). As the tractor can make only 3,9 trips per day, 4,9 tractors have to be employed all day (= 19.2 trips required per day / 3,9 trips possible per day). When the efficiency factor is included the required number of tractors is increased to 6,2 vehicles (= 4,9 vehicles x 1,25).
In the beginning when there is not enough urine generated on a day for a tractor to be busy full-time, the collection trips of the tractor need to be organised in proportion to the quantity generated.

Although the required number of vehicles is fixed and with this the collection costs, the question remains how big the household storage containers have to be (how much capacity is needed at the transfer station and how many transfer stations are needed is covered a little further in this section).

Size of (household) storage containers
Instead of making individual storage containers at the house, one can make a large container at the end of the pipe with a certain safety margin to allow for fluctuations in the generated quantity and the collection moment. As this would require large investments at once, one could also consider each household still purchasing their own household storage container and connecting the small containers amongst each other; then the required total storage capacity is also reached and the storage costs are incremental to the level of participation in the community; in that way everyone pays automatically a contribution to the storage requirement when one's household participates.

Concerning the size of the household storage containers if one chooses to connect the small household container: the more houses are connected, the smaller the household storage container can be. This has two reasons:

- *The more houses are connected, the lower the safety margin can be*
  When more houses are connected and the total storage capacity becomes larger, fluctuations per household have more opportunity to level out. The more fluctuations are levelled out, the smaller safety margin will suffice. The safety margins are not determined in this study, because of time limitations.
- *The more houses are connected, the higher the collection frequency can be*
  The more households are connected in a certain street the sooner enough urine is generated to fill the tank of the transport vehicle completely. When not so many houses are connected the more days go by before enough urine is generated for the collection vehicle to have a full load. As the size of the individual storage container depends on the frequency of collection, connecting more houses lowers the required size of the container.

By making a quick calculation one can see that only a small number of households are required to be able to have small household containers. With a collection frequency of 14 days, 86 litres are generated per household when no water is added. For a tricycle to fill his vehicle respectively 2 to 4 houses would have to be connected to fill the 100-litre and 300-litre collection tank at one stop and for a tractor 35 houses. A storage tank of 150 litres (or smaller) would suffice in this case probably, depending on the safety margin that is required. When more houses are connected the collection frequency, and thus the household storage container size, can be lowered.

Transfer station

The calculation of the required number of transfer stations can be seen in Table 7.10. Input are the number of hours during which vehicles can arrive (8 hours) and the average (un)loading time of the most constraining vehicle; in this case 3000 litre can be processed in ± 25 minutes (see Annex 14). These 3000 litres per 25 minutes can be translated to the number of litres that can be processed per minute: 120 litres per minute (= 3000 litre / 25 minutes). By multiplying these 120 litres/minute with the 8 hours the transfer station is open, 57.600 litres can be processed per day, the capacity of the transfer station. The capacity has to be adjusted for the efficiency factor to prevent long queues of vehicles at the transfer station and for the workday factor to be able to translate the capacity to the number of households that can be served by one transfer station. This results in a capacity of 39.497 litres per day (=57.600 litres x 6/7 x 0,80). By dividing this capacity per day by the quantity that a household generates per day, the maximum number of households that is served by one transfer station is obtained; 6400 households when no flush water needs to be processed and 2900 households when extra water has to be processed. With this capacity two to three transfer stations are necessary in case 8000 households participate.

Table 7.10 Calculation of capacity of transfer station (Option 2)

1. Input	**Value**	**Unit**	**Assumptions**
Operational time per day	480	min/day	The tricycle and tractor operators arrive during their 8 hours workday
Average unloading time	± 25	min per 3000 litre	See Annex 14 for assumptions
2. Calculation of # litres that can be processed by one transfer station			
# Litres that can be processed per minute	120	litre/min	= 3000 litre / 25 minutes
# Litres that can be processed per day (excl. workday and efficiency factor)	57.600	litre/day	= # Litre that can be processed per minute x Operational time per day
Workday factor	6/7		In a week 6 out of 7 days work is preformed
Efficiency factor	0.80		An overall efficiency of 80% is assumed
# Litres that can be processed per day (incl. workday and efficiency factor)	39.497	litre/day	= # Litres that can be processed per day x Workday factor x Efficiency factor
3. Calculation of maximum # households served by one transfer station			
No water added	6407	Households	= # Litres that can be processed per day / (1,23 litre per person x 5 persons per household)
Water added	2891	Households	= # Litres that can be processed per day / (2,73 litre per person x 5 persons per household)

The capacity of the transfer station can be increased by using more equipment, such as a second generator or by making more inlets, to enable more vehicles to (un)load at the same time. This is discussed in Annex 14 . However, increasing the capacity above the 2900-6400 households per transfer station as calculated in Table 7.10 is of no use. Two to three transfer stations is the minimum quantity advised considering that the area is geographical divided in two areas (see Annex 6 ; one area, Harsh Vihar, has considerably more inhabitants; the third transfer station could be placed in that locality) to limit the transport time per trip for the primary collection tricycles.

Table 7.11 Insight in required size of the household storage container depending on the collection option, the scenario and the frequency of collection or the number of houses connected

	No Connection - No Water Added	**No Connection - Water Added**	**Connection - No Water Added**	**Connection - Water Added**
	Size of the household containers in relation to the chosen frequencies of collection in the cost calculations for the costs per ton collected urine to be small and the size of the household containers to be limited		Insight in the minimum number of houses to be connected for a certain sized household container to be sufficient	
	Minimum size of household container / Frequency		Size of household container (frequency) / Minimum number of houses to be connected	
Option 2a Tricycle without engine	100 litre - 7 days	150 litre - 7 days	50 litre (3-4 days) - 5 houses	50 litre (2 days) / 4 houses
Option 2b Tricycle with engine	150 litre - 14 days	300 litre - 14 days	100 litre (7 days) - 7 houses 50 litre (3-4 days) - 14 houses	100 litre (3-4 days) - 7 houses 50 litre (2 days) - 12 houses
Option 3 Tractor	150 litre - 14 days	300 litre - 14 days	300 litre (21 days) - 23 houses 150 litre (14 days) - 35 houses	300 litre (14 days) - 16 houses 150 litre (7 days) - 32 houses

In conclusion, the required number of transfer stations to serve 8000 households is set to two for the scenario in which no flush water is added for flushing and set to three stations in case there is water added.

Other scenarios and vehicles

The calculations as shown above in this section need to be performed for the other scenarios and vehicles as well. Annex 15 lists the result for each scenario and vehicle and for different participation levels. The next subsection gives a summary of the required number of vehicles and their costs impact. The chosen frequencies of collection and the required size of the household storage containers in the different scenarios and for the different options are summarised in Table 7.11. For the scenarios in which houses are connected Table 7.11 gives insight in how many houses have to be connected for a certain size container to be sufficient. In general, no larger containers are needed than 300 litres.

7.4.3 Results

The results of the analysis of the required number of vehicles is listed in Annex 15 ; it lists the required number of vehicles for each scenario and for different levels of household participation. Multiplying these numbers with the costs per vehicle (Table 7.6) gives the total investment costs and yearly costs for each option. These results are listed in respectively Annex 16 and Annex 17 . This subsection gives a summary of the yearly costs and investments and draws conclusions from this. To give more insight into the height of the costs some attention will also be given to the question how to cover the costs.

The currency rate is set to 53 rupees for 1 euro (July 2005).

= 140,5 tricycles x 8.600 rs + 13,6 tractors x 111.200 rs + 3 transfer stations x 42.000 rs (with

= 6,1 tractors x 121.200 rs (with unrounded

Table 7.12 Total investment costs and number of vehicles and employees required for the different options and scenarios for a participation level of 8000 households

Option	Scenario	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added	Remarks
Total investment costs (rs)						
2a	Tricycle without engine	1.354.200	2.849.400	1.266.050	2.750.500	= Required number of vehicles (see rows below) x Investment costs per vehicle (Table 7.6)
2b	Tricycle with engine	1.193.500	2.473.038	1.115.088	2.415.663	
3	Tractor - Direct transport	1.196.850	2.090.700	742.350	1.651.350	
Number of vehicles						
2a	Tricycles without engine	68,5	140,5	58,3	129	See Annex 15 for the results for different participation levels and section 7.4.2 for an explanation of the calculation.
2b	Tricycles with engine	28,0	54,4	22,9	50,6	
2	Tractors for secondary transport	6,1	13,6	6,1	13,6	
2	Transfer stations	2	3	2	3	
3	Tractors for direct transport	9,9	17,3	6,1	13,6	
Employees						
2a	Tricycle without engine	75	154	64	143	One operator per tricycle and per tractor for secondary transport
2b	Tricycle with engine	34	68	29	64	
3	Tractor - Direct transport	20	35	6	14	In case of collection at individual houses two operators per tractor

Summary of the costs and investments

Table 7.12 on the left gives an overview of the total investments required to serve 8000 households. Multiplying the number of vehicles required with the investment costs per vehicle gives the total investment costs. Table 7.12 gives two worked out examples. The investment ranges from 7½ lakhs rupees (± € 14.000) for the scenario *in which no flush water is added and houses are connected together and a tractor collects and directly transports it to the farmers* to almost 30 lakhs rupees (± € 55.000) in case *flush water is added and collection takes place at individual houses by tricycles without engines*. Under the total investment costs in Table 7.12 one can find the number of vehicles and employees required for the operation giving a picture of the fleet size involved for each option.

Fig 7.3 Monthly costs per household for the different options

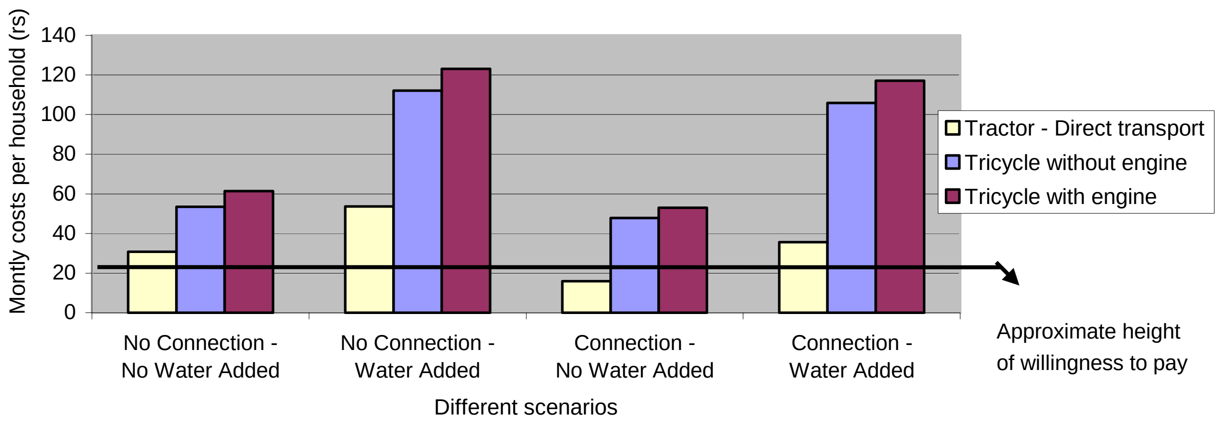


Fig 7.4 Costs to fertilize one hectare of farmland per year

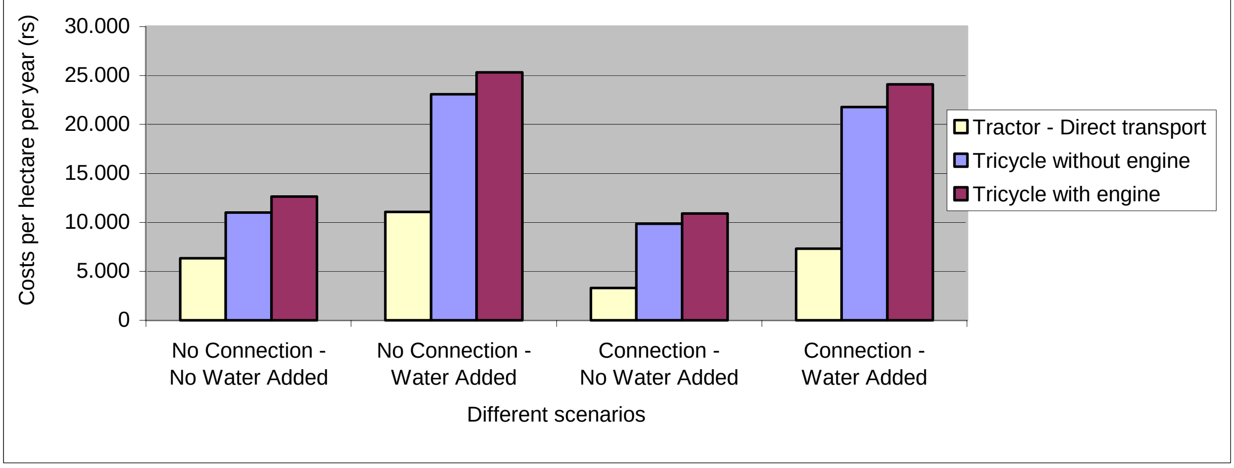


Table 7.13 gives an overview of the annual costs when 8000 households participate. Multiplying the number of vehicles required with the yearly costs per vehicle gives the total yearly costs. Table 7.13 gives two worked out examples in the footnotes. For the scenarios in which water is added for flushing the yearly costs are more than one crore rupees (± € 220.000) for the options in which tricycles are used. The lowest yearly costs, 15 lakhs rupees (± € 29.000), are realised in the case where also the lowest investments were reached: no addition of water, houses connected and tractors collecting and going directly to the destination. The costs to transport one litre of urine can also be calculated from the total yearly costs and is added to Table 7.13.

Covering the costs

Although the question how to cover the costs is not part of this research, indicators such as the cost per household give more insight into the overall costs than the costs per litre. If one would let the households account for the total yearly costs, Figure 7.3 indicates the amount each household would have to pay per month to cover all the costs. This result varies from 16 rs to 120 rs per month per household (Annex 18 gives an overview of the precise numbers and calculations). According to the director of FODRA, the willingness to pay would be around 20 rs per month, under the condition that service is guaranteed (for comparison, households currently pay 10 rs per month to the kitchen waste collector and do not have a problem with this figure). An executive engineer of the Municipal Corporation of Delhi explained a study done by them found a willingness to pay of 30 rs per month per household for solid waste collection under low-income communities. This figure can probably also serve as an indication for an excreta collection service.

Table 7.13 Total yearly costs and costs per litre of the different options and scenarios (in rs)

	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added	Remarks
Total yearly costs for 8000 households (rs/year)					
Tricycle without engine	5.140.056	10.766.917[25]	4.597.298	10.157.969	= Required number of vehicles (Table 7.13) x Yearly costs per vehicle (Table 7.6)
Tricycle with engine	5.888.012	11.823.581	5.087.200	11.237.621	
Tractor - Direct transport	2.952.516	5.157.560	1.537.308[26]	3.419.725	
Costs per litre urine (rs/litre)					
Tricycle without engine	0,29[27]	0,60	0,26	0,56	= Total yearly costs / Total transported litres of urine
Tricycle with engine	0,33	0,66	0,28	0,62	
Tractor - Direct transport	0,16	0,29	0,09	0,19	

If the farmers would have to bear all the costs, Figure 7.4 indicates the amount that a farmer would have to spend per year to fertilize one hectare with urine. Annex 18 gives an overview of the precise numbers and calculations and also gives an indication of the amount a small farmer and a big farmer would have to spend per crop.
As the households are the party delivering the valuable material and the farmers are the users, in principle the farmers should pay the costs and the households should get some money for offering it or collection should be free of costs for them (like is e.g. done with old paper collection). However, when the collection and transport costs are higher than the value of the urine to the farmers as fertilizer (e.g. in relation to the price of chemical fertilizer and/or the increase in yield achieved; this is not researched in this report) a middle way has to be found: the households can pay part of the costs as they also benefit from a proper removal of excreta. The government or another party can also subsidise some of the costs.

Conclusions

The following conclusions from the costs calculations can be drawn:

- *Most cost-effective option for each scenario*
  Collection with a tractor is the most cost-effective option for each scenario. The investments required are also lower than the tricycle options. Given the low capacity the required number of tricycles is very large compared with the number of tractors required. On top of this, a transfer station is needed and a few tractors for secondary transport, all adding to the costs. In the scenarios where houses are connected the same number of tractors for secondary transport are necessary as for the scenarios in which tractors directly transport the urine to the farmers (collecting the urine at the transfer station or at a households connection does not make a difference for the duration of a trip for the tractor). Therefore, the costs of the tricycle options in the scenario where houses are connected are much larger compared to direct transport: in addition to the same number of tractors for direct transport a whole fleet of tricycles is required. As the tractor is not able to go into the small streets and the (long) hose might not be long enough to reach every house, a tricycle for these streets is necessary when these houses are not connected (yet). This tricycle can work nearby the area where the tractor is working that day and can go to the tractor combination when their tank is full; the tractor can then empty the tricycle the same way as he does with the household containers.
- *Comparison tricycles with and without engine*
  The use of tricycles without engines is a little cheaper when looking at the yearly costs. This can be explained by the high fuel costs[28] and it is likely these will rise considerably more with time. On the other hand, the total

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[25] = 140,5 tricycles x 52.952 rs + 13,6 tractors x 238.399 rs + 3 transfer stations x 26.325 rs (with unrounded figures)

[26] = 6,1 tractors x 250.989 rs (with unrounded figures)

[27] = 5.140.056 rs / (8000 households * 5 persons * 450 litres per year)

[28] Estimates of the fuel consumption are very rough and should be further analysed, because the fuel consumption accounts for a large portion of the total costs of the tricycle with engine.

investments needed for the tricycles without engines are higher, because almost three times more tricycles are needed compared with the option in which the tricycles are used that can carry a three times larger load per trip[29].

- *Relation total costs and addition of water*
  For all four options addition of flush water to the urine has a large impact, because the water quantity is (almost) directly related to the workload. The adding of ½ litre of water after urination already doubles the costs. Sensitising the participants about this is very important to be able to limit the costs.
- *Relation total costs and connection of houses*
  Whether or not houses are connected does not have much impact on the costs when tricycles are used. For the tractor option on the other hand, this has a large impact; collection at one spot instead of collection at the individual houses reduces the costs with ± 40%. This can be explained by the relatively small size of the tricycles. Because of the small tank size of the tricycles, few stops are made per trip. The time gained per trip by reducing the number of stops is therefore relatively small. This is the opposite for the tractor. The tractor with is its large tank needs to make many stops if one chooses to keep the storage container at the household limited to e.g. 300 litres (to realise the full savings on the collection costs by connecting the houses, only 17-35 houses have to be connected (see Table 7.11).

  As said, in case of tricycle collection, connecting the houses does not have much impact on the total transport and collection costs. On the other hand, if more houses are connected together, the smaller the household containers can be as explained on page 59, which is a costs advantage for the households. People also might prefer the connection of the houses over the individual house collection, because it means not only a lower collection fee per month, but also a reduction in vehicle movement in front of their house and in their area (preferred from a social/cultural point of view).

Other considerations, next to the costs, are the number of jobs created, the complexity and the size of investments needed at the start of the project.

Number of jobs created
The number of operators needed is (almost) directly related to the number of vehicles required. Therefore, in the tricycles options the number of jobs created is much larger with the huge number of tricycles that are required. This can be seen in Table 7.12.

Complexity
The operation of the option in which tractors carry the urine directly to the farmers is fairly simple compared to the options in which tricycles are used. In the tricycle options much more vehicles and employees are involved and coordination has to take place between the primary and secondary collection, as the capacity for storage at the transfer station will be limited. Table 7.12 indicated the number of tricycles and tractors required. A higher complexity demands for a more skilled and larger overhead. Note that overhead costs are not included in this research.

Size of the investment needed at the start of the project (100 households participating)
When starting the project and only 100 households participate one to two tricycles have to be employed full time in case collection takes place with tricycles, depending on the scenario and the tricycle type (see Annex 15). This will require an investment of ± 16.000 rs (± € 300). At the transfer location a (trolley with) tank has to be present and a generator with pump to collect the material the tricycle(s) brings during the day. The tractor needed for the secondary collection only has to make a trip to the farmers every other day to once a week, depending on the amount of flush water added by the participants. Purchasing a tractor and trolley for this is not sensible. Hiring a trolley for these trips is also complicated, because a plastic tank needs to be put on the trolley each time (hiring a

[29] The required number of 100-litre tricycles is *less* than three times more instead of *exactly* three times more than the number of 300-litre tricycles, because the trips take less time for the smaller vehicles as they have to visit less houses per trip.

standard water tanker is not possible, because then it needs to be cleaned very thoroughly to be able to use it for water again). As a full-time tank already has to be present at the transfer station, it might be sensible to purchase a trolley and attach a tank to it and place it at the transfer station. The tractor can be hired to collect the trolley at the end of the day when it is almost full. A trolley (second-hand) with tank and a generator with pump will come to ± 47.000 rs (± € 900). Together with the required investments for the tricycles total initial investments come to 63.000 rs (± € 1200).

Table 7.14 Financial assessment of the different options

Policy criteria • The system is affordable to all households in the community • The costs are affordable for the community as a whole • Economic use of scare resource such as money, energy, space, land and water		
Design criteria	**Option Tricycle & hand pump**	**Option Tractor & pump**
Reasonable price for the service performance (price/quality performance)	+/-	+
Affordable price for the users	+/-	+
Affordable costs and reasonable benefits for the community (municipal)	+/-	+
Reasonable income for the employees	+	+
The advantages of the service should be competitive with existing practices	+/-	+
Required initial investments should be limited	+/-	+/-

When collection takes place with the tractor, the number of trips per week is the same as for the tractor for secondary collection; for 100 households every other day to once a week. However, the duration of one trip is longer in case collection takes place at the individual houses, but is still limited to two to three hours. Therefore purchasing a tractor is also not sensible, but it might be easier to purchase a trolley with tank and generator with pump and fix it properly on the trolley as explained above. The investments needed for this would be also ± 47.000 rs (± € 900). However, in this case no investment is needed for the tricycles and no labour has to be paid to operate the tricycles, making the tractor option requiring less investments.

7.4.4 Financial assessment

Section 7.3 assessed the options on the health and environmental, technical and social/cultural aspects. Now that the costs consequences are known the financial aspects can be assessed. However, the benefits and the costs of comparable services are not fully known, limiting the value of this financial assessment. An overview is given in Table 7.14.

The lower score for first three points for the tricycle option can be explained by the more than twice higher costs for the same service performance. Although the size of the household containers can be the same for both options and the households do not have to pay all the transport costs, someone has to. On the other hand, in case of the tricycles the number of jobs created in the community is much larger, offsetting the much higher costs a little. For both options the income for the employees is good. Concerning the competitiveness with existing

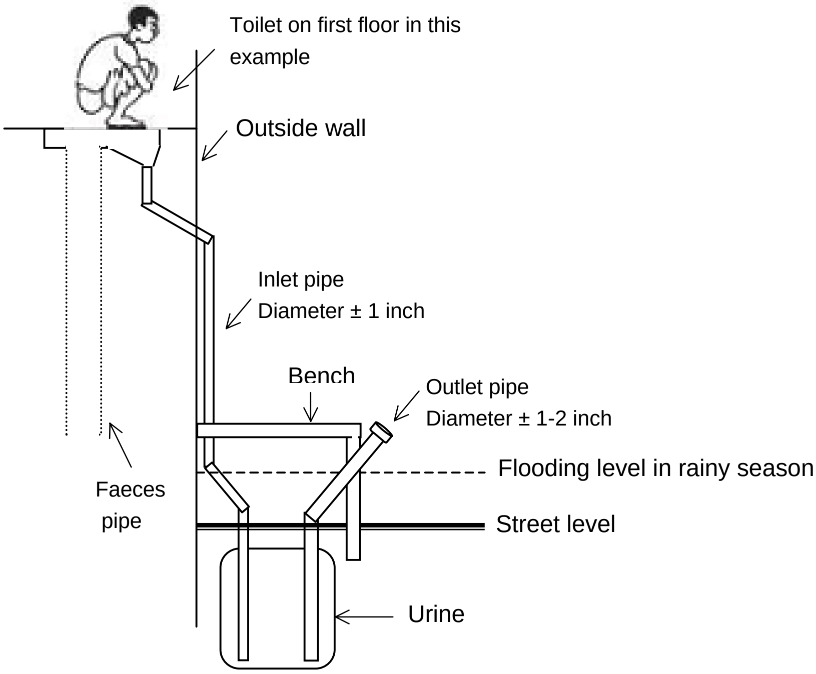


Figure 7.5 Side-view of an urine-diverting construction, an example.
The faeces segment will be further explained in the next chapter.

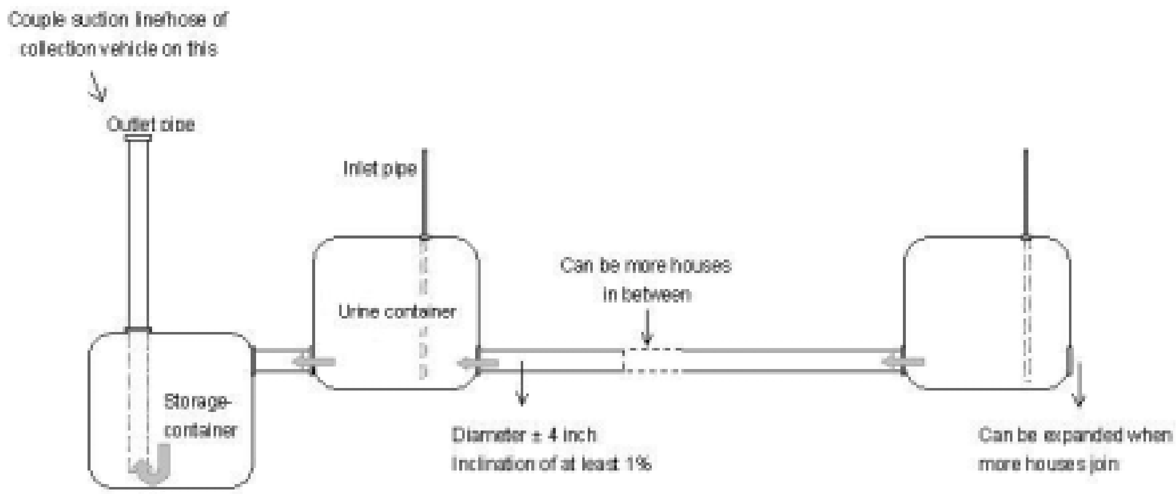


Figure 7.6 Side-view of how construction might be when the urine containers are connected to each other

practices, the current practice is letting the excreta overflow in the open drains which does not cost anything, although medical costs are higher wherever a proper sanitation system is not in place. Mr Sengupta of the World Health Organisation indicated that medical expenditure in a bad area could be reduced with 50% if a properly working sanitation system is introduced in combination with hygiene education and potable water supply. In that way and with the consumption of more nutritious food that could be realised using a more rich fertilizer, the service could be competitive with existing practices (although at higher costs for the tricycle option compared to the tractor option). Please note that the health benefits will probably only be realised when the whole community participates, otherwise excreta in open drains will still expose the people participating in EcoSan.

Another important aspect is that the ability to raise money for investments to set up a small collection enterprise is limited. There is often no collateral or back-up money and the risks in this case are high, because it is a new business with social and cultural difficulties attached to it. The institutional capacity is not present in the community to lend money for buying e.g. a trolley. The micro-credit groups in Saboli have large savings in total, but these are all small non-connected groups. When the micro-credit groups would form a corporation this money could be used for this. However, as explained above, initial investments are low for both options.

7.5 Thoughts on the design of household urine container

This section will provide some suggestions for the design of the urine storage containers at the households. Note that the remarks and drawings are merely suggestions. A wide range of materials, methods and styles can be used within the basic principles that should be adhered to for the system to function properly. Creativity should be encouraged to adapt the system to the individual situation and preferences.

In the previous section it was concluded that the size of the household containers had to range between 100-300 litres, depending on the amount of flush water added and the type of collection vehicle. The size of a 500-litre container is e.g. ½ meter x 1 meter x 1 meter. This indicates the containers dimensions will be small and that the container does not require a large space. The community members indicated that they want to store the container outside and under the ground or under a bench. This could be done right in front of the house alongside the wall of the house. As the depth of the container can stay very small, traffic will not be able to damage the container if a bench does not cover the container. However, construction of a small wall around the container or some kind of bars around it to protect the container and to prevent that the container will be able to move is advised to minimise damage to the container and the in- and outlet. Figure 7.5 gives an impression of what the whole construction could look like.

The pipes have to be made of plastic, as metal will react with the urine; PVC pipes can be used for this. It is very important that all connections are completely watertight to prevent odour problems and the filling of the tanks with rainwater, groundwater and water from the drains. To prevent odour it is advised to extend the inlet pipe to the bottom of the container (± 5 cm above the bottom) to minimise movement of the urine when urination and flushing takes place. It serves at the same time as an odour seal; ammonia can only escape from the surface of the inlet pipe (when the diameter of this pipe is only 1 inch, the amount of ammonia that will come off the container is very small).

It is advised to insert a permanent pipe into the container to which the hose or suction line of the collection vehicle can be attached. This way the collectors hose will not get dirty on the outside. This outlet pipe should be easy to (de)couple and be secured in such a way that children cannot easily open it. The pipe can also stay under the bench as long as the pipe is easy to access by the collector. Annex 19 provides some more attention points, for example concerning the diameter of the pipes and how odour can be avoided.

If the option is chosen to connect the household containers to each other in a street the construction will be different. Figure 7.6 gives a suggestion for this. Instead of making one big storage container at the beginning of the street where all the urine from the connected houses accumulates, it might be possible to still use the individual storage containers at each house. By connecting the small storage containers the total required storage capacity can also be reached. The advantage is that the capacity is automatically increased incrementally; each time a new house connects the capacity of the whole street is also increased a little. Furthermore, no high investment has to be made in the beginning and each time a household wants to connect it can contribute for the connection directly by paying the construction of his own container and connection to the system. The participant does not have to pay a general fee for the whole system. This might be more readily acceptable.

It is better to install an intermediate storage tank at the beginning of the street to prevent damage of the pipes by the suction power of the pump; by pumping the urine out of a container air is available and a vacuum is not created. The number of bends can be reduced (bends are more prone to get blocked) by directly fixing the connection pipe to both sides of the container instead of using T-joints to connect the container to the connection pipe. However, the construction requires the containers to be aligned. Pay attention that the containers need to be situated more or less horizontally level otherwise the lower located containers have more chance of overflowing. As a slope is advisable for the connection pipe (see Annex 19), the containers at the end of the pipe might have to be a little larger to still have the top of the container at the same height as the others. Annex 19 provides some more attention points, for example concerning the diameter of the pipes with regard to blockages that might occur.

Table 7.15 gives a very rough estimate of the total costs for each household. From this table it can be concluded that the costs for the option in which collection takes place at each house individually or when the houses are connected, do not differ much. The longer PVC pipe that is necessary in case the outlet pipe needs to reach to the next house that is connected, will only costs around 250 rs (houses are very small and all are built next to each other); a relatively small amount of the total costs. Labour costs do not need to be higher as well, as household members can dig the small furrow themselves if wanted.

Table 7.15 Investment cost for installation of a urine-diverting toilet for a household (in rs)

Changing of slab (materials + labour)	1.000
Piping 6 meter	250
Bends	200
Container 200 litre	700
Labour for plumbing	500
Connection pipe 6 meter	250
Total	**2.900**

It is very important for acceptability and motivation that people have access to choices. That way people can decide themselves how much money they want to spend and then an option might be available for every income level. This could be realised in the following ways for example:

- The location of the storage container can be wherever the people want, partly in the ground or not, under a bench or not, as long as the collector can easily access it and no water can enter the tank;
- One can choose to connect to a neighbour, to prevent or minimise movement in the street;
- One can for example opt to install a water seal in the toilet (this might not be advisable, because blockages are likely to occur in the bends) and one can choose the quality of the material. One can also choose to have a larger container to feel more secure (the size of storage container also depends on family size).

7.6 Related issues that need attention before implementation

There are some issues that must not be overlooked:

- *(Future) attendance problems of the sweepers has to be dealt with in relation to the continuity of the project*
  It is most likely collection will be done by the sweepers, but they could pose a real problem. As explained in Section 5.2, they currently come as they please for the solid waste collection and they have the power to do this. If the urine is not collected regularly it needs to overflow into the drains. This will directly undermine the success of the project. Mr Agarwal of Toxics Link explained that to minimise chances of this happening for the urine collection as well, the sweepers have to be motivated in some way. Involving them from the beginning in the design of the system, what (not) to do, might help in this respect. Another important thing he said is to work towards the community monitoring the sanitation service and giving suggestions for improvement instead of the initiating organisation making all suggestions. In that way the community starts to own the service and give the service legitimacy. Then they might start to exert some pressure on the sweepers themselves. This social pressure will be much more effective than for example financial motives.

Making an emergency overflow requires an extensive pipe system, which is unattainable at the start of the project. A solution that does not depend on the current sweepers might be to form a corporation for the excreta removal service, which buys and owns the vehicles and equipment. The vehicles and equipment will then be rented to the collectors and they will get a good wage. Then, when the collectors do no collect the urine regularly, daily labourers can be hired as needed, as the specific equipment needed for this is owned by the cooperation and therefore available. This is quite similar to some of the solid waste collectors renting their collection vehicle, because it had been stolen.

- *The households are not easily motivated to adopt the new system*
  As the EcoSan toilet requires a higher level of commitment from the users than the toilets currently used (because EcoSan toilets are more sensitive to improper use) and because the potential users have to spend extra money to change their toilets, they are not easily motivated to adopt this new system. Regular sensitising on the benefits and what the new system entails is a necessity. Installing a few demonstration toilets (preferably at households of influential and respected persons in the community and in schools) with the subsequent collection will be very helpful, because then people will more easier understand and believe the claims of EcoSan. It is also very important to continue motivation building and education after people have implemented the toilet systems and also to regularly visit people to see if they have questions and to check if toilets are functioning and being used correctly. It is also important that payment for the installation can be arranged in instalments over several months.
- *Integration with proper drain management and solid waste management should be considered*
  The community might be more motivated when this sanitation service is integrated with proper drain management and solid waste management at the same time. Proper drain management has a high priority for the people and people see sanitation, solid waste and drain management as one issue. Tackling only one issue will not solve their problem i.e. living in an unhealthy and dirty environment. By also tackling drain management people might start to trust and be willing to make some investments and changes sooner. Proper drain management is also very beneficial to the collection service (solid waste and sanitation), because it will improve the road conditions a lot. The excreta service can for example be combined with the solid waste service by giving a discount on the fee when people participate in both collection services.
- *The technical system needs to be of a high standard*
  To reduce the amount of water used for flushing not only health education and motivation is important and necessary, also the technical system needs to be of a high standard. The (pour-flush) slab needs to have a good top layer to prevent the material taking up some of the urine, because this will cause smell and therefore the need to flush with ample water. The slab should also be easy to clean and the slab should be designed in such a way that the occurrence of faeces falling into the urine bowl is minimised. The use of EM (Effective Micro-organisms) could be considered for odour and fly control in the toilet as it is biodegradable, low-cost, harmless for human health and very effective in odour elimination, eliminating the need to use water after urination[30]. The State Department for Rural Development of Tamil Nadu is recommending the use of EM for (public) toilets, household hygiene, and hygiene management of sanitary complexes and Pune Municipality uses EM in composting of municipal solid waste (odour and fly control) (AuroAnnam, 2005). EM could probably also be used to spray on the vehicles after use and on spillages on the soil.
- *Proper use of the toilets should be taught and incentives should be considered for good use*
  It is important that residents know how to use the toilets properly and that they are satisfied with the system. If not, there is a great risk that they will not bother to separate the urine or use more water, which will lead to failure of the system. To stimulate proper use Mr Sengupta of the WHO explained in an interview that financial penalties are not very effective in general and only authorised organisations might be able to impose

[30] EM can be used in gardening, farming, and animal husbandry, composting and solid waste management, wastewater treatment, for elimination of bad odours, for control of flies, cockroaches, mosquitoes, termites and other pests, in household surface cleaning, in drains and toilets, etc. Maple Orgtech Ltd., Dehradun (Uttaranchal) is the authorised producer in India.

them. Financial incentives work very well on the other hand. In this case a reduction in the loan repayment after a certain period of good use might be agreed to or a lower interest rate.

- *A (preventive) maintenance programme should be set up*
  It is advised to set up a (preventive) maintenance programme for all the equipment used to increase their life and minimise downtimes. The procedure could be for example that each tricycle or tractor (and trolley) is returned to a workshop at least every six months for checking out, repairing any cracks or rust damage, replacing tires, wheel bearings and repainting when required. Introducing these procedures could extend the life of the carts by three fold (Coffey, 1996b).

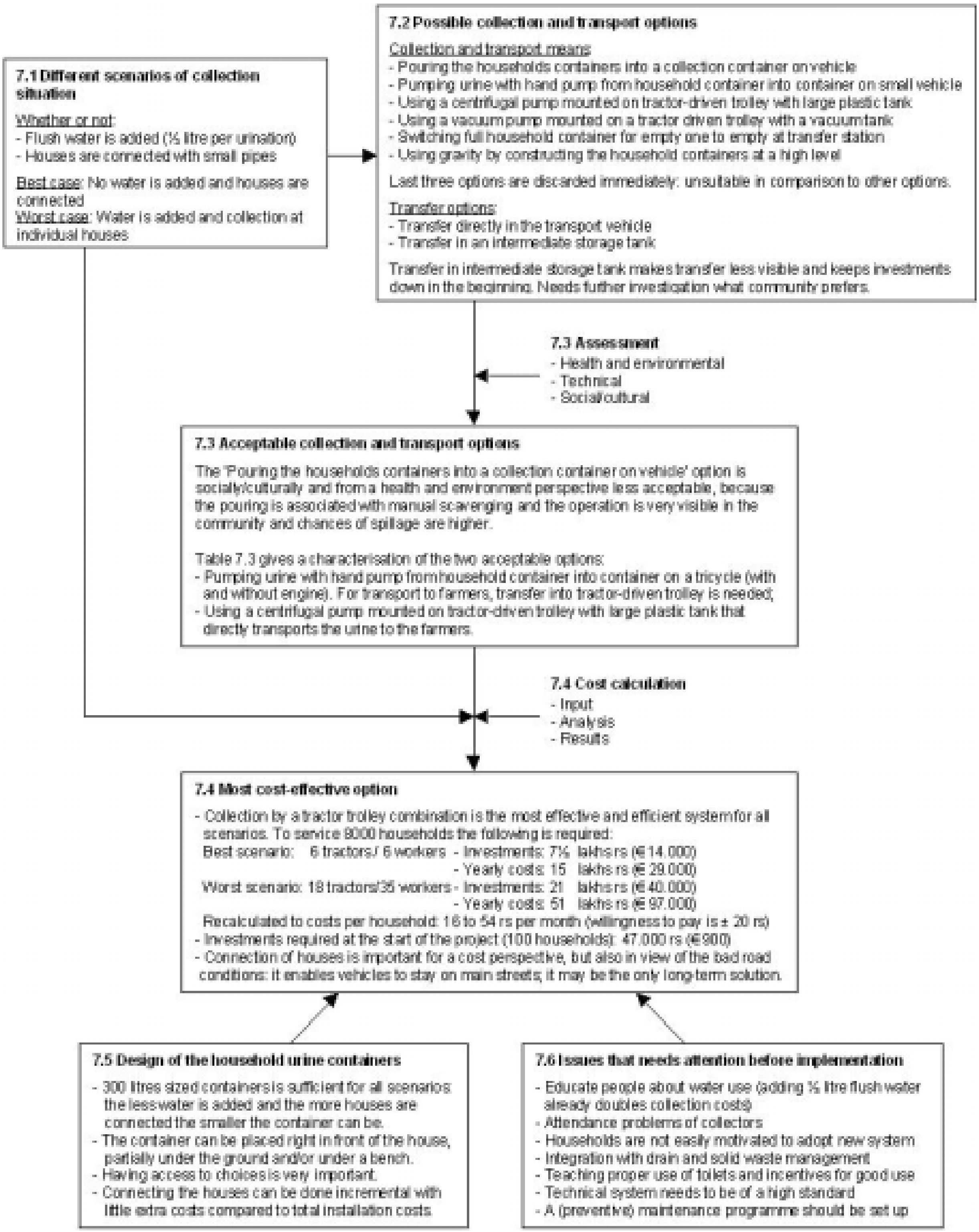
The sensitising strategy should be focussed on specific areas/streets instead of the whole community at once
The number of participants will be low in the beginning and will increase slowly with time. The more concentrated the participants and the closer to a suitable place for transfer (if required), the lower the collection costs. For this reason, sensitising efforts should be focused on specific areas and streets and move slowly to new areas instead of taking up a whole community at once. This way the opportunity for connecting the houses will be higher as well.

In Annex 20 one can find some additional issues that must not be overlooked.

7.7 Summary

On the next page figure 7.7 offers a summary of the chapter is given complemented with the section numbers in which the subject was discussed.

Figure 7.7 Logistics – Urine collection and transport: A summary



8 LOGISTICS - FAECES COLLECTION AND TRANSPORT

The previous chapter addressed the question how collection and transport of urine could be designed effectively and efficiently. This chapter addresses the same question for faeces collection and transport. The set-up of this chapter is therefore similar to the previous chapter. First, an explanation of the two conditions in which faecal matter can be offered for collection and transport. As these options require very different collection and transport options, the next section will assess which of the two options is preferable from a health, technical and social/cultural point of view. The option that emerges as the most preferable is further analysed on more concretised options for collection, transport and transfer in the third section and on investment and costs level in the fourth section. Some suggestions for the design of the household containers will be given in the fifth section. Section 8.6 will list several social and technical issues that should not be overlooked before implementation. The chapter will conclude with possibilities for integration of the collection services for faeces, urine and solid waste.

8.1 Dry and wet collection of faeces

Faecal matter can be offered for collection and transport in two conditions: dry and wet. These two conditions have very different characteristics and different handling and transport options might therefore be appropriate. The description of both conditions below will give an impression of the collection and transport options and the generation quantities, as these are also very different.

Photo 8.1 Wet collection of faeces: manually emptying of pits
In this photo a storm drain is emptied. The emptying of septic tanks or pits happens in a similar way: a person inside filling the buckets and a person outside, lifting the buckets up.

Wet collection of faeces

The ‘wet condition’ means the faecal matter still has the liquids that it naturally possesses and possibly the additional water for flushing and washing is also added to this. Pits and septic tanks that have ‘wet’ faecal matter are emptied in a mechanised or manual way:

- Manual handling normally comprises the use of shovels and buckets and may demand that the workers have to step into the pit to fill buckets one by one and lift them out of the chamber (Photo 8.1). Manual emptying should be eliminated wherever possible and is discarded as an option for this report, because the workers are exposed to great health risks and degrading work conditions and the law specifically prohibits this kind of handling.
- The classic technology for emptying of septic tanks and pits is by suction with a vacuum pump. A hose is introduced into the tank or pit and the content is sucked out (Photo 8.2). A vacuum pump can handle the viscosity of slurry and solid parts, which makes it a robust pump. Sludge removal by suction pump largely

minimises the direct contact of the workers with sludge and is therefore the safest technique available (WHO, 2005). By inserting a permanent pipe into the container to which the suction hose of the collection vehicle can be attached, the suction line does not have to go into the faecal matter and will not get dirty on the outside. This minimises the contact of the hose with the faecal matter and thereby contact of the workers with the faecal matter is also minimised.

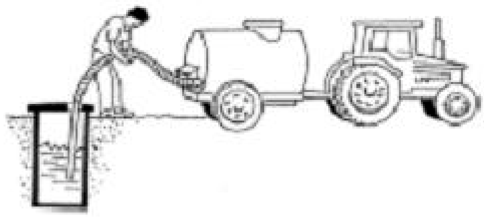


Photo 8.2 Wet collection of faeces: use of vacuum tankers
These can be made in different sizes (Right picture: Esrey, 1998)

Generation quantity – collection frequency

To stop percolation of water into the ground, causing contamination of the groundwater, the collection chamber has to be watertight. Most sanitation publications and guidelines state that a certain distance of sand between the pit and the groundwater level is an effective barrier for pathogens not to enter the water resources. However, this highly depends on e.g. the type of soil and the amount of water that has to be dealt with and has been dealt with in the past by the soil. More recent scientific research contradicts the conventional notion of the transport and survival of micro-organisms. In a study done by the University of Sheffield contamination by sewage-derived microbiological bacteria was widespread and found at great depths (Lerner). Given the fact that each year Saboli gets flooded, groundwater levels are high (± 3 meter) and that the amount of water that will seep into the ground is not negligible[31] the vaults are advised to be made watertight. Diverting the ablution water (the water used for cleaning the anal region) to a soak-away instead of letting it flow into the collection chamber is not advised[32]. It communicates the wrong message that ablution water is clean and/or that this system does not handle excreta safely (there is also no or limited space for soak-aways). Diverting ablution water also requires the changing of toilet habits (having to re-squat to wash above a different hole), which is difficult to realise on a large scale. Diverting the ablution water into the urine collection container is also not preferred as it may contaminate the urine and the faeces might become difficult to suck when too little water comes into the chamber for wet faeces collection.

Table 8.1 Generation quantity for wet collection of faeces (in litres)

Water use per person each time after defecation (Excl. water for regular cleaning)	Generation quantity per person per year (use of 1 time a day, 50 litre faeces per year)	Generation quantity per household per year (avg. 6 persons)	Generation quantity per household per month (avg. 6 persons)

[31] Most positive scenario: on average 6 persons per household x 0,5 litre of ablution water after each use x 1 time use per day x 365 days a year = 1100 litre of water per year (excl. water for toilet cleansing). Currently people use 9 litre of water for faecal matter defecation per person per day (see Table 5.4) increasing the total amount of water per year enormously.

[32] The amount of water being present in the closed container may create anaerobe conditions for a part of the sludge. The drawback is that this will cause some of the nitrate content to be lost through disappearance of the produced biogas. However, most of the nitrate content is located in urine, not in faeces.

1	415	2500	200
2	780	4700	400
3	1145	6900	575
9	3335	20,000	1650

Photo 8.3 Wet collection of faeces: an example of a mini vacuum tanker and transfer
Left photo: a 500 litre mini tanker (pedestrian controlled and in traction mode, the engine can propel the vehicle at speeds of up to 5kph) (Source picture: UN-HABITAT, 2005)
Right photo: Transferring the faecal sludge from a small sized tanker to a large sized tanker (Source picture: Strauss)

Watertight chambers have the consequence that all the water that goes into the toilet needs to be pumped out and transported away. Table 5.4 shows people currently use 2 litres for washing and 7 litres for flushing after defecation. With 9 litres of water use per person per defecation, a huge amount of dirty water is generated each month. Table 8.1 displays the quantities generated in different cases of water usage. When choosing the wet collection of faeces one can see the importance of limited water use in Table 8.1. With every extra litre of water use the workload and, with this, collection costs rise substantially.

Photo 8.4 Dried collection of faeces: use of double vault system and the result
Left picture: The two chambers under the toilet slab where the faeces are collected and are dried with time. (Photo: Agricultural University of Norway)
Right picture: The result: the dried faeces taken out of a double vault system

The current semi-septic tanks that the people in Saboli have built under their houses could serve as the collection chamber for the 'wet' faeces. Most current pits in Saboli have a contents of 5.5 m^3 (EcoSan database). This size is quite adequate, but the pits would have to be made watertight (see Section 8.5).

Options for collection and transport
The vacuum pump is usually connected to a truck-mounted tank of variable capacity or tanks may be mounted on carts pulled by a tractor or animals, a system being considerably cheaper and technically equivalent to truck-mounted systems. Conventional-sized vacuum tankers (Photo 8.2) have great difficulties accessing some urban areas, because of narrow lanes and roads, such as in Saboli. Smaller sized tankers of 0.35-1 m^3 have been developed for this reason (Photo 8.3). Mini-tankers would need to be employed in Saboli as well if wet collection of faeces would take place. Conventional sized tankers could go directly to the farmers nearby Saboli, but the mini-tankers are designed to travel only a small distance and it is uneconomic for such small tankers to haul their load to a disposal site of e.g. 10 km. Transfer between the mini-tanker and a conventional-sized vacuum tanker would have to take place near the area serviced by the mini-tanker.

Dry collection of faeces
The ‘dry condition’ of faecal matter means that the faecal matter has a very low moisture level giving it a similar psychical appearance to compost or soil. The low moisture level can be realised through e.g. the use of a double vault system in which two chambers are used in alternation. The retention period in the chamber gives the faecal matter time to dispose of the liquids and any additional water such as flushing and ablution water. After the retention period the faecal matter is dry and can simply be dug out of the chamber. Figure 1.6 at the beginning of this report illustrates the double vault principle and Photo 8.4 displays an example of a double vault system and dried faeces.

Prolonged storage is advised for Saboli as the primary treatment method in the double vault system, the simplest form of treatment of faeces. Other treatment measures such as composting or anaerobic digestion are not regarded as feasible options. The composting process requires space and a high level of management of several conditions such as moisture level, ph-level, temperature and carbon-nitrogen proportion. In practice, in small-scale systems a well-functioning process is rarely achieved (Jönsson, 2004). The fermentation process for anaerobic digestion also requires a high level of management of the process such as airtight storage and production of methane gas. Therefore simple storage is advised as the primary treatment method. However, faeces cannot be regarded hygienically safe after storage of about one year. The WHO (2005) states there are currently few studies indicating the pathogen die-off rate in dehydrating toilets, although those available indicate that Ascaris eggs have proven to be particularly resilient to dehydration. Depending on the local situation and the level of safety one wants to apply, extra safety barriers might have to be implemented, such as e.g. secondary treatment and measures listed in Section 6.3.2.

For the same reason as explained for the ‘wet’ collection of faeces the double vault system should be watertight. It is assumed that with a well-designed vent pipe and the positive climate conditions in Delhi (a warm and dry climate) the necessary level of evaporation is achieved, but this needs further research. Double vault systems often allow water to seep into the ground to speed up the drying process and no data has been found on the level of evaporation in ‘mostly closed’ containers, like is the case for a watertight double vault system. It should be noted that the adding of bulking material (materials that take up fluids, e.g. ash or woodchips) to speed up the drying process will probably not be practiced on a large scale. It requires extra daily work and a change in long lasting toilet habits. Apart from this, the adding of bulking material can be regarded as fouling the toilet in India and is therefore not preformed (the adding of ash would be more accepted in this respect, because ash is considered clean). This means the system has to be designed in such a way that the material will still dry fully when no bulking material is added to relatively wet faecal material due to the addition of ablution water and lack of seepage of liquids into the ground. If the evaporation level is not sufficient, expanding the retention time and the size of the containers might be a solution. For the following handling, collection and treatment processes this would make no difference as long as the faeces fully dry.

Generation quantity – collection frequency

As a design parameter one year of retention time in the vaults is chosen. After a year of storage in the retention chamber a sharp reduction in the number of effective pathogens will be realised. The reduction in health risks associated with a second year of storage is likely to be relatively small and for an extra year of storage the double vault chambers have to be dimensioned much larger, depending on the evaporation rate. Therefore one year is chosen as a sufficient pre-treatment measure. Table 8.2 calculates the generation quantities per household for faecal matter after one year of retention time: 90 litres of dried faeces per year.

Table 8.2 Generation quantity for dried collection of faeces (in kg per year)

Generation levels	Value (in kg per year)	Remarks
Generation quantity per person per year of fresh faeces	50	See Table 2.1
Generation quantity per person per year of dried faeces after a retention period of one year	15	A conservative 70% volume/weight reduction is assumed
Generation quantity per household per year of dried faeces (avg. 6 persons)	90	The average family size is 6.1 persons (see Table 5.1). For faeces collection an average family size of 6 will be used, because losses due to excretion outside the house will be small.

Options for collection and transport

The dried faeces can be taken out with e.g. a fawari (Photo 5.4) and can be loaded directly or with the help of a basket on a tricycle or a tractor pulled trolley. These vehicles are chosen for the same reasons as explained in Section 7.2.2. As explained in Section 7.2.3, transfer is advisable when primary collection is done with tricycles; secondary transport can take place in a tractor pulled trolley. Transfer can either be done by digging the contents of the tricycle in the trolley with the help of a bench or platform on which the digger can stand or by tipping the tricycle with the help of a ramp into the trolley or by lifting the smaller containers within the tricycle when using containerised tricycles.

When primary collection takes place with tractor pulled trolleys there are streets the tractor cannot access as explained in Section 7.2.2. For these areas the faeces can first be loaded on a wheelbarrow or a handcart and then taken to the trolley that can be located as close as possible to the street in which collection can take place.

8.2 Comparison of the two system: wet and dry collection

This section will assess the wet of dry collection of faeces on the criteria for a good logistical system that have been drawn up in Section 0. This assessment will give insight into the strong and weak points of each option. Based on this assessment a choice can be made which option will be further worked out and analysed on cost implications.

Table 8.3 Specific options for wet and dry collection of faeces options

	Primary transport		Transfer	Secondary transport
Option 1 Wet collection	Handling	Pumping contents of household container in tank on vehicle	Pumping the contents of the mini tanker into a conventional sized vacuum tank (Photo 8.3)	Conventional sized vacuum tank
	Vehicle	Conventional sized vacuum tank and/or Mini tanker		
	Equipment	Pump with hose		
Option 2 Dry collection	Handling	Digging contents of household chambers in collection vehicle	Digging the contents of the tricycle in a tractor pulled trolley	Tractor with trolley

	Vehicle	Tricycle (with/without engine) and/or Tractor with trolley	or Tipping the tricycle with the help of a ramp into the trolley or Lifting the smaller containers within the tricycle when using containerised tricycles	
	Equipment	Fawari Wheelbarrow/handcart in case of tractor use to access streets that are otherwise inaccessible by tractor		

Some criteria have been omitted from the list developed before the field research, because these have more reference to the design of the storage containers at the household. Section 8.5 will get back to the design of the storage containers. Also, some criteria have been added to the list in response to the meetings held with the potential users and collectors in Saboli (discussed in Section 5.3). The institutional and political/legal aspects lie outside the scope of this research.

Table 8.4 Assessment of wet and dry collection of faeces

	Option 1 **Wet collection**	**Option 2** **Dry collection**
Health and environmental assessment - Policy criteria • The occupational and public health is safeguarded • Faeces and urine do not enter the direct living environment • Valuable resources are reused to the maximum extent		
Health and environmental assessment - Design criteria		
No direct contact of workers with fresh faeces	-	+/-
No or minimal occurrence of fresh faeces spillage during handling	+/-	+
Spillage consequences of failures should be limited and easily cleanable	+/-	+
Container and equipment is cleanable	+	+
In case of fresh faeces collection the storage and transport container is watertight In case of drying of the faeces a double vault pit latrine is used	+	+
Technical assessment - Policy criteria • The system is easy to construct and maintain in the local context • The system is robust enough to meet the exigencies of normal use • The system is safe, user friendly and reliable • The system is as cost efficient as possible		
Technical assessment - Design criteria		
Suitable to the physical conditions of the area	+/-	+/-
Vehicles and equipment are available on the local market and safe to use	+/-	+
Rely on locally widely available knowledge, skills, spare parts and materials for operation and maintenance	+/-	+
Handling is easy and quick	+/-	+/-
Service is performed in the way and at the time that is agreed upon	+	+
The total weight of vehicles does not exceed the maximum allowed axle weight	+/-	+
Critical sections are easily reachable and replaceable	+	+
Use of vent pipe	+	+
Social/Cultural Assessment - Policy criteria • The system is consistent with cultural and social values • The system is aesthetically inoffensive • The system meets the needs of all household members and workers considering gender, age and social status and caste • The system is acceptable to the users and waste workers		
Social/Cultural Assessment - Design criteria		
Everybody has access to the service and feels safe using it	+	+
The fee for the service fits within the expenditure pattern of the households	-	+
Potential users have identified the sanitation service as a necessity	+/-	+/-

Table 8.4 Assessment of wet and dry collection of faeces

	Option 1 Wet collection	Option 2 Dry collection
Potential users are involved in selecting the option most appropriate for their community	+	+
Users feel responsibility to manage and maintain their toilet and corresponding storage	+	+/-
A complaint mechanism is present	Unclear yet	
Operation is done in a way that preserves the dignity of the workers	+	+/-
No association with manual scavenging	+	+/-
Collection vehicle is closed to avoid spillage and to hide the faeces from the public eye	+	+/-
The users can not handle the faeces themselves in any way	+	+
Collection must not create tension and hassle	+/-	+
Financial assessment - Policy criteria • The system is affordable to all households in the community • The costs are affordable for the community as a whole • Economic use of scare resource such as money, energy, space, land and water		
Financial assessment - Design criteria		
Reasonable price for the service performance (price/quality performance)	-	+
Affordable price for the users	-	+
Affordable costs and reasonable benefits for the community (municipal)	-	+
Reasonable income for the employees	-	+
The advantages of the service should be competitive with existing practices	-	+
Required initial investments should be limited	-	+/-

Assessment

The previous section gave an impression of how the collection and transport could take place for both the wet and dry collection of faeces. Table 8.3 on the previous page shortly characterises the specific options for primary collection, secondary transport and transfer (if necessary) to carry the faeces to its destination, the farmers. Table 8.4 assesses respectively the health and environmental, technical, social/cultural and financial aspects one by one. This is done by giving a rating in the form of +, +/- and - where a '+' means that the design criteria is met and a '-' that the design criteria is not met. An explanation for the rating is given in Annex 21 in an adjacent column.

Conclusion

Both options have health risks associated; this is inherent to working with faeces. The risks in the wet collection option are caused by the fact that the workers have to handle fresh faeces, which can be spilled on their hands and the ground when they do not handle the equipment correctly and do not wear protective clothing. Dry collection is in principle much safer, because pre-treatment is realised and the collection amount and the number of times of handling (the activity that poses the most health risks) is less. However, when the double vault system is not managed correctly, there is a real risk that workers are handling faeces that still contain a non-neglectable pathogen concentration. Together with the fact that the workers most likely have a lot of contact with the faeces when digging all day[33], the risk of contamination should not be underestimated for the dried faeces option, because protective clothing is unlikely to be worn by everyone. Proper management of the double vault system requires a level of understanding, a long-term view from the users and most of all it will be very uncomfortable for the users getting used to the new habit of using less water. However, it is assumed that proper management can be realised (e.g. with intensive awareness programs, inclusion of the users in the planning and implementation process and supervision with the authority to lay on penalties or benefits). The local NGO FODRA has the infrastructure to do this. The number of contact points in the community is high through the large number of micro-credit and health related groups. Furthermore, the willingness of the community to deal with waste and health

[33] When using containers that can be pulled out of the chamber as suggested in Section 8.5 the degree of spillage and contact with the faeces can be reduced. As these have not been designed yet and it is unclear if this will also be realised in Saboli, digging as the handling method is taken as the point of departure.

issues is picking up and people relate to the idea of using dried faeces as fertilizer. However, more awareness, education and most of all motivation is still needed. Under the assumption that proper management is realised the dried collection of faeces is preferable from a health point of view; otherwise further research is required to determine which option is preferable.

From a technical point of view the dry collection of faeces is preferable. Vacuum technology is less available and more complicated. With regard to the social/cultural aspects dried faeces is less acceptable. The need to change toilet habits, in the form of using less water, is bigger and the digging out of the dried faeces evokes associations with the manual scavenging of fresh faeces. The dignity of the workers is affected in this way, because people will still disapprove of them as it is perceived as an unclean thing to do, even though the faeces do not smell and do not look like faeces anymore. However, when people see with their own eyes what the dried faeces look like, the disapproval might lessen. Demonstration toilets/families could realise this. As for the wet collection option with its vacuum technology and the use of pumps and hoses make the material invisible and the mechanised way of handling has no association with manual scavenging of fresh faeces.
Financially, the wet faeces collection is much more expensive for two reasons:

- much higher collection quantity (generation quantity is more than 10 times higher);
- more expensive technology (a vacuum tank construction instead of a simple tricycle or trolley and fawari).

When looking further to treatment and reuse the costs for wet collection are also much higher, because primary treatment has not taken place yet and the material to be treated is much more. Reuse of dry faeces can be done by the farmers in the traditional way (see Chapter 6). Reuse of wet faeces, if treatment does not result in dry faeces, requires a new way of application that probably requires more expensive equipment.

In conclusion, dry faeces collection is chosen over wet faeces collection in this research. The dry collection of faeces scores much better on the financial and technical aspects. From a health and environment perspective dried faeces is preferable when proper management at the household is realised, otherwise further research is needed to determine which option is preferable. Socially/culturally, wet faeces collection is more acceptable, because the manual handling of dried faeces collection is associated with handling of fresh faeces. When people see themselves what dried faeces look like, disapproval might lessen.

8.3 Possible collection and transport options for dry collection

The first section gave an impression of how collection for dry collection of faeces could take place and Table 8.3 shortly characterised the specific options for primary collection, secondary transport and transfer. Similar to the urine collection a tricycle can be used (with or without engine) and a tractor with trolley. There is not much difference between the three options for faeces collection. The vehicles, spare parts and skills for operation and maintenance are all widely available and the way of handling is the same in all three options:

- Digging the faeces out of the household chambers with some kind of shovel, such as a fawari and with the help of a basket to put it in the (primary) collection vehicle if this is easier;
- The handling from the tricycles into the trolley for secondary collection is similar as in both options it has to be thrown in a trolley;
- The handling at the farmers is also equal, because the transportation vehicle to the farmers is the same in every option: a trolley.

The difference between the three options has mostly to do with the size of the vehicles and it therefore mostly financial in nature. This difference will be calculated in the next section. Before going to the cost calculation in the next section some more comprehension is needed of how transfer could take place and what kind of equipment is necessary.

Transfer

The situation is as follows: several tricycles in a certain collection area collect the material from 1-3 houses, depending on the size of the tricycles. When a tricycle is full, the collector goes to the trolley designated for secondary collection. He empties his load and starts with his next trip again. There are three options how this transfer from the small vehicle into the bigger vehicle can be organised:

- With the help of a ramp; either a ramp brings the tricycles up to such a height that the tricycles are higher than the trolley or the trolley goes down a ramp so that the trolley is completely below street level; by tilting the tricycle the load is deposited into the trolley. Note that tilting a tricycle requires considerable effort and strength. Weaker collectors are not able to do this. Attention should be paid that emptying is made easier by making e.g. the centre of gravity of the tricycle close to the pivot (usually the wheel axle) and/or by making a removable back panel in the tricycle (then the tricycle does not need to be tilted as far, or the faeces can be scraped out using some kind of shovel).
- With the help of a removable platform or bench. By climbing into the tricycle and from there shovelling out the faeces into the trolley reduces the height distance that needs to be crossed by half and becomes manageable. As the tricycle will tip over when the collector climbs in his tricycle, a solution could be for the collector to step up a platform or bench (see Figure 8.1). When he locates this behind or half under his tricycle he can easily shovel the faeces from that position from his tricycle into the trolley. The platform or bench can be e.g. an iron or steel frame with four legs with a flat wooden covering, like a table. By moving the platform or bench half under the back of the tricycle, the collector is able to stand in his vehicle. This makes emptying easier, especially if the tricycle has a removable back panel. Each trolley can be equipped with two benches to prevent that collectors have to wait for each other to empty their vehicle. When the trolley leaves for secondary collection the benches can be taken in the trolley as they are small and liftable.
- Using containerised tricycles. In this case the faeces are arranged in smaller containers within the tricycle, which can be removed and emptied individually by hand when standing next to the trolley.`

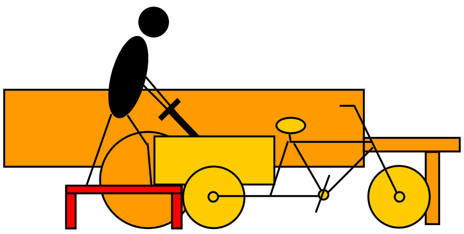


Figure 8.1 Transfer with the help of a movable bench or platform

A ramp makes handling quick and involves less contact with the dried faeces. The drawback of a ramp is that it requires investments and space; a considerable length should be reinforced for vehicles to be able to go up the incline. Another consequence is that the transfer location is fixed for a long time. The other two transfer options require only a small investment; two benches per trolley or several small containers per tricycle. Another advantage of these two options is that the transfer location is not fixed to one place. The trolley can be located each day at a location nearby the collection streets of that day (where it is standing out of the way and where a tractor has access to pick it up). This movable nature of the transfer location reduces the collection time and reduces the need to argue where the fixed transfer station(s) should be made. As no one would approve of a fixed transfer station located next to his house, a movable transfer station that disappears every day or every few days is much less offensive. Together with the small investments needed, the second and third option are much more attainable (in the near future).

As for the choice for containerised tricycles or the use of a bench, the use of a bench seems preferable. For the 300 kg tricycles more than 20 containers would be needed to keep the containers liftable (15 kg). This takes quite some money and it is not very practical in the tricycle itself, one would need to layer the containers. The collectors feel that the containers only take extra money as they can also manage to collect and empty their vehicle without it. When containers are provided, they are likely to be sold or used for other purposes and they are prone to theft.

As for the bench one only needs two benches per trolley, not per tricycle, making the option cheaper. Handling speed might be a bit slower and contact with the faeces might be a bit more, but it will not make much difference. Therefore, the transfer via a bench is advised and assumed in the cost calculation.

8.4 Cost calculation

This section will calculate the costs to collect the dried faeces in Saboli and to transport it to the farmers. Similar to the urine collection, a tricycle can be used (with or without engine) and a tractor with trolley. For an overview of this and the breakdown into the primary collection, transfer and secondary transport Figure 7.1 in the previous chapter is usable for the transport of dried faeces as well. Table 8.3 gives a description of the handling mode and the equipment used. The following subsections will calculate the costs for each step and compare the options on the total costs involved.

8.4.1 Input

To be able to calculate the collection and transport costs several inputs have to be determined:

- Quantities generated per day
- Capacity of the vehicle combination
- Duration of one trip
- Capacity factors
- Investment and yearly costs of vehicle combinations and transfer stations

These inputs are summarised in Table 8.5 and Table 8.6 and will be covered one by one below.

Quantities generated per day

The first section of Table 8.5 gives an overview of the quantities generated per day and the number of houses to be covered.

Table 8.5 Input assumptions for costs calculations

Quantities generated per day	Value	Remarks
Number of households	8000 Households	See Chapter 5
Average household size	6 Persons	The actual average household size is chosen for calculation purposes, because the occurrence of excretion of faeces outside the house is little.
Generation quantity	90 kg per household per year	See Table 8.2
Capacity of vehicle		
Tricycle without engine	100 kg	
Tricycle with engine	300 kg	
Tractor	3000 kg	
Duration of one trip		
Tricycle without engine	46 minutes (9.1 trips/day)	See Annex 22 for assumptions and calculations.
Tricycle with engine	89 minutes (4.7 trips/day)	
Tractor for secondary collection	185 minutes (2.3 trips/day)	
Tractor for direct transport	807 minutes (0.5 trips/day)	
Capacity factors		
Workday factor	7/6	Work is performed 6 out of 7 days in a week
Rainy season factor	12/10	Work is performed 10 out of 12 months in a year
Efficiency factor	1.25	An overall efficiency of 80% is assumed

Table 8.6 Overview of investment and yearly costs of the different vehicle combinations and transfer stations (in rs)[34]
Annex 23 lists what equipment is needed in addition to the vehicle itself.

Primary collection with tricycle – Secondary collection by tractor								
Vehicle	*Tricycle without engine*		*Tricycle with engine*		*Tractor*		*Transfer station*	
Investment costs per vehicle/station	7.500		13.500		103.000		28.000	
Yearly Capital costs	2.400	5%	4.320	5%	22.660	14%	6.160	67%
Yearly Operational and maintenance costs	1.500	3%	39.460	43%	93.160	57%	3.000	33%
Yearly Labour costs	48.000	92%	48.000	52%	48.000	29%	0	0%
Total yearly costs per vehicle/station	51.900	100%	91.780	100%	163.820	100%	9.160	100%

Collection by tractor - Direct transport		
Investment costs per vehicle	107.000	
Yearly Capital costs	23.540	15%
Yearly Operational and maintenance costs	40.764	25%
Yearly Labour costs	96.000	60%
Total yearly costs per vehicle	160.304	100%

Capacity of the vehicle combination
The weight loads that the tricycle, without and with engine, and the tractor can carry in one trip are respectively around 100, 300 and 3000 kg taking into account the road conditions in Saboli (an explanation can be found in Section 0 under the heading 'Capacity of the vehicle combination'.) The effects of the rainy season will be addressed during the discussion of the capacity factors below.

Duration of one trip
The time that one trips takes determines how many trips can be made per day. Annex 22 lists the assumptions that have been made and Table 8.5 lists the results. These assumptions are based on a combination of talking to several operators of tractors and tricycles and the observation of the researcher of these vehicles in Delhi and Saboli in particular.

The number of houses that can be covered per hour is set to 3 houses per hour. The actual speed depends on how the faeces chamber and the emptying mechanism are designed. Designing something with a "drawer" that can be pulled out of the chamber might speed up the handling per house, but a viable design has not been found yet. Therefore, the assumption is made that the faeces are dug out of the vault and that it takes 20 minutes per house, including driving to the next house (see Section 8.5 for thoughts on the design of the vaults).

Capacity factors
In addition to the workday and efficiency factor already explained in Section 0 a rainy season factor is added for faeces collection. During the rainy season the work becomes more difficult as a result of the muddy streets and in the severely flooded areas it becomes almost impossible. Therefore it is decided for the costs calculation that during two months a year collection does not take place; only 10 months a year. Postponement of the collection moment for the houses who should be emptied during this period is not a problem, given that the vaults are dimensioned bigger than for a collection period of one year (this is always necessary). On the other hand, only a few households might want to or have built a double vault during these wet periods, as they are unsuitable conditions for brickwork.

Investment and yearly costs of vehicle combinations and transfer stations
Table 8.6 on the previous page gives an overview of the investment costs and yearly costs. The investment costs include the benches/platforms, a shovel and basket, covering of the load and two wheelbarrows for the tractor for

[34] 53 rupees equals 1 euro (July 2005).

direct transport. The yearly costs include capital costs (depreciation and interest), operation, maintenance and labour costs, but exclude overhead costs. A more detailed break-up of the costs can be found in Annex 23 . The numbers are an average of several inquires by the researcher on local markets and operators.

8.4.2 Analysis

The investment and operational costs per vehicle have been determined in the previous subsection. One further needs to know the required number of vehicles to calculate the total investment and operational costs. This section will explain how the number of vehicles can be calculated for a certain number of houses participating. There are two standpoints that one can take in this calculation.

Different standpoints in calculation

The first standpoint is to spread the workload evenly during the year; then the least number of vehicles is required, as one does not need to cover peak periods. This is also the viewpoint taken in the urine collection calculation. However, opposite to the urine collection, the faeces quantity that needs to be collected each year is relatively small. A large participation level is needed before one tricycle collector can be employed full-time e.g.. Therefore one can think of hiring a few daily labourers and collect all the material full-time in a small period of the year, for example within a month. For faeces collection, no special vehicles or skills are required (only simple tricycles, tractors and trolleys and digging the faeces out) making this easy to arrange. A lot of people in Saboli are daily labourers and tractors employed at agricultural fields have periods in which the workload is very small; such a period would be appropriate to hire one or two tractors for direct or secondary transport. In conclusion, this gives two types of calculations:

- To spread the work evenly during the year (if collection has to take place every day, how many vehicles/workers are required each day?)
- To concentrate the work to a small period in the year (if one hires a certain number of full-time labourers, in how many days can the work be done?)

These two standpoints are the two extremes. From these calculations one can calculate a scheme that fits better with the specific preferences and circumstances at hand; one can go for e.g. one collection day per week.

Workload spread evenly during the year

First the calculation of the required number of vehicles is explained and after that the number of trolleys required for transfer.

Tricycles with(out) engine and tractors for secondary and direct transport

The tricycle with engine will be used in this subsection as an illustration of the calculation. The only differences with the other vehicles are the values for the load capacity and the duration of one trip. Table 8.7 on the next page gives an overview of the complete calculation. The calculation is similar to the analysis of the required number of vehicles for urine collection at one spot, because the question on the frequency of collection for the faeces can be left out. As explained in Section 8.1, the retention period in the vaults has been set to a year and the size of the vaults has to be dimensioned for that. The calculation can be divided into two steps:

1. **Quantity to be collected**

   The first step is to determine the quantity that needs to be collected per day. When 8000 households participate and an average household generates 90 kg per year, multiplying these two numbers gives the total quantity per year. Dividing this by 365 days a year gives the total quantity to be collected per day and when the workday and rainy season factor are included the total quantity to be collected per day comes to 2762 kg ((=8000 households x 90 kg / 365 days) x 7/6 x 12/10). By varying the number of households one can obtain an overview in time when the number of participants gradually increases.

2. **Analysis of number of vehicles required**

   To calculate the required number of vehicles one needs to calculate the number of trips required per day and the number of trips possible per day. With 2762 kg to be collected per day as calculated in Step 1 and a 300-

kg collection vehicle one needs to make 9,2 trips per day (= 2762 kg per day / 300 kg per trip). As one trip takes 1½ hour, 4,7 trips can be made per day (= 420 minutes per day / 89 minutes per trip). With 9,2 trips that need to be made per day and 4,7 trips possible per tricycle, 2 tricycles are needed (= 9,2 trips required per day / 4,7 trips possible per day; see Table 8.7). When the efficiency factor is included, the required number of vehicles is increased to 2,4 tricycles (= 2.0 tricycles (rounded) x 1,25).

The calculation as shown above needs to be performed for the other vehicles as well. Table 8.8 lists the result for each vehicle option for different participation levels.

Transfer station requirement and number of trips for secondary collection
Table 8.8 shows that the number of tractors required for secondary collection is very small. When 8000 households participate and 2762 kg needs to be collected per day (see Table 8.7) this is only just enough to fill one trolley load per day. This means in practice that the trolley can be emptied at the end of each day when the tricycle collectors have finished their round. A second trolley to take over when the first trolley is away for emptying at the farmers is not necessary. The trolley can just be emptied at the end of the day and brought back the same evening to be ready for the tricycle collectors the next morning.

Table 8.7 Analysis of required number of vehicles when the vehicles/collectors work all year to cover a certain number of households
Case: Tricycle with engine

1. Quantity to be collected	**Value**	**Unit**	**Remarks**
# Households that need servicing per year	8000	Households	
Generation per household per year	90	kg	Table 8.2
Workday factor	7/6		In a week 6 out of 7 days work is preformed
Rainy season factor	12/10		In a year 10 out of 12 months work is preformed
Total quantity to be collected per day (incl. workday and rainy season factor)	*2762*	*kg*	= (# Households that need servicing per year x Generation per household per year / 365 days) x Workday factor x Rainy season factor
2. Analysis of required number of vehicles	**Value**	**Unit**	**Remarks**
Capacity of collection vehicle	300	kg	
# Trips needed per day	9,2	Trips per day	= Quantity to be collected per day / Capacity collection vehicle
# Trips possible per day	4,7	Trips per day	= See for calculation Annex 22
# Households covered in one trip	3,3	Households	= Capacity of vehicle / Generation per household per year
# Vehicles required (excl. efficiency factor)	2,0	Vehicles	= # Trips needed per day / # Trips possible per day
Efficiency factor	1,25		An overall efficiency of 80% is assumed
# Vehicles required (incl. workday, rainy season and efficiency factor)	*2,4*	*Vehicles*	= # Vehicles required x Efficiency factor

Calculation of number of trips possible per day	
Activity	*Minutes*
Driving to first house	5
Handling per house + driving to next house	67 (3,3 houses x 20 min)
Driving to transfer station	5
Unloading	12
Total duration of one trip	*89 min*
Working hours (7 hours)	420
# Trips possible per day	*4,7 Trips*

For other levels of household participation, the trolley needs emptying accordingly. When for example 1000 households participate one tricycle collector working half days or every other day is sufficient (see Table 8.8). In that case, it takes 9 days for him to fill up one trolley, so the trolley needs emptying every 9 days[35]. For these small quantities purchasing a tractor and trolley is not sensible. An agreement with a tractor owner in Saboli can be made to do this at the end of the day the trolley is filled completely.

Table 8.8 Required number of vehicles for different participation levels when the vehicles/collectors work all year

# Households	Primary collection - # Tricycles without engine	Primary collection - # Tricycles with engine	Secondary collection - # Tractors	Direct transport - # Tractors
100	0,0	0,0	0,0	0,0
200	0,1	0,1	0,0	0,1
300	0,1	0,1	0,0	0,1
400	0,2	0,1	0,0	0,1
500	0,2	0,2	0,0	0,1
600	0,3	0,2	0,0	0,2
700	0,3	0,2	0,0	0,2
800	0,4	0,2	0,1	0,2
900	0,4	0,3	0,1	0,2
1000	0,5	0,3	0,1	0,3
2000	0,9	0,6	0,1	0,6
3000	1,4	0,9	0,2	0,8
4000	1,9	1,2	0,3	1,1
5000	2,4	1,5	0,3	1,4
6000	2,8	1,8	0,4	1,7
7000	3,3	2,1	0,4	1,9
8000	3,8	2,4	0,5	2,2

Workload concentrated to a few days/weeks a year

First the calculation of the required number of workdays to collect the faeces of the whole year with a certain number of full-time collectors and after that the transfer is discussed.

Tricycles with(out) engine and tractors for secondary and direct transport

The tricycle with engine will be used in this subsection as an illustration of the calculation. The only differences with the other vehicles are the values for the load capacity and the duration of one trip. Table 8.9 on the next page gives an overview of the complete calculation. The calculation can be divided into three steps:

[35] Table 8.8 indicates 1/10 full-time employed tractor for secondary collection is required at a participation level of 1000 households or in other words the tractor needs to work 10% of the time. By calculating the quantity to be collected at a participation level of 1000 one can precisely see how many days it takes to fill one trolley: when 1000 households participate and 345 kg (= (1000 x 90 kg / 365 days) x 7/6 x 12/10) is collected per day, it takes 9 days to fill the 3000 kg trolley.

Table 8.9 Analysis of required number of workdays with a certain number of vehicle - collector combinations
Case: Tricycle with engine

1. Quantity to be collected	**Value**	**Unit**	**Remarks**
# Households that need servicing per year	8000	Households	
Generation per household per year	90	kg	Table 8.2
Total quantity to be collected per year	720.000	kg	= # Households that need servicing per year x Generation per household per year
2. Analysis of required # workdays with one vehicle - collector combination			
Capacity of collection vehicle	300	kg	
# Trips needed per year	2400	Trips per year	= Total quantity to be collected per year / Capacity of collection vehicle
# Trips possible per day	4,7	Trips per day	See Annex 22
Efficiency factor	1,25		An overall efficiency of 80% is assumed
# Workdays required (incl. efficiency factor)	636	Days	= # Trips needed per year / # Trips possible per day x Efficiency factor
3. Analysis of required # workdays with a certain number of vehicle - collector combinations			
# Vehicle - Collector combinations employed	10	Vehicle - Collectors	
# Workdays required (incl. efficiency factor)	64	Days	= # Workdays required (incl. efficiency factor) / # Vehicle - Collector combinations employed

Table 8.10 Required number of workdays when employing a certain number of vehicle collector - combinations (incl. efficiency factor)

Tricycle without engine					**Tricycle with engine**					**Tractors for direct transport**				
# Tricycle collectors : # Tractors (ratio 7 : 1)	Number of households				# Tricycle collectors : # Tractors (ratio 4 : 1)	Number of households				# Collectors (# Tractors) Two collectors on a tractor	Number of households			
	100	**500**	**1000**	**8000**		**100**	**500**	**1000**	**8000**		**100**	**500**	**1000**	**8000**
7 : 1	2	9	18	143	**4 : 1**	2	10	19	150	**2 (1)**	8	38	75	> 1year
14 : 2		5	9	72	**8 : 2**		5	10	75	**4 (2)**		19	38	300
21 : 3		3	6	48	**12 : 3**		3	7	50	**6 (3)**		13	25	200
28 : 4				36	**16 : 4**				38	**8 (4)**		10	19	150
35 : 5				29	**20 : 5**				30	**10 (5)**			15	120
42 : 6				24	**24 : 6**				25	**14 (6)**				100
Tricycles: 9 trips a day of 100 kg Tractors: 2 trips a day of 3000 kg					Tricycles: 5 trips a day of 300 kg Tractors: 2 trips a day of 3000 kg					Tractor: 0,5 trips a day of 3000 kg				

= ((500 households x 90 kg) / 100 kg per tricycle / 9 trips per day) x 1,25 / 7 collectors

1. Quantity to be collected

One first has to calculate how much in total has to be collected per year. This is a multiplication of the number of households participating and the quantity generated per household per year. When 8000 households participate and each household generates 90 kg, 720.000 kg needs to be collected per year.

2. Analysis of required number of workdays with one vehicle – collector combination

The question is now how many days work this is for one collector and his vehicle (a tractor for direct transport requires two collectors). If 720.000 kg needs to be collected per year and the tricycle can do 300 kg per trip the collector has to make 2400 trips per year (=720.000 kg / 300 kg). As he can do 4,7 trips per day, it takes him 636 days when one includes the efficiency factor (= 2400 trips per day / 4,7 trips x 1,25). One person cannot manage this alone; more collectors are needed (Table 8.8 already indicated at least 2,4 collectors are needed to perform all the work).

3. Analysis of required number of workdays with a certain number of vehicle – collector combinations
Dividing the number of workdays required for one persons by the number of collectors one wants to employ gives the total number of workdays required for the group of collectors. 10 full-time employed collectors can do the work in only 64 days instead of the 636 days for one person (= 363 days / 10 vehicle - collector combinations). If the collectors work six days a week the work is done in 11 weeks (= 64 days / 6 days). The rainy day factor is not applicable, because collection is not required during the whole year. The work can be done outside the rainy season.

Ratio Tricycles : Tractors for secondary transport
The number of tricycles and tractors for secondary transport that one employs on a day has to be in balance to keep both the primary and secondary collection busy full-time. When too few tricycles are employed in relation the tractor(s) for secondary collection, the tractors are standing at a halt a considerable amount of time during the day. The same goes for the other way around. This would be a waste of money.

To tackle this, one has to calculate the Tricycle : Tractor ratio for the workload that the individual vehicle can do on a day. On an average day, a tractor can make 2,3 trips (Table 8.5). To allow for a safety margin and clarity for the labourers, assign the tractor for 2 trips a day, each having 3000 kg. This means one tractor can handle 6000 kg on a day. One tricycle with engine can make 4,7 trips on a day. When one assigns the tricycle collectors to make 5 trips a day of 300 kg, one tricycle collector can do 1500 kg per day. As one tractor can do 6000 kg and one tricycle collector is able to do 1500 kg, the ratio is 1 : 4; for every tractor for secondary collection, 4 tricycle collectors with engine have to be employed.

The same can be calculated for the tricycle without engine. When the tricycle makes 9 trips per day of 100 kg and 900 kg per day is collected the ratio becomes 1 : 7 (= 6000 kg / 900 kg); for every tractor for secondary collection, 7 tricycle collectors without engine have to be employed.

With these ratios in mind Table 8.10 is filled in. It calculates the required number of workdays when employing a specific number of collectors for certain levels of household participation. When only 100 households participate a tractor for secondary collection with the matching number of tricycles only has to work 2 days. It takes 8 days for two collectors with a tractor directly transporting the faeces to the farmers.
Depending on how quickly one wants the work to be done one can hire more employees and/or increase/lower the number of trips per day, as long as the number of vehicles is in balance (the wage of the workers has to be adjusted accordingly).

Transfer station
When the tractors for secondary transport have to make multiple trips per day, a second trolley is needed per tractor to take the place of the trolley that is being emptied at the farmers. When a safety margin is kept on the number of trips the tractor for secondary collection will make, there is no need to put in a third trolley. However, when several tractors work full time during the day and many tricycles are operating one or two extra trolley in total is advisable to take over when a tractor gets delayed.

= 2,2 tractors x 160.304 rs

= 3,8 tricycles x 7.500 rs + 0,5 tractors x

Table 8.11 Total investment and yearly costs and size of fleet indicators for the different options for a participation level of 8000 households

	Tricycle without engine	**Tricycle with engine**	**Tractor - Direct transport**	**Remarks**
Total investment and yearly costs (in rs)				
Total investment costs	80.000	83.900	235.400	= Required number of vehicles (see rows below) x Investment costs per vehicle (Table 8.6)
Yearly costs	279.130	302.182	352.669	= Required number of vehicles (see rows below) x Yearly costs per vehicle (Table 8.6)
Yearly costs per kg faeces (rs/kg)	0,39	0,42	0,49	= Total yearly costs / (8000 households x 90 kg)
Size of fleet				
Number of vehicles	3,8 Tricycles + 0,5 Tractor	2,4 Tricycles + 0,5 Tractor	2,2 Tractors	See Table 8.8
Employees	± 5	± 4	± 6	One operator per tricycle and per tractor for secondary transport. Two operators per tractor for direct transport.
Covering the costs (in rs)				
Costs per household per month	3 (35 rs per year)	3 (37 rs per year)	4 (44 rs per year)	= Total yearly costs / 8000 households / 12 months
Costs per hectare per year	291	315	367	= Total yearly costs / 960 ha (see Table 6.2)

8.4.3 Results

This subsection gives a summary of the total costs and investments involved for the faeces collection. The number of vehicles/collectors required for the scenario in which the work is spread evenly during the year and the number of workdays and daily labourers required for the scenario in which collection is restricted to a limited period in the year is depicted respectively in Table 8.8 en Table 8.10. In principle, the total costs for the two scenarios are the same, as the workload is the same for both scenarios (the only difference in the required equipment is that extra trolleys are needed for the transfer when collection is focused to a limited period). However, differences can occur, because e.g. hiring a tractor for a small period a year might be relatively more expensive than purchasing a tractor and operating it during the whole year. On the other hand, one does not need to perform maintenance oneself if one hires the equipment (for a small period a year). As the cost for hiring equipment are not know, this scenario is not calculated specifically. The costs calculation with the estimates for purchasing the equipment (summarised in Table 8.6) can serve as a cost indication.
The currency rate is set to 53 rupees for 1 euro (July 2005).

Summary of the costs and investments

Table 8.11 on the left gives an overview of the total investments required to serve 8000 households. The required investments do not differ much for the two options in which tricycles (with and without engine) perform primary treatment and a half-time employed tractor does the secondary transport: ± 82.000 rupees (± € 1.500). The option in which two tractors and a part-time tractor directly transport the faeces to the farmers requires an investment of more than 200.000 rs (± € 4.400). Table 8.11 lists the exact number of vehicles and employees required for the different operations. This also gives a picture of the fleet size involved for each option.

Table 8.11 further gives an overview of the costs per year when 8000 households participate. This ranges from 280.000 rs per year (± € 5.300) to 353.000 rs per year (± € 6.650): the tricycle without engine option being the least expensive and the tractor doing direct transport being the most expensive. The costs to transport one kg of faeces can also be calculated from the total yearly costs; the result is added to Table 8.11.

Covering the costs

Covering the cost is not a problem for faeces. When recalculating the total yearly costs to the costs per household the costs come to only 3 to 4 rs (€ 0,07) per month. If the farmers would have to bear all the costs, they would have to spend per year 290-370 rs (± € 6) to fertilize one hectare with the faeces. For a small farmer with 1.75 ha and for a big farmer with 6 ha this would come to respectively ± 600 rs (± € 11) and ± 2000 rs (± € 38) per year. The value of the faeces to the farmers as fertilizer (e.g. in relation to the price of chemical fertilizer and/or the increase in yield achieved) is not researched in this report.

Conclusions

The following conclusions can be drawn:

- *Most cost-effective option*
  Collection with a tricycle without engine is the most cost-effective option. The required investments are also lower than required for the other two options. A tractor is for the faeces, as opposed to the urine collection, not the most suitable vehicle. This can be explained by the long handling time per household (digging out the faeces instead of quickly pumping the urine), which has the consequence that the expensive tractor is standing still most of the day. Assigning more collectors to the tractor would fill up the trolley quicker and would make the tractor more cost-effective. This is exactly what is being done in the tricycle options: several tricycles delivering the faeces to one trolley. And as the tractor for secondary collection only has to be there when the trolley is full, not when it is being filled, more savings are gained, because transfer is cheap for faeces collection. No extra equipment is necessary and it only requires the (de)coupling of the trolley for the tractor and the tricycles can also empty their vehicles relatively quickly.
- *Comparison tricycles with and without engine*
  The use of tricycles without engine is a little cheaper than using a tricycle with engine. The high fuel costs for the tricycle with engine do not offset the time savings that are gained by driving quicker and having to make less trips. This can be explained by the fact that the handling time at the houses is relatively long and the distance to the transfer station is short (the transfer station can be placed close to the place of collection of that week as the trolley can be placed everywhere where there is space). Both factors lower the percentage of driving time in one trip, which lowers the potential for a quicker and larger vehicle.
- *Comparison of spreading the workload during the whole year or concentrated to a few days/weeks a year*
  When participation is lower than 1000-2000 households it might easier to concentrate the work to a few days/weeks a year. Then still a limited number of people are needed for a limited period of time (see Table 8.10). The advantage is that supervision for collection is only required for a limited period and the (social/cultural) inconvenience for the inhabitants is also limited to a small period of the year. Together with the farmers one can decide what period or which periods during the year would be convenient for the farmers and the collectors (it is advisable to empty the pits before the rainy season starts). However, when more than 1000-2000 households start to participate one has to find many collectors and equipment to collect everything in a few weeks and the operation gets more complex. With a high participation level it might be easier to appoint one or more collectors, depending on the participation level (see Table 8.8), that collect the faeces from the participating houses. At the participation level of a 1000 households only a part-time collector is needed. Together with the collector one can decide what hours / days are convenient for him if he also has another job. At a participation level of 2000 households one collector with a tricycle without engine can almost work full-time.

Other considerations, next to the costs, are the number of jobs created, the complexity and the size of investments needed at the start of the project.

Number of jobs created

Around five full-time employees are needed for all three options if 8000 households participate, because every option requires only a few vehicles if one spreads the workload during the year (see Table 8.11). When one chooses to hire daily labourers and 500 people or more start to participate the number of people required to do the job within e.g. a week can become large, but these are temporary jobs.

Complexity

The three options do not differ much in complexity, all three options involve a small fleet of vehicles. Transfer is also easy, as it only requires a trolley with equipment that does not have to be operated and cannot breakdown. One only has to plan where to place the trolley (nearby the location where collection is taking place the coming days) and supervise that the tractor for secondary collection empties the vehicle at the right time and that the driver knows where to bring it.

Size of the investment needed at the start of the project (100 households participating)

When starting the project and only 100 households participate it is advised to hire a tractor with trolley and driver and a few daily labourers operating tricycles without engines. The work can be done within two days at that participation level and this should not be a problem as no special equipment or skills needed and there are ample daily labourers. The costs are limited to a few thousand rupees in this case (± € 75). This has to be done once a year, starting two years after the installation of the double vault systems as the collected material during the first year has to dry for a second year before it is ready to be emptied.

8.5 Thoughts on the design of the double vault system at the household

The purpose of the storage system at the household is to prevent people, animals and the environment coming into contact with faeces and to prevent nuisances, such as odour. To ensure the drying of faeces the use of a double vault system in which two chambers are used in alternation was advised in the first section of this chapter (the retention period in the chamber gives the faecal matter time to dispose of the liquids that come into the chambers). This section will discuss the issue of the required size of the chambers, restructuring the current pits and how to make the chambers watertight. The section will start with some thoughts on the emptying mechanism of the chambers as this also gives an idea of the overall design of the double vault system.

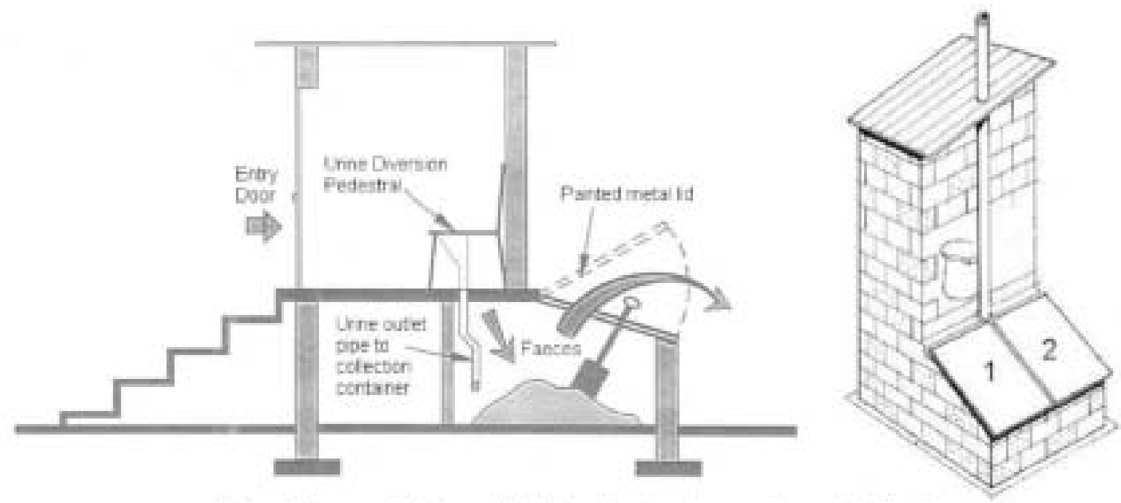
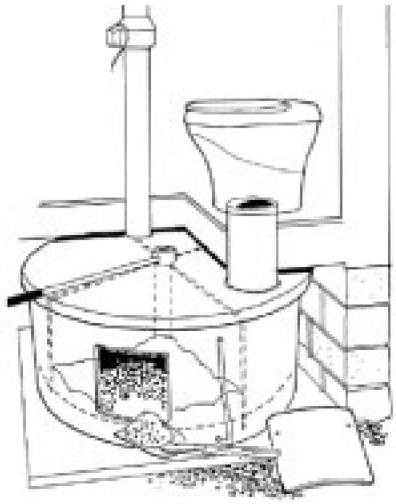


Figure 8.2 An example of a general double vault system when one chooses to dig the faeces out. Left pictures adapted from Austin (2002) and right picture adapted from Winblad (2004).

Figure 8.3 Collection of faeces in containers (Winblad, 2004)
The faeces are collected in a wide, low plastic container. When one container is full, an empty container is placed under the drophole and the full container can be placed next to it to dry.

Figure 8.4 A carousel composting toilet (Winblad, 2004)
The design of the carousel consists of a cylindrical outer tank in which a slightly smaller inner tank is able to rotate on a pivot. The inner tank is divided into four chambers. The one in use is positioned directly below the drop chute from the toilet. When a chamber is filled, the inner tank is rotated so that the next chamber is positioned below the toilet. Liquid drains through holes at the bottom of the inner tank into the outer one, where it may be collected in a separate container, discharged into an evapo-transpiration bed or evaporated.



Design of the emptying mechanism

The way the chambers need to be emptied influences the time it takes to empty it, how heavy the work is, to what degree the collectors come into contact with the faeces and the amount of spillage that occurs. This therefore requires a well-thought out design. Figure 8.2 gives a general idea how the double vault system can be designed if one chooses to empty it by digging the faeces out. Pay attention that the height of the outlet lid is high enough to keep floodwater out. Instead of digging the faeces out, another idea is to use containers that can be pulled out of the chamber by the collectors (see Figure 8.3). This might speed up the handling process per house and might reduce the degree of spillage and contact with the faeces if the containers are properly designed. When designing such a system pay attention that when the retention period is one year, 90 kg is gathered on average in the container. One or two collectors cannot lift this and take it to their collection vehicle. The total weight needs to be divided among several containers for the collectors to be able to lift it properly. During the year e.g. the containers inside the chamber need to be rearranged so that the faeces come into the next empty container. This can be done manually by opening up the chamber and physically switch places of two containers (the collectors would have to do this by regularly stopping by the houses as the users will not accept to do this themselves). Figure 8.4 displays a carrousel that might give an idea how to upgrade this process.

Size of each chamber

To determine the required capacity of the vaults several factors have to be analysed: Table 8.12 on the next page gives a list. As discussed in Section 8.1, prolonged storage as primary treatment method is advised for Saboli with a retention period of one year (the total time the faeces are in the vaults also includes the time in the operational vault). Furthermore, the vaults are advised to be watertight and the urine is diverted to a separate storage (see Chapter 7). Table 8.13 on the next page gives an idea of the volume that comes into each vault; mostly water. Removal of this water can only occur through evaporation, because the vaults are watertight. It therefore depends on the evaporation rate and the safety margin how large the vaults have to be. Evaporation starts from the moment the chamber is taken into use when the first faeces and water drop into the operational vault. Therefore the chambers can be smaller than the total volume that will come into the chamber. No data has been found on the level of evaporation in ‘mostly closed’ containers, like is the case for a watertight double vault system (double vault systems often allow water to seep into the ground to speed up the drying process). This has to be researched further. Further research also needs to be done on the assumption that with a well-designed vent pipe and the positive climate conditions in Delhi (a warm and dry climate) the necessary level of evaporation is achieved for the faeces to be sufficiently dried after the retention period. The question is how much water per day can maximally be added to still have dried faeces when the moment has come to empty the chambers. As Table 5.4 showed, people currently use 9 litres of water each time after defecation, people need to be instructed what quantity the double vault system can handle, because the system will not be able to cope with these quantities (the question then remains if the maximum quantity the system can handle, is attainable for the users). Since the evaporation rate is also influenced by the design of the double vault, it is also very important to ask which parameters have an impact on the evaporation rate and how this affects the design and construction of the storage system. If the vaults fill up more quickly than designed for, people may start to overflow the water into the open drains or the workers might handle not completely dried faeces causing health threats for the community and/or the workers.

Restructuring the current pits and making the chambers watertight

The current pits are lined with bricks, but are not watertight. As the size is properly large enough to divide the pit into two chambers (most current pits in Saboli have a contents of 5.5 m^3 (EcoSan database[36]), partly using the current construction might be possible. Beware that the current pits are filled with faeces and contaminated water. This first has to be removed safely before anything can be done. Emptying the current pits by vacuum tanker is not affordable to most people and an investment that people will not be willing to make. As of yet, no one has emptied their pits (in that way) and e.g. one person said they emptied their pit when it was full by removing the wall and letting the faeces flow out of it, because ordering a vacuum tankers was too expensive. To avoid that people will take these kind of actions, a suggestion might be to subsidise/arrange the emptying of the current pits. This will also take away a hurdle to adopt the new system.

Table 8.12 List of factors that influence the required capacity of each vault

- Primary treatment method
- The retention period in the vaults
- Whether or not the urine is diverted
- Whether or not the vaults are watertight (and the percolation rate when vaults are not watertight)
- Whether or not bulking material is added (materials that take up fluids, e.g. ash or woodchips)
- The amount of water that come into the vaults for washing, flushing and regular cleaning
- The evaporation rate (how fast the water will evaporate. This depends on climate conditions and the design of vaults (especially the degree of ventilation that is realised)
- The required safety margin

[36] Most common dimensions current pits: depth 1,83 meters (6 feet); length 1,22 meters (4 feet); width 2,44 meters (8 feet)

Table 8.13 Incoming volume into the vault

Water use per person after each defecation (washing + flushing)	Per household per year (avg. 6 persons) *
1 litre	2500 litre **
2 litre	4700 litre
3 litre	6900 litre
* Excl. water for regular cleaning	
** (1 litre x 365 days + 50 litre faeces a year) x 6 persons)	

Photo 8.5 A closed body tricycle and and the heightened sides of a tricycle body (photos related to text on next page)

After cleaning the current pits, they have to be made watertight and a separation wall, one or two vent pipes and an outlet to empty the chambers have to be made. The urine-diverting system has to be set up as well if this is not done in an earlier stage. It is unclear how much money this will take in total, but (partial) subsidy is probably required for people to be willing to change their current system, because their current system does not cost them anything as the faeces/water are overflowing freely into the drains.

The current pits can be made watertight by plastering the walls. However, cracks and leakages can come in time if this is not properly done. An idea might be to place two plastic containers in the pit. This might be cheaper and will be leak free. Perhaps some kind of plastic bag can be found on the market that can serve to make the pits watertight. Bags are much easier to bring into an already constructed building than a plastic container or lining the pits under the house.

Pay attention that the construction of the houses might be weak. Care should be taken that e.g. parts of the house do not collapse when breaking up large parts of the floor in the small houses. When a lot of construction is needed to make the current pits suitable for dry faeces collection, urine diverting might be the highest attainable. In that case the construction of the double vaults has to be reserved for houses that are newly built.

8.6 Related issues that need attention before implementation

The issues mentioned for urine collection in Section 7.6 are mostly also applicable for faeces collection. Mentioned here are some specific issues for faeces collection that must not be overlooked:

- *Dealing with potentially hazardous material*

When primary treatment does not take place correctly, the collectors have to handle potentially hazardous material. To avoid or minimise the consequences some measures can and should be taken:

- The users of the toilet should be educated how to use and clean the toilet. They should use little water for washing after defecation, not clean the toilet with large amounts of water (when using e.g. EM for cleaning (see Section 7.6) hardly any water might be needed) and not throw any other water in the toilet. If people are not willing to do this in practice, they should not install a double vault system.
- The collectors should get instructions not to empty a chamber in which they see material lying that is not dry. They should be instructed to close the chamber again and report this to the supervisor. The supervisor can then see to it that protective clothing is worn during emptying and that it is taken to a separate location where it can further dry safely with direct sun access (this will dry the faeces fast so that it can be added to the normal operation again). The supervisor should also talk to the users to find out why the faeces were not dried and lay on a penalty when the users have a part in it. When technical flaws were the cause, this should be solved and measures should be taken that this will not happen again and that it will not happen at other places as well.
- The people involved in the collection should be provided with regular checkups and relevant medication and vaccinations when necessary (providing medical attention to the family of the collector could also be an incentive to do the work when one experiences difficulties in finding personnel). When hiring many daily labourers this could become difficult to arrange when contact with these people fades and it may become costly. But most important is that workers are made aware of the nature of the health risks to which they are exposed and that they know how to protect themselves. Training and targeted information may therefore be the most successful measures (WHO, 2005).
- When the vehicles are used for other purposes as well (what is most likely for faeces collection as it takes a high participation level before vehicles can be operated full-time) the supervisor should see to it that the vehicles and other equipment are cleaned properly with water and detergent. Pinning down a plastic sheet in the tricycle and trolley that can be removed again when the vehicle is used for other purposes might be useful; also from a psychological point of view people might prefer this (this would have be strong plastic and spanned tightly, as one needs to be able to empty the vehicles with a shovel).
- The trolleys will have to stay somewhere overnight at the end of the day; half-filled most of the time. Covering it with a plastic sheet might not be sufficiently safe from people, animals and the weather. In that case the trolley needs to be parked somewhere at a proper location.

- *Visibility of the material to the inhabitants*

The inhabitants indicated that they could accept the collection of faeces if the collection vehicle has a closed body to keep the faeces out of their sight and to prevent that material falls on the ground. Tricycles with a closed body (Photo 8.5 on the previous page shows an example) are less common and solid waste collectors or other transporters in Saboli only have tricycles with open bodies. It will not cost a lot of money to adjust the body, but the supervising organisation would have to pay for this, as it is unlikely that the collectors are willing to finance this themselves. The collectors also might not want their vehicle body closed as the faecal collection job is not full-time and they have to use it for other purposes as well: enclosing it restrains access from different sides. Heightening the sides of the body, like in Photo 8.5, might be enough for the inhabitants, as collection in their area only has to take place once a year.

- *Getting into contact with new inhabitants*

Reconstructing the pit or septic tank of already built houses might be problematic as explained in Section 8.5. It would be easier and less costly to build an EcoSan toilet in a new house. Houses that are being newly built are under orders of new immigrants. It is difficult to persuade a new arrival in Saboli to build an EcoSan toilet instead of a normal toilet. Firstly, the people are not living there yet making contact difficult. Secondly, as they are unfamiliar with FODRA (or other organisation looking after EcoSan) there is no trust yet to accept something unknown. An idea might be to train plumbers and masons not only how to construct EcoSan toilets, but also to train them to inform people about the different toilets and refer new people to FODRA and/or to other people who have built an EcoSan toilet who could give further explanation. If the newly arrived people hear that their masons and plumbers have training in this design and others have already built it, people might consider it more quickly.

- *Using a planning instead of emptying at customer request*

For faeces collection, the time between two collection moments is very long; a year. One cannot depend on the users to remember when the chamber needs emptying. The supervisor of the faeces collection needs to keep an administration of who installed a toilet and at what date. The supervisor can then make a planning which houses the collector has to empty in a certain month e.g. As it is no problem to deviate somewhat from the collection moment according to the installation date, the supervisor can make a planning that minimises driving distances by putting together all houses that have to be emptied in e.g. the same month to allow the collectors to take the most convenient route among these houses. This administration is also useful to organise the regular checkups on the users to see if there are questions and if toilets are functioning and being used correctly as advised in Section 7.6.

8.7 Summary

Figure 8.5 summarises this chapter, complemented with the section numbers in which the subject was discussed. The chapter will conclude with possibilities for integration of the collection services.

8.8 Integration of faeces, urine and solid waste collection services

Integration of the faeces, urine and solid waste collection services can be advantageous:

- The same employees and vehicles might be used among the services. This could improve the efficiency of the vehicles (this is especially important for equipment that has to be purchased) and an employee could be employed full-time more quickly. Employing a person full-time is not only relatively cheap, it could also reduce attendance problems when employees do not have other jobs at the side.
- Overhead can be partly shared.
- The inhabitants might be more willing to accept all three services if the services are offered in one package instead of having to interact with three separate persons/organisations. This will be less of a hassle for them and it gives them more prospect that their area will improve. Only tackling one or two issues will not improve their living area in their opinion and they are therefore not willing to pay for services that only tackle part of the problem. Integrating drain management as well might be needed as this is regarded as the biggest problem.

Figure 8.5 Logistics – Faeces collection and transport: A summary

8.1 Dry or wet collection of faeces

Wet collection: All the liquids and additional toilet water is collected in a watertight pit and emptied regularly with a (mini) vacuum tanker.
Generation quantity: 2500-20.000 litres per household per year.
Dry collection: The faecal matter and additional toilet water is collected in a watertight double vault system with a retention period of a year. Emptying takes place once a year by digging the dried faeces out. Generation quantity: 90 kg per household per year.

8.2 Assessment

- Health and environmental
- Technical
- Social/cultural
- Financial

8.2 Choice for dry collection of faeces

The 'dry' option is chosen to be worked out further, because pre-treatment is realised, vacuum technology is less available and more complicated and the 'wet' faeces collection is much more expensive. 'Wet' faeces collection has much higher generation quantities and requires expensive technology (vacuum tanks instead of simple tricycles or tractors).
Note that both options have health risks associated and that further research is needed to assess whether a proper working double vault system can be realised.

8.3 Possible collection and transport options

Similar to the urine collection the following vehicles can be used:
- Tricycle with/without engine and transfer into tractor with trolley for transport to farmers
- Tractor trolley combination taking the faeces directly to the farmers.

There is not much difference between the three options. The vehicles, spare parts and skills for operation/maintenance are all widely available and the way of handling is the same in all three options. Transfer with the help of a movable bench is advised as this is very cheap and makes it possible to locate the transfer trolley nearby the collection area each day.

8.4 Cost calculation

- Input
- Analysis
- Results

8.4 Most cost-effective option

- Collection with a tricycle without engine transporting the faeces to a transfer trolley is the most effective and efficient system. When the transfer trolley is full a tractor transports the trolley to the farmers at the end of the day. To serve 8000 households the following is required: - 4 tricycles + 1 trolley full time and a tractor half of the time
  - Investments are 80.000 rs (€1500) with yearly costs of 280.000 rs (€5300)
  Recalculated to costs per household: 3 rs per month (€0,07).
  The yearly costs of the other two options are nearly the same.
- At the start of the project (100 households) it is advised to hire a tractor with trolley and driver and a few daily labourers operating tricycles without engines or wheelbarrows. The work can be done within two days. Costs are limited to a few thousand rs (€75) each year.

8.5 Design of double vault system at household

- The current pits are probably large enough to divide into two chambers. They have to be cleaned, made watertight and a separation wall, 1 or 2 vent pipes and an outlet to empty the chambers have to be made. The urine-diverting system has to be set up as well if not already done.
- The total costs for this are unclear, but partial subsidy is required.
- When the houses are too weak to reconstruct the pits, construction has to be reserved for newly built houses.
- The required size of the chambers and the emptying mechanism need further investigated.

8.6 Issues that needs attention before implementation

- Dealing with potentially hazardous material
  - Teach users how to use and clean the toilet
  - Training and targeted information to collectors
  - Provision of checkups and relevant medication to workers
  - When using equipment for other purposes it should be cleaned first
- Visibility of the material to the inhabitants
- Getting into contact with new inhabitants
- Using a planning instead of emptying at customer request

The following points discuss possible ways of integration:

- *Urine collection with tractor and trolley: also using the trolley for faeces and solid waste collection*

Chapter 7 concluded that collecting the urine was cheaper and easier by tractor, even in the starting phase. With a participation level of a few hundred households the tractor only needs to make one trip per day or work a few days full-time every 14 days (the collection frequency). As one trip takes about two hours it was advised to outsource this out to a local tractor owner who brings his own tractor. The trolley on the other hand requires specific equipment (the tank and generator with inbuilt pump). Therefore, it was advised to have this purchased by a new to be formed corporation for the excreta removal service. The tractor owner can then use the trolley as needed for urine collection, but with a low participation level the trolley stays unused most of the time. It is probably technically feasible to fix the tank and generator with pump in such a way that it can be easily removed, as the empty plastic tank and pump are not too heavy to lift separately probably. If this is possible, one could choose to rent the trolley out to realise some extra income.

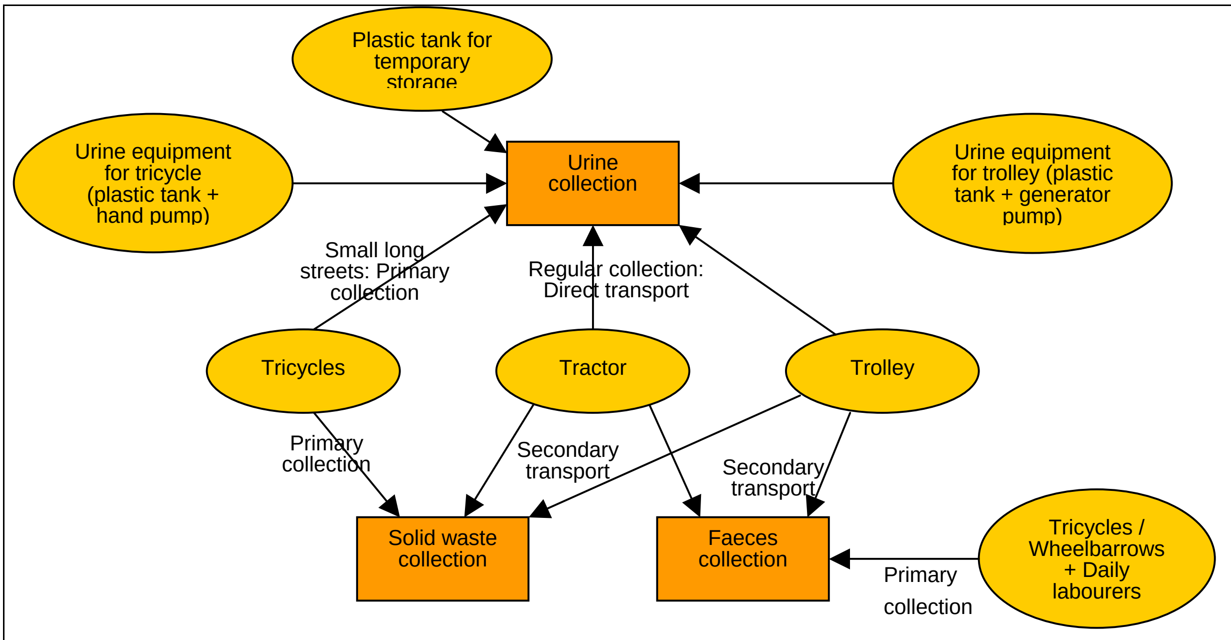


Figure 8.6 Overview for which services each vehicle or piece of equipment can or needs to be employed. The ovals represent vehicles/equipment and the rectangles represent the different services. Annex 13 and 23 list what equipment is needed in addition to the vehicle for respectively the urine and faeces collection.

The trolley can also be used for the faeces collection. This will take up only a few days per year in the beginning. An idea might be to also use the trolley as a transfer station for the solid waste collection. Currently the government has not set up a transfer station in Saboli itself. The consequence of this is that the solid waste collectors have to bring the waste to a nearby area where the government does perform secondary collection. It takes the solid waste collectors 30 minutes to reach this place. By placing the trolley somewhere within Saboli where surrounding inhabitants are not hindered by it, the solid waste collectors can benefit from this. They could be more willing to come more regularly as the trip times become shorter (they can empty their tricycle in the same way as for faeces collection, only instead of using a shovel, they can use a fork). When the tractor owner goes on his trip for the urine collection he first empties the trolley (e.g. at the place where the solid waste collectors previously brought it) and then attaches the tank and pump for urine collection again. When the participation level increases above a few hundred, the trolley mostly needs to be employed for the urine collection. Then the trolley cannot be used for solid waste collection anymore until a new trolley is purchased for the urine collection or one can choose to buy a new trolley more quickly if using the trolley as a transfer station for solid waste collection was a success.

- *Combining the solid waste collection with tricycles with faeces collection*

The tricycle that is used for solid waste collection can be used for the faeces collection as well if it is cleaned afterwards. Although technically possible, appointing the same person to collect the solid waste in e.g. the morning and the faeces in the afternoon is not advised. By emptying only a few houses each day and with only a few collectors it will take a long time to fill one trolley. This leaves the trolley unattended for a longer time and makes it impossible to use the trolley for something else. This is then of little use and the tricycles require cleaning each time. For faeces collection it is advised to collect this within a few days by hiring a couple of daily labourers as explained in Section 0. When the trolley and the tractor for urine collection are available for that period those can be used for secondary transport, otherwise they can be hired somewhere else. This is quick, easy and cheap.

- *Combining urine collection with tricycle with solid waste collection*

Although it is advised to do the urine collection with a tractor, one could consider purchasing the equipment to equip one or two tricycles (a plastic tank and hand pump). These tricycles can be rented out to collect the urine in some long and small streets where the tractor does not have access. As the tractor does not perform urine collection all day the tricycle cannot always be emptied directly by the tractor. It could then be emptied in a spare container. If there is not enough work for the urine collection, it could be employed for the collection of solid waste as well. It is probably technically feasible to attach the equipment in such a way that it can be easily removed again as the empty plastic tank and hand pump are not heavy to lift.

- *Combining awareness, education, payment and supervision*

Awareness and education should be integrated, as the purpose of all these services is the same: creating a healthy and clean environment. As explained in the beginning of this section, tackling all three issues at the same time will make people more willing to participate. Supervision and payment organisation can also be combined for the different services as the operations have many similarities and the employment of the people and equipment can be divided among each of the services. One could also consider giving the households a discount if they participate in multiple services.

Figure 8.6 summarises for which services each vehicle or piece of equipment can be employed.

9 CONCLUSIONS AND RECOMMENDATIONS

This research examined the question what an effective and efficient system is to transport the excreta from the households in Saboli, a low-income area in Delhi - India, to the farmers nearby who can use the excreta as fertilizer. This chapter will present the conclusions and recommendations and will conclude with subjects that require further research.

9.1 Conclusions

Urine

- *Collection by a tractor trolley combination equipped with a pump is the most effective and efficient system*
  Vehicle combinations in which the urine is handled with a pump score better on the formulated criteria for a good logistic system (Section 0) than a system which pours the household containers into a collection container. Of the three vehicle combinations analysed on costs – a tractor trolley combination, a tricycle with engine and a tricycle without engine - the tractor trolley combination equipped with a large plastic tank and a generator with inbuilt centrifugal pump which transport the urine directly to the farmers is the most cost-effective option. The investments for this option are also lower than required for the tricycle options equipped with a hand pump. On top of the large number of tricycles required for the tricycle options (because of their small capacity) a transfer station is needed and a few tractors for secondary transport, all adding to the costs.
- *Required number of vehicles and costs involved*
  At a participation level of 8000 households 6 to 18 tractors are required, depending the way the households offer the urine to the collector. The most positive scenario is the scenario when no water is added for flushing and people connect their houses in their street with a small pipe reducing the number of houses the collector has to visit. The worst scenario is when flush water is added and collection has to take place at individual houses. Given these two extreme scenarios, the required number of tractors (the most cost-effective collection vehicle for all four scenarios) that need to be employed ranges from 6 to 18 tractors with related investments ranging from 7½ lakhs rs to 21 lakhs rs (± € 14.000 - € 40.000). The yearly costs range from 15 lakhs rs for the most positive scenario to 51 lakhs rs for the worst scenario (± € 29.000 - € 97.000). When recalculating the yearly costs to the costs per household per month the costs lie between 16 and 54 rs (€ 0.30 - € 1; the willingness to pay is probably 20 rs). For the collection by tricycle these costs amount to 53-120 rs per household per month, considerably more. When starting the project and 100 households participate the investments required for purchasing equipment are 47.000 rs (€ 900).

- *The adding of ½ litre of flush water doubles the collection costs*
  The addition of water to the urine to flush has a large impact, because the water quantity is directly related to the workload. Adding ½ litre of flush water already doubles the costs, but people will feel uncomfortable when they cannot add water.

- *The connection of the individual houses of a particular street to the main street with a small pipe is important to realise*
  Whether or not houses are connected does not have much impact on the costs when tricycles are used. For the tractor option on the other hand, this has a large impact; collection at one spot instead of collection at the individual houses reduces the costs with ± 40%. The tractor with is its large tank needs to make many stops per trip; the time gained by reducing the number of stops is therefore large.
  Connecting the houses is also important in light of the bad road conditions. Especially during the rainy season transport becomes difficult to impossible. Furthermore, the tractor cannot go in every small street (one or a few tricycles might be necessary in addition to the tractor therefore). Connecting the houses enable the vehicles to stay on the main streets; this may be the only long-term solution. An incremental system is suggested that requires little extra costs compared to the installation costs for a urine-diverting toilet.

- *Size of household storage container can be limited to 300 litres or less*
  In general no larger household containers than 300 litres are needed to limit the costs per ton-collected urine. When no water is added for flushing 150 litres is sufficient. The related frequency of collection is 14 days. The more houses are connected the smaller the containers can be, offsetting the costs to connect the house.

Faeces

- *Collection of dried faeces with a tricycle without engine is the most effective and efficient system*
  Dry collection of faeces scores better on the formulated criteria for a good logistic system than the wet collection of faeces. Of the three vehicle combinations analysed on costs - a tractor trolley combination, a tricycle with engine and a tricycle without engine (all handle the faeces by digging) - the tricycle without engine transporting the faeces to a transfer trolley located nearby the collection area, is the most cost-effective option. When the transfer trolley is full a tractor transports the trolley to the farmers. The investments for this option are also lower than required for the other two options. A tractor is for the faeces, as opposed to the urine collection, not the most suitable vehicle. The long handling time per household (digging out the faeces instead of quickly pumping the urine) means the expensive tractor is standing still most of the day. Assigning more collectors to the tractor would fill up the trolley quicker and would make the tractor more cost-effective. This is exactly what is being done in the tricycle options: several tricycles delivering the faeces to one trolley. The use of tricycles without engines is a little cheaper than using a tricycle with engine, because the handling time at the houses is relatively long and the distance to the transfer trolley is short.

- *Required number of vehicles and costs involved*
  At a participation level of 8000 households, 4 tricycles without engine are required and a tractor working half of the time. The related investments are 80.000 rs (€ 1500) and the yearly costs are 280.000 rs (€ 5300). When recalculating the yearly costs to the costs per household the costs are 3 rs (€ 0,07) per month as the collection quantity is only 90 kg per household per year. The yearly costs of the other two options are nearly the same (note that the investments for the tractor option are three times higher).

  When starting the project and 100 households participate it is advised to hire a tractor with trolley and driver and a few daily labourers operating tricycles without engines or wheelbarrows. The work can be done within two days at that participation level and the costs are limited to a few thousand rs (± € 75) each year.

- *Design of double vault system at the household*
  As the size of the current pits is probably large enough to divide the pit into two chambers, partly using the current construction might be possible. After cleaning the current pits, they have to be made watertight and a separation wall, one or two vent pipes and an outlet to empty the chambers have to be made. The urine-diverting system has to be set up as well if this is not done in an earlier stage. The total costs for this are unclear, but (partial) subsidy is required. Pay attention that the construction of the houses might be weak. When a lot of construction is needed to make the current pits suitable for dry faeces collection and there is a risk that part of the house collapses, urine diverting might be the highest attainable. Then the construction of the double vaults has to be reserved for houses that are newly built.

Integration of faeces, urine and solid waste collection services

Integration of the faeces, urine and solid waste collection services can be advantageous as economies of scale can be released e.g. At a low participation level the trolley purchased for urine collection stays unused most of the time. It is probably technically feasible to easily remove the urine equipment in the trolley. In that case, the trolley can also be used for the faeces collection. As the faeces collection takes up only a few days per year in the beginning, it is suggested to also use the trolley as a transfer station for the solid waste collection. Currently the solid waste collectors have to go a long way to the nearest transfer location, as the government has not provided

any facilities in Saboli. When one needs to purchase a tricycle for the urine collection in case the tractor cannot access every house this could be employed for the solid waste collection as well.
For faeces collection it is advised to collect this within a few days by hiring a couple of daily labourers instead of regularly using the tricycles that are also used for solid waste collection. When the tractor trolley for urine collection is available this can be used for secondary transport, otherwise it can be hired somewhere. This is quick, easy and cheap.

Awareness and education should be integrated, as the purpose of all these services is the same: creating a healthy and clean environment. Tackling all three issues at the same time will make people more willing to participate. Supervision and payment organisation can also be combined for the different services as the operations have many similarities and the employment of the people and equipment can be divided among each of the services.

Farmers
The total area of the four surrounding farmer villages was found to be large enough to reuse the urine and faeces of the 50.000 people as fertilizer. With general rules of thumb it has been estimated that around 1-5 m^3 of faeces needs to be applied per crop and 23 m^3 to 77 m^3 urine; depending on the size of the farmer. Note that when the people in the community add flush water the urine amount will double or more. Before application the urine and faeces probably have to be stored for a certain period of time as secondary treatment. For urine with its large quantity, creating storage facilities for this is difficult. As it is likely this will not be created any time soon by the local government or cooperative ventures among the farmers at a (more) central level, suggestions have been given on how storage (and application) can be realised in a low-cost way at the farmer level.

Acceptance and viability in Saboli
The collectors are in favour as the working conditions will be much better than the manual scavenging they have done. The farmers see potential in urine and faeces as fertilizer and want to experiment with it. Acceptability depends on the costs and yield in relation to the chemical fertilizer they are using. This relation is yet unclear. The users easily relate to the production and reuse of dried faeces, but cannot easily relate to urine as fertilizer. The urine diverting toilet and collection is also perceived as requiring more effort from them, but to facilitate the drying of faeces it is acceptable. Restructuring their current pits and toilets into double vault systems will only be acceptable if users get a subsidy for a large part of the costs as people are not willing to make substantial investments a second time (90% of the households have an individual toilet). Urine collection without a double vault system can be more easily constructed in already built houses without high costs, but as urine-diverting is not that acceptable by itself much motivation building will be required for this. As for the costs of the transport, the yearly costs for faeces are very low considering the willingness to pay. The costs for urine transport are several times higher. When flushing water is added the costs might be too high for the farmers and households to bear, requiring outside subsidy. In conclusion, EcoSan is viable in Saboli when subsidy is provided for the reconstruction of the toilet systems (for newly build houses, subsidies can be lower) and when the fertilizer costs for the farmers are lower. When flushing water is added urine collection might require subsidy.

Usability of research for other regions in developing countries
The ISWM framework was found very useful, because it highlighted more aspects than the health, technical and financial aspects. The social/cultural aspects came up in every interview as toilet habits are deeply rooted and excreta have strong associations. Full attention is required for these aspects to realise acceptance and a proper working system. ISWM is directly usable for other regions on the understanding that the elements need to be applied and adjusted to the specific characteristics of EcoSan and the local situation. This leads to the subject of the formulated criteria.

The criteria have served their purpose in the assessment, because it necessitated to look at the options from different angels and to thoroughly think an option through. It also gave good insight into the weak points of an

option giving valuable information what needs attention during awareness training, implementation and operation. It is important not to quickly think that it is clear what the best option is. The criteria are usable for other regions as well, although the researcher felt the criteria can be formulated more concise as there might be some overlap between different criteria and the criteria always need to be adjusted to the local situation.
The calculations for the required number of vehicles, people and the costs involved are basic and can be used in other regions as well, because the parameters and choices can be easily adjusted to different settings and equipment. As for the possible options, similar local available vehicles can almost always be found. In this respect it is useful to remember that the longer the distance to the reuse or storage location and the smaller the handling time per house, the larger capacity vehicles are more suitable in general.

In conclusion, the steps and rational of thinking in this research can serve as a guideline for different regions and settings when one needs to develop a collection and transport system for EcoSan.

9.2 Recommendations

The following is recommended:

- *Start with hardware building for demonstration purposes as soon as possible*
  After the initial introduction of EcoSan and awareness raising no concrete actions have followed yet. Until demonstration toilets are set up with the subsequent collection people will not start to consider whether they would adopt such a system, as it is very difficult to understand what the whole system will actually look like; they have never come into contact with it before. Note also that people are not easily motivated, as the EcoSan toilet requires a higher level of commitment from the user than the toilets they are currently using and they have to spend extra money to change their toilet. Demonstration will be essential for the people to believe what is being claimed. After identifying the families who are interested to install a demonstration urine-diverting toilet (the restructuring of the current pits to a double vault system can wait until the required research is finished) an engineer/plumber can start making a design for the specific houses and build it. The collection method has to be discussed with some collectors to see what is workable for them.
  The local farmers have already been waiting for a long time for urine to come to be able to start experimenting. Together with an agricultural expert a few farmers should start planning the set-up of field trials to determine what the best application rates and methods are. This plan should also include the set-up of storage in order for them to be ready when urine starts to arrive. Hardware building for the demonstration toilets, the first equipment required for collection and transport and the field trials should be included in the project as this is very important in enabling people to make an informed choice and has to start as soon as possible.

- *Educate people about water use*
  The addition of flush water quickly increases total collection costs. Sensitising the participants about this is very important to be able to limit costs. Water reduction is also necessary for the double vault system.

- *Stimulate the connection of the individual urine containers*
  Laying a small pipe between the participants in the same street should be stimulated. This is not only important to lower transportation costs, it is also important in the light of the bad road conditions. Collection becomes a lot easier when the vehicles can stay on the main streets and may be the only long-term solution. People might be easily motivated to do this, because the more houses are connected together, the smaller the household containers can be; a cost advantage for the households. It also means a reduction in vehicle movement in front of their house and in their area.

- *Integration with drain management and solid waste management*
  The community might be more motivated when EcoSan is integrated with proper drain and solid waste management. Proper drain management has a higher priority for them and they see sanitation, solid waste

and drain management as one issue. Tackling only one issue will not solve their problem i.e. living in an unhealthy and dirty environment. By also tackling drain management people might start to trust and be willing to make investments and changes sooner. Proper drain management is also beneficial to the collection service (solid waste and sanitation), as it will improve the road conditions.

- *Give training and targeted information to the collectors*
  To avoid or minimise the consequences of handling the potentially hazardous faeces several technical and organisational measures can be taken and have been suggested. But most important is that workers are made aware of the nature of the health risks to which they are exposed and that they know how to protect themselves. Training and targeted information may be the most successful measure.

- *Include hygiene promotion*
  Technology alone cannot break the cycle of disease transmission; poor domestic and personal hygiene diminish the positive impact of improved sanitation. Hygiene promotion should therefore receive a prominent and reoccurring place in the awareness and education programs.

- *Encourage and educate urban agriculture*
  By growing food products on the rooftops (there is ample space on rooftops in Saboli) the high incidence of malnutrition in Saboli can be reduced. The food can be used for direct consumption and to generate income, improving food security as well. Furthermore, when people can use the urine and faeces for their own purpose, they will be much more motivated to adopt EcoSan (this became clear during the women group meetings in Saboli) and manage the system properly.

9.3 Recommendations for further research

The following issues are advised to be research further:

- *Double vault system*
  Several questions need to be further investigated before a good double vault system can be designed:
  - Which parameters have an impact on the evaporation rate and how does this affect the design and construction of the double vault system?
  - What will the evaporation rate be in the chambers and what safety margin should be taken into account? This needs to be researched to determine the required capacity of the vaults and whether the necessary level of evaporation will be achieved in relation to the amount of water added.
  - How much water per day can maximally be added after defecation and for regular cleaning to realise a sufficiently high level of pathogen kill-off when the moment has come to empty the chambers?
  - How long should the retention period be and to what degree is secondary treatment necessary?
  - The degree of secondary treatment affects the storage requirement at the farmers.
  - What is the best way to realise watertight chambers?
  - What is a good design for the emptying mechanism of the chambers?

  The way the chambers are emptied influences the handling time per house, how heavy the work is, to what degree the collectors come into contact with the faeces and the amount of spillage that occurs.

- *Urine diverting slab*
  Further research is needed to obtain a proper urine-diverting slab. Very important is that proper diverting is realised for all groups of people and that the occurrence of faeces falling into the urine bowl is very small. All groups of people must feel comfortable using the toilet. The slab needs to have a good top layer to prevent the material taking up some of the urine, because this will cause smell and therefore the need to flush with water and the slab should be easy to clean.

- *Fuel costs*

Estimates of the fuel costs are very rough and should be further analysed to make a more accurate projection of the yearly costs, because the fuel consumption accounts for a large portion of the total costs of the tricycle with engine and the tractor. When analysing this one should keep in mind that roads are sandy, bumpy and not paved. It is not expected that the outcome of which vehicle is the most cost-effective will change.

- *Transfer station*
  If one chooses to use tricycles for urine collection, specific research is needed how and where to organise transfer. It is a crucial link that requires two systems to be balanced to each other. The placing of a transfer station also tends to raise many objections by people living nearby. It should be well-thought over how best to proceed to prevent that the transfer station has to be (re)located far away from a strategic location.

- *Setting up a corporation for the excreta removal service and small businesses*
  Further research needs to be done whether the setting up of a corporation for the excreta removal service is a suitable way to ensure the continuity of the project in case the collectors do not regularly collect the material. Suggested is to have the corporation buy and own the required equipment, which can be rented to the collectors. In case of emergencies daily labourers can be hired as needed, because the specific equipment is owned by the cooperation and therefore easily available. This cooperation could also take care of the required planning. How this corporation or other body can be set up and organised should be investigated as well. For when the demonstration phase is over and cost recovery can start one should investigate whether and how a small businesses can be set up to provide collection services.

- *Cost recovery*
  The value of excreta to the farmers as fertilizer - in relation to the price of chemical fertilizer and/or the de/increase in yield achieved - is not researched. Marketing strategies for the recovered nutrients to generate money are very important to make the system sustainable and need to be made. As the households are the party delivering valuable material and farmers are the users, in principle the farmers should pay the costs and the households should get some money for offering it or collection should be free of costs. However, when costs are higher than the value a middle way could be that households pay part of the costs as they also benefit from proper removal of excreta. The government or other party can also subsidise some of the costs.

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LIST OF ANNEXES

ANNEX 1 WASTE, FODRA AND ISSUE PROGRAMME

This Annex will give an introduction to WASTE and FODRA, the two organizations who facilitated this research. Also, the ISSUE programme, of which this research study is a part, will be discussed.

WASTE

The foundation Advisers on Urban Environment and Development (WASTE) was established in 1983. It is a non-profit adviser for development projects in countries in Africa, Asia, Latin America and Eastern Europe. WASTE aims at sustainable improvement of the urban environment and the living conditions of the low-income population. Cities in developing and transitional countries are growing rapidly and the related problems are increasing, especially in lower-income groups. WASTE is active in four fields:

- Solid waste management and resource recovery
- Low-cost sanitation and liquid waste management
- Community based environmental improvement
- Micro and small enterprise development

The reason for substantive focus on sanitation and solid waste management is that it is a high-impact (affecting even life expectancy) and high profile (highly visible to the public) area of urban life. A focus in this area can set processes in motion, which then work through to housing, the food system, and other important environmental and socio-economic areas.

The focus is not only on improving sanitation and waste management in poor and slum areas. The focus is on improving overall performance of these systems in other areas as well, because poor communities are the dumping-places of choice for waste from all over the city for which there are no appropriate collection, treatment or disposal options.

WASTE's work has a special emphasis on the stakeholders who are active in urban waste management. Although in principle urban waste management is the responsibility of the local authority, it is frequently the case that the municipal government alone is not capable of solving urban waste problems. In the vacuum left by governments, small and micro-scale civil society initiatives often provide the only working services. Micro and small entrepreneurs and social groups earn a (frequently marginal) livelihood working in urban services: collection, removal, and upgrading of waste and excreta, and extracting, processing and trading materials and items found in the waste stream.

WASTE's approach is to facilitate, rather than implement, local initiatives. WASTE does not send its staff abroad for long-term missions. From a sustainability perspective it is preferred to let the work be done by local partners, such as NGOs, community organisations, and municipalities. Through building local capacity and empowering local actors, locals become more capable of introducing additional improvements without the assistance of WASTE or other development organisations. WASTE offers support in the form of consultancy, information, programme management, programme design and implementation, monitoring and evaluation, organisation of training, workshops, conferences and meetings. WASTE carries out assignments in close cooperation with its local partners, but the local partners are ultimately responsible for their own projects. WASTE's staff consists of ten multi-disciplinary consultants, seven of them permanent and three of them freelance.

With regard to funding, DGIS (Directorate-General for International Cooperation, The Netherlands Ministry of Foreign Affairs) has been the major client since 1988 by funding a sequence of multi-year programmes. Other clients have been, among others, EU, World Bank, Asian Development Bank, United Nations Industrial Development Organization and Cordaid.

Currently, by far the most important project within WASTE is the ISSUE programme. ISSUE stands for Integrated Support for a Sustainable Urban Environment. The programme is funded by DGIS with an amount of € 3.6 million in total for the period 2003-2006 (it is co-financed by Cordaid). The next section will focus on this project, because the research study is carried out under the capacity of the ISSUE programme. (Source: www.waste.nl and WASTE, 2002).

ISSUE - Integrated Support for a Sustainable Urban Environment
In response to the challenges formulated in the Millennium Development Goals, ISSUE supports the creation of an enabling environment that facilitates the introduction of integrated waste and sanitation management. Special attention is given to the introduction of ecological sanitation as an environmental sustainable and socio-economic viable option for addressing urban sanitation problems. According to the ISSUE Annual Plan 2004 (WASTE, 2004) the operational goal is to have key stakeholders in four Southern cities adopt ecological sanitation as the guiding principle for meeting the sanitation and environmental needs. The key indicator is that the stakeholders express this acceptance in a strategic plan for the implementation of a communal ecological sanitation program, a so-called Strategic Sanitation Plan. To gain different experiences, ISSUE is active in 5 regions: Central America, West Africa, East Africa, India and the Philippines. The programme is arranged into 4 phases, which are depicted below.

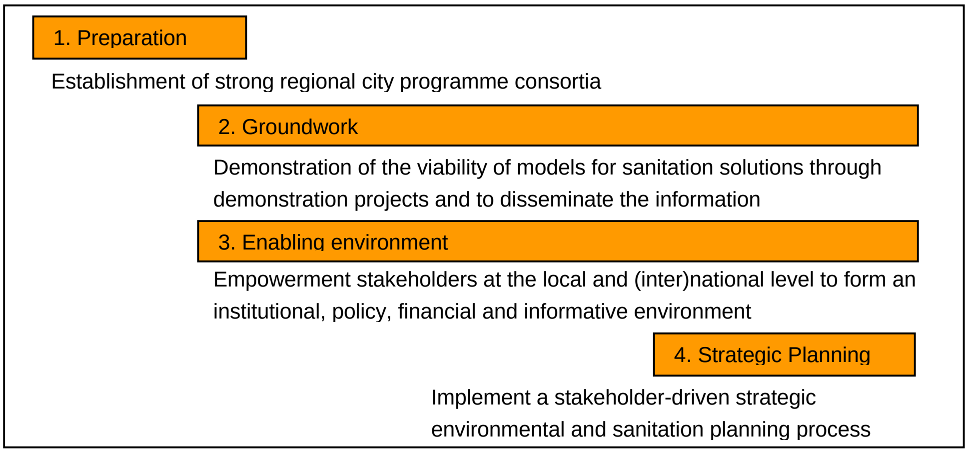


Figure 1 Phases in ISSUE programme

The consortia, a group of key-stakeholders who have formed an established working group, are the driving forces in the region. The consortia formulate and implement the three-year plan of the ISSUE Regional Programme. As part of the plans, the consortia facilitate a number of demonstration projects in their regions. Through the implementation of the demonstration projects, experience and information is generated presenting opportunities and bottlenecks. It may also capture the interest and commitment of the local decision-makers and give them the necessary information they need to make well-informed choices and decisions. Once local decision-makers are convinced that ecological sanitation provides a viable solution for the sanitation problems in their cities, the consortia support the development of a Strategic Sanitation Plan in collaboration with the local decision-makers. Parallel to these activities institutional capital is established in the form of knowledge and practitioner's networks, platforms, etc, ensuring spreading of experiences, collaboration between peer organisations and promotion. In conclusion, the main focus of the regional ISSUE programmes is the creation of a supportive enabling environment rather than on constructing toilets. The emphasis is on policy development and infrastructure financing. WASTE provides beside overall programme management and monitoring, direct support and guidance to the consortia.

The ISSUE programme is split in three thematic subdivisions:

- Ecological Sanitation Programme Track
- Waste Ventures Business Development Facility
- Knowledge Facility

The Ecological Sanitation Track supports activities directly related to sanitation and in particular ecological sanitation issues. The Waste Venture and the Knowledge Facility, support the ecological sanitation track. The Waste Ventures facility facilitates the involvement of micro, small, and medium-sized enterprises working on sanitation and waste management in cities in the South by focusing on mobilising structural funds. The Knowledge Facility supports knowledge development and dissemination.

FODRA - Fountain of Development Research & Action
FODRA is an independent non-governmental organisation in Delhi, India. It is committed to promoting and undertaking actions for sustainable development among the people living in poverty. FODRA started in 1994 as a non-profit organisation with the objective of building capacity of NGOs to be responsive to communities through sustainable project planning, implementation and monitoring. After a few years FODRA decided to work directly with poor households. In 1998, FODRA started its intervention programme among the people living in sub standard housing and sanitation conditions with little access to basic amenities in a cluster in North-East Delhi. Gradually, FODRA has expanded its programme by 2001 to eight adjoining clusters with an approximate 12,000 households. FODRA works directly with 2,000 households under different programme interventions such as:

- savings and credit programmes formed around self-help groups (promoted basically around micro credit related issues and gradually oriented to address social and community issues)
- cluster-level health committees (promoted around issues on community cleanness, health and sanitation)
- two remedial education centres and a skills training centre (such as soft-toy and candles production)
- a health centre and a community information centre

The goals of these programmes, mainly targeted at women, are on the one hand to improve the economic stability of individuals and families, creating opportunities for skill upgrading and income generation, safe and affordable health care for women and newborns. And on the other hand they are to inform and empower the community in analysing social and environmental problems affecting their lives.

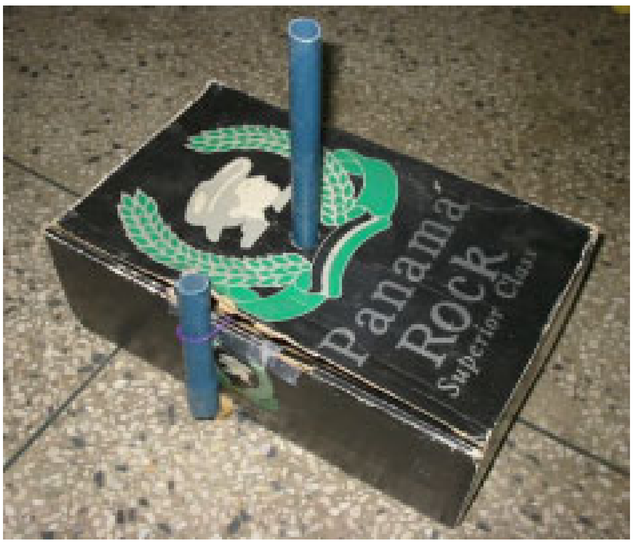
The basic purpose of FODRA's development interventions has been to create a development process whereby communities equip themselves to participate in articulation of problems and finding solutions. The reason for this is that it has been increasingly realised while working with these vulnerable groups that delivery of services alone will not overcome poverty. Making the community group informed and the promotion of social capital within the community through extensive sensitisation and awareness building are more likely to achieve long term sustainable changes. In this respect, for example, 350 leaders/members of the self-help groups are provided step by step training for intervention on leadership, group management and record keeping, community problem identification and self help collective solutions. This change process from being observers to passive participants to active participants to supervisor and manager takes time. Hence, FODRA’s interventions strategy is to work in the area until 2010.

FODRA has a staff of 25 employees, of which 17 employees are field staff. Furthermore, there are 11 community volunteers who are paid a small wage. The annual budget for the past years has been ± 4,5 million Indian Rupees (± € 80.000), mainly provided by CORDAID and SIMAVI, two Dutch development organisations.
(Source: www.fodra.org and an interview with the Director of FODRA).

ANNEX 2 ATTRIBUTES USED IN THE GROUP INTERVIEWS: THE SHOEBOXES

Construction representing basic double vault chambers and a urine-diverting toilet

Construction representing double vault chambers with an proposal how to easily empty the dried faeces



Construction representing wet faeces collection. Box is first used in the meeting as a representation of current pit (pipe on outside can be removed for this)

ANNEX 3 AMOUNT OF NUTRIENTS PRESENT IN EXCRETA

Source: copied from Jönsson (2004)

The requirements for plant growth include light, water, a structure for roots to grow in and nutrients. Nutrients can be divided into the two categories; macronutrients and micronutrients. The uptake of macronutrients is about 100 times that of micronutrients. The six elements normally classified as macronutrients are nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). Micronutrients are as essential for plant growth as macronutrients, but are taken up in small (micro) amounts. The elements normally considered micronutrients are boron, copper, iron, chloride, manganese, molybdenum and zinc. These nutrients are normally available in sufficient quantities through initial soil content and mineralisation of organic material. Only in special circumstances does scarcity of micronutrients limit plant growth. When human excreta are used as a fertilizer, the risk for such deficiency is minimal as excreta contain all micronutrients necessary for plant growth.

Consumed plant nutrients leave the human body with excreta, once the body is fully-grown. While the body is still growing, some nutrients are taken up and integrated into the body's tissues. However, only a small proportion of the nutrients are retained in the body even when children and youngsters grow rapidly. Thus, the amount of excreted plant nutrients essentially equals that consumed. This has three important implications: 1) The amount of excreted plant nutrients can be calculated from the food intake, on which the data are both better and more easily available than on excreta. 2) If the excreta and biowaste, as well as animal manure and crop residues, are recycled, then the fertility of the arable land can be maintained, as the recycled products contain the same amounts of plant nutrients as were taken up by the crops. 3) Differences in composition of excreta between different regions reflect differences in the uptake of the consumed crops and thus in the plant nutrient supply needed for maintained fertility. Irrespective of the amounts and concentrations of plant nutrients in the excreta, one important fertilizing recommendation is thus to strive to distribute the excreta fertilizers on an area equal to that used for producing the food.

Only few measurements exist of the amounts and composition of human excreta and thus there is a need for a method to calculate the composition of the excreta from easily available data. Such a method, which uses the Food and Agriculture Organization statistics (www.fao.org) on the available food supply in different countries, has been developed by Jönsson & Vinnerås. This method uses equations derived from the FAO statistics and an estimation of the average excretion by the Swedish population, where many large measurements on excreta have been made. Table 1 below gives the estimated excretion per capita in India of the three major nutrients used in chemical fertiliser (based on the statistics of the Food and Agriculture Organisation for the year 2000).

Table 1 Estimated excretion of nutrients per capita per year in India (in kg)

India	Nitrogen	Phosphorus	Potassium
Total	2,7	0,4	1,5
Urine	2.3	0,3	1,1
Faeces	0,3	0,1	0,4

Source: Jönsson, 2003

These estimated numbers are average values and the actual excretion can, depending on diet, vary very widely between individuals, families and population strata. The actual division of the nutrients between urine and faeces depends on the digestibility of the diet and on successful diversion of all urine from faecal matter. No more specific or more recent numbers have been found and measuring more specific averages is outside the scope of this research.

Not mentioned yet, faeces are rich in organic matter. Organic matter contributes in several ways to crop growth: by improving the soil structure, increasing the water-holding capacity and the buffering capacity, and by supporting the soil micro organisms by serving as an energy source.

ANNEX 4 TRANSMISSION ROUTES, DISEASES AND FACTORS INFLUENCING PATHOGEN DIE-OFF

Transmission routes

There are two ways in which excreta can cause infection:

- the pathogen in the faeces of one person reaches to the mouth or other port of entry of another person
- flies, mosquitoes and other rodents and animal can act as vectors of diseases

Transmission of excreta-related diseases is largely faecal-oral or through skin penetration. Figure 1 below illustrates the potential transmission routes for pathogens found in excreta. Pour hygiene practice, particularly involving food and hands, may be a major cause of disease transmission, even where appropriate excreta disposal facilities are in place. Inadequate and unsafe disposal of human faeces can lead to the contamination of ground and water sources, and can provide breeding sites for flies and mosquitoes which may carry infection. In addition, faeces may attract domestic animals and vermin, which can both increase the potential for disease. Figure 2 exemplifies some of the safety barriers required to prevent the transmission of disease.

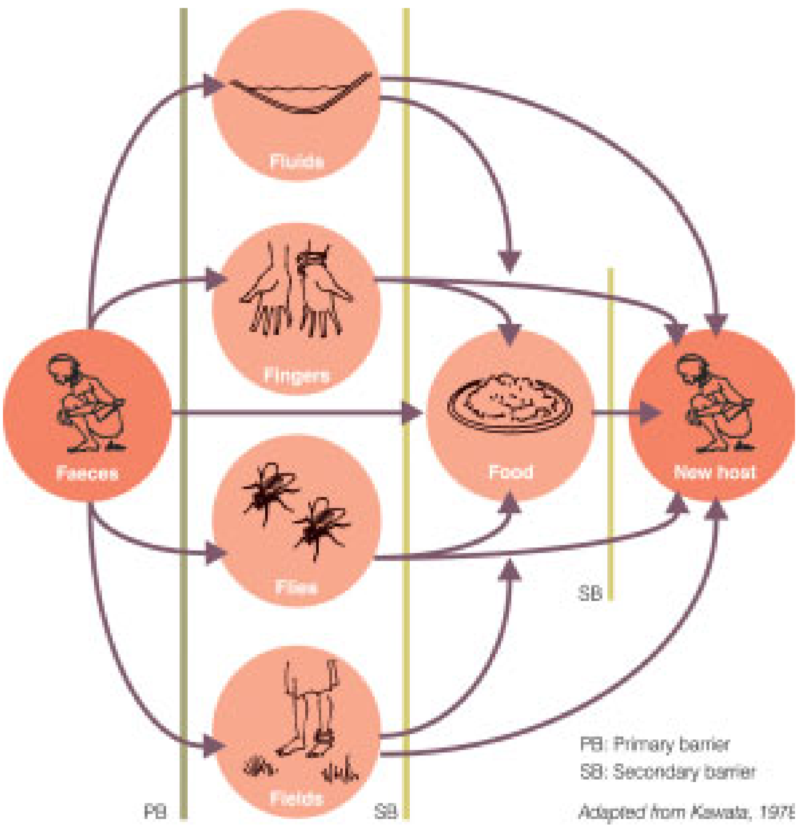


Figure 1 Transmission routes for pathogens found in excrete (Harvey, 2002)

If a disease-causing organism infects a person, the clinical manifestations are determined by factors related to the organism in question and by factors related to the infected individual. The likelihood new infections in other susceptible individuals is a function of contact and exposure. This in turn is governed by factors such as the excreted amounts and the infective dose (number of organisms that need to be taken in orally to cause an infection), which varies between different organisms. The likelihood of contact and exposure is further governed by the ability to withstand adverse environmental conditions outside the human body and persist in a stage where they can infect a new individual upon exposure (Source: Schönning, 2004).

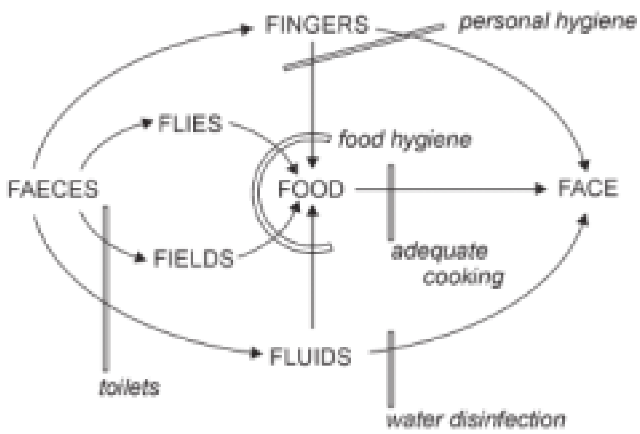


Figure 2 Barriers required to prevent the transmission of disease/spread of pathogens (Schönning, 2004)

Risk of pathogens in urine

Figure 3 below lists the pathogens that may be excreted in urine and the importance as a transmission route.

Pathogen	Urine as a transmission route	Importance
Leptospira interrogans	Usually through animal urine	Probably low
Salmonella typhi and *Salmonella paratyphi*	Probably unusual, excreted in urine in systemic infection	Low compared to other transmission routes
Schistosoma haematobium (eggs excreted)	Not directly but indirectly, larvae infect humans via freshwater	Need to be considered in endemic areas where freshwater is available
Mycobacteria	Unusual, usually airborne	Low
Viruses: CMV, JCV, BKV, adeno, hepatitis and others	Not normally recognized other than single cases of hepatitis A and suggested for hepatitis B. More information needed	Probably low
Microsporidia	Suggested, but not recognized	Low
Venereal disease causing	No, do not survive for significant periods outside the body	-
Urinary tract infections	No, no direct environmental transmission	Low

Figure 3 Pathogens that may be excreted in urine and the importance of urine as a transmission route (Source: Schönning, 2004)

The WHO (2005) concludes that pathogens that may be transmitted through urine are rarely sufficiently common to constitute a significant public health problem and are not considered to constitute a health risk related to the reuse of human urine in temperate climates. An exception in tropical areas is Schistosoma haematobium, which however implies a low risk due to its lifecycle. The main risks in the use of excreta are related to the faecal fraction and not the urine fraction. Therefore, it is of major importance to avoid or diminish faecal cross-contamination to the urine fraction. Even though some pathogens may be excreted in urine, the faecal cross-contamination that may occur by misplacement of faeces in urine-diverting toilet is related to the most significant health risk.

Risk of pathogens in faeces

From a risk perspective, the exposure to untreated faeces always is considered unsafe, due to the potential presence of pathogens where many different types of organisms causing enteric, parasitic or other types of infections may occur and their prevalence in a given society is often unknown. The list of diseases is long and include cholera, typhoid and shigellosis. More than 120 different types of viruses may be excreted in faeces, where the most common are members included in the enteroviruses, rotavirus, enteric adenoviruses and human caliciviruses (noroviruses) groups. Giardia is occurring with high prevalence as an enteric pathogen. In developing countries, geohelminth infections are of great concern. The eggs, of especially Ascaris and Taenia, are very persistent in the environment, and therefore regarded as an indicator and index of hygienic quality. Hookworm disease is widespread in most tropics and subtropics areas, and affects nearly one billion people worldwide. In some developing countries, these infections exaggerate malnutrition and indirectly cause the death of many children by increasing their susceptibility to other infections, which could normally be tolerated. The eggs from Ascaris and hookworms that are excreted in the faeces require a latency period and favourable conditions in soil or deposited faeces to hatch into larvae and become infectious (Source and for a more elaborate explanation: WHO, 2005).

Nevertheless, the presence of human pathogens does not necessarily represent a health risk if suitable health protection measures can be taken. These measures may prevent pathogens from reaching the handlers of excreta both at “the site of production”, in the transport chain, in contact in the fields both for workers and from the crop later used by the consumer. This could thus include treatment, crop restriction and human exposure control including protective measures as laid out in the Table 1 below. The table gives more insight what measures should be taken during handling.

Table 1 Potential transmission routes related to toilets and the use of excreta with simple technical and behavioural measures to limit exposure and minimise risks (Source: WHO, 2005)

Area or procedure leading to pathogen exposure	**Transmission route**	**Technical measure**	**Behavioural measure**
Toilet	Direct contact; contact with flies; transport to groundwater; environmental contamination	Clean water and soap for hand washing available; elevated collection chamber; design that facilitate cleaning, lined collection chamber (no seepage to groundwater or environment), Fly control measures (tight fitting lid, ventilation pipe with screen	Washing hands; keeping toilet area clean
Primary handling – collection and transport	Direct contact	Ash, lime or other means of reducing microorganisms at toilet; informed persons collecting and transporting mechanisms that reduce contact, e g removal containers; adequate storage time in double vault toilets	Wearing gloves; washing hands; addition of ash, lime or other means of reducing the microbial content during use.
Treatment	Direct contact; environmental contamination	Suitable choice of location; treatment in closed systems; information signs in place	Wearing gloves and protective clothing; washing hands; avoid contact in treatment areas
Secondary handling – use, fertilising	Direct contact	Informed farmers reusing excreta; special equipment available	Wearing gloves; washing hands; washing the equipment used
Fertilised field	Direct contact; transport to surface and groundwater	Working excreta into the ground; information and signs	Avoid newly fertilised field; avoid over-fertilization
Fertilised crop	Consumption; contamination of hands, kitchen utensils, food	Choice of suitable crop or crops always cooked before eating	Proper preparation and cooking of food products; cleanliness of kitchen surfaces and utensils, domestic and food hygiene; thorough hand washing.

In small-scale systems it is most often impractical to denote and try to apply specific guideline values to ensure compliance for health protection. Rather, the on-site treatment should be designed to assure a substantial and consistent reduction of potential pathogens present.

Factors influencing die-off of pathogens

Factors that influence the die-off rate of pathogens in excreta are listed in Table 2 below. These die-off processes are vital in sanitising processes of human excreta.

Table 2 Factors that influence die-off rate of pathogens

Factor	Process
Moisture/Humidity	Low moisture (urine diversion, dehydration, ventilation)
Time	Increasing retention time (storage)
pH level	High pH rate (adding sawdust, ash, etc.)
Temperature	Higher temperature (solar/artificial heating)

Increasing the temperature during storage for example shortens the required storage time to realise die-off and vice versa.

ANNEX 5 TYPE OF SETTLEMENTS IN DELHI

S.NO	Type of Settlement	Estimated population in lakh in 2000	% of total population
1.	JJ Clusters	20.72	14.8
2.	Slum Designated Areas	26.64	19.1
3.	Unauthorised Colonies	7.40	5.3
4.	JJ Resettlement Colonies	17.76	12.7
5.	Rural Villages	7.40	5.3
6.	Regularised-Unauthorised Colonies	17.76	12.7
7.	Urban Villages	8.88	6.4
8.	Planned Colonies	33.08	23.7
	Total	139.64	100.00

Source: Economic Survey of Delhi, 2003-2004, Planning Department, Government of National Capital Territory of Delhi

The first two categories account for the bulk of slum population in Delhi. JJ clusters are illegal occupants or squatters on public or private land. Slum Designated Areas are legally notified slums. JJ Resettlement colonies comprise of JJ clusters households that have been 'resettled'. In addition to the above settlement types, many slums also fall under 'unauthorised' colonies and 'regularised- unauthorised' colonies, though the exact proportion is not known.

ANNEX 6 MAP OF THE CLUSTERS OF SABOLI

Figure was put together by an employee of FODRA (2005)

ANNEX 7 GENERAL RESPONSE OF SABOLI COMMUNITY TO ECOSAN AND TO THE MEETINGS

Response to the meetings

The responses to the attributes were positive. People took the shoeboxes and e.g. explained with them how their current pits are constructed using these items. In the sweeper group the pictures of different vehicles made them tell the drawbacks and advantages of the different vehicles and what they would use. They raised all the concerns that had been imagined in advance and they disapproved at some points and gave limits to their acceptance. Issue that e.g. a sticker has to be put on the wall to explain the two holes in the slab to guests and that a larger storage container is less prone to overflowing when the sweeper does not show up regularly, indicates they really gave it thought.

General response to EcoSan

Explaining the reuse of the nutrients in ecological sanitation was not very difficult, because the people come from villages where manure and chemical fertilizer is or was used by them and seen as valuable. They also link defecation in the fields to this, which has been done for centuries. Making these links and seeing the dried faeces sample without smell, makes it not a dirty idea anymore. People who were already aware of EcoSan were not afraid to touch the bottle with the dried faeces sample. Others were afraid of it, but one group later commented that if the researcher could touch it, they could also touch it.

The urine separation is less readily accepted, because they cannot relate to something in their past that indicates that urine, separately, is also a good fertilizer. The new slab in the toilet that is needed to realise this, makes people hesitant to accept urine separation, because they are not sure how this works in practice if they have to relieve themselves. It also seems to take extra effort to them. However, if urine separation is needed to realise the drying of the faeces, then they can tolerate it. The production of fertilizer and the reduction of the disease burden are valuable benefits to them. However, when they realised that they could not use the manure themselves, some groups were not so interested in the new system anymore. They would build the double vault system in their villages, but here it the city it was useless to them. Later, when they saw the link more clearly with the farmers in the neighbourhood and that it would also bring them benefits like more nutritious food and less contamination, it was useful again to build a double vault system in the city. The general opinion is that if their current pits contaminate the groundwater, then they have to do something about it.

They explained that to start with this new system will be very difficult for them psychologically, but after they get used to it and it gets collected easily, then there will be no problem anymore. They see it will have benefits for them, for the health of their children and for the productivity of the fields, so they will tolerate it. The problem is that they have built already a toilet system and changing it requires money again that they cannot afford. There were also voices in the women groups that indicate that sanitation is not a priority. During the meetings the women make comments like: it takes extra money, lets see what we do over five years when the pit has to be emptied. Also, at the end of the meeting women commented to the translator or the employee of FODRA that e.g. electricity is more important to them and why that was not the subject of the meeting and that they were disappointed that the meeting was about the toilet. Also, the response given to the open question of the EcoSan database (no distinction between gender) what needs improvement, 93% of the 1300 families say: “drains, road and electricity”. Water, diseases and/or hospital (mentioned solely or in conjunction with drains, roads and/or electricity) are mentioned only 4% of the times.

ANNEX 8 OVERVIEW OF ASSUMPTIONS IN THE CALCULATION OF THE AMOUNT OF URINE, FAECES AND LAND NEEDED FOR APPLICATION

Assumption	Explanation
One person excretes in a year: - 450 litre of urine - 15 litre of faeces	See Section 2.2 For faeces a 70% reduction rate is taken (50 litre fresh material x 70% = 15 litre)
The excreted amount of one person in a year can fertilizer - Urine: 0,035 hectares of land - Faeces: 0,02 hectares of land	Rule of thumb EcoSanRes / WHO Urine: Average of 0.03 ha-0.04 ha Faeces: Lower end of 0.02 ha-0.03 ha, because ground needs improvement probably
Size of field - Small farmer 1,75 hectares - Big farmer 6 hectares	Interviews with 4 farmer groups
Number of inhabitants is 40.000 for urine collection Number of inhabitants is 48.000 for faeces collection	The average family size is 6.1 persons and Saboli has 8000 households (see Table 5.1). For calculation purposes of the amount of urine generated, a family size of 5 persons will be taken, because there are some losses due to excretion outside the house. Especially men and children urinate in the open where it is not collected by a toilet. For faeces collection an average family size of 6 will be used, because losses will be smaller.
Number of crops per year for application: - 3 crops for urine - 1 crop for faeces application	Interviews with 4 farmer groups: - 2-5 crops are grown of all kinds of vegetables - 1-2 crops of wheat are grown Faeces are preferable utilized for crops that are processed, such as wheat (see safety guidelines, Section 8.1)

ANNEX 9 GENERAL RESPONSE OF FARMER COMMUNITY TO ECOSAN AND TO THE MEETINGS

Response to the meetings

To make the research more interesting also two groups were interviewed who had no previous knowledge of EcoSan to get a more unbiased response. Because FODRA was also new to these villages a person from the first farmer group offered to make the appointment and introduce us. This man is a highly respected person in the area and came across as very friendly and trustworthy. In the meeting itself he introduced the researcher and translator and shortly explained the difference between chemical fertilizer and organic fertilizer (he works for an environmental organisation and knew these things already) and then left it to the researcher.

In the two groups that already had previous contact with FODRA a lot of people participated, around 15 persons and most of them contributed. In the two groups that were contacted for the first time, in the first group only the village leader talked and in the second group mostly the farmer who got the prize “best farmer of the year” of the region. A difference was also that also only a few other men were present.

Especially in the newly contacted groups, the discussion was taken very seriously. They answered thoughtfully and clearly stated what they believed, what was acceptable to them and what was not. The ‘best farmer of the year’ farmer did not take everything for granted and asked further questions. One of the two groups that FODRA has already contacted is not genuinely interested in EcoSan. They were probably only interested to talk to us, because they hope they will get something for free. This feeling rose, because several times they said they agreed with something and said it was very useful to them before they knew anything about it. Furthermore, with each subject they told us that they are very poor and backwards and asked for financial help.

General response to EcoSan

The farmers already know or understand that chemical fertilizer destroys their fields in the long run and prefer organic fertilizer. There is no need to convince them of that. The problem is that they do not have enough animal manure. For the two groups who were not previously informed about EcoSan it was the first time they heard human manure could also be used. The ‘Farmer of the year’ farmer indicated he knows excreta is good for the fields, but he does not know how to do that. In their village they have experimented with solid waste composting and already irrigate their fields with the drain water from the latrines. The Muslim leaders own words in response to characteristics and application possibility of urine and faeces: “Now the urine and faeces goes waste, we were not aware of that.”

All four groups have the concern that they do not know how to process and how to apply the urine and faecal matter[37]. The two groups who were not aware of EcoSan had no other concerns. The other two groups were afraid of skin diseases, because they had seen the black parts on arms of scavengers. All groups were informed about the diseases that might still be present in the faeces and urine they will receive, but this was not a concern to them. One group responded that the pesticide they use is also harmful and they know they have to wear gloves and wash hands.

Urine is not a problem for the Hindus. They point out urine is used as an antiseptic (one told also how he had washed a wound on his own toe with urine) and ex-prime minister of India (1977) Morarji Desai regularly drank his own urine. Concerning the faecal matter, the three Hindu groups all said the exact same thing “if its cheaper, than

[37] In this respect two individual concerns were raised:

- If the faeces are dried very long then it is not usable anymore, because the manure needs to be moist to be usable for the plants. (Solution: the field could be irrigated afterwards.)
- We cannot just stop with the chemical fertilizer completely, because the soil demands the chemical fertilizer now. If we do that we will suffer less yield. (Solution: You could replace the chemical fertilizer with the organic material slowly.)

it is not dirty anymore and we will start rushing for it". The only question to them is whether their yields will go up or down compared to the old and new purchase prices and investments they will have to make. In this respect all farmers first want to experiment with the new fertilizer themselves on a small piece of their field before they are prepared to make any investments[38]. In conclusion, their main condition to start using the urine and faeces is that it has to be cheaper.

The Muslim group had a different attitude towards faeces and urine than the Hindus. They explained Muslims hate urine, more than faecal matter. The Koran very explicitly says what is dirty and what is clean: urine and faecal matter are very dirty. Open defecation is therefore not allowed; this should not be visible to any person, it should be hidden. That is also why everyone in this village has toilets. They continue by saying: "We are very rigid in our religion, but in the Koran nothing is written about the use of urine and faeces as fertilizer. That is why we can accept it. If the urine and faeces can be beneficial to us and other people then we will not oppose to it. If it is beneficial, people will not come walking for it, but running". He exemplified this by telling they first imported seeds from Australia, but now they grow the seeds themselves: "if it is cheaper and brings benefits, people will change". In this respect the chief is willing to try it on a small part in his own field, because if one person starts and benefits from it, others will follow. "For demonstration", the Muslim leader said, "we could start with the excreta from e.g. a school".

Interesting to note is that FODRA also contacted a few other farmers a few months earlier, but they were not interested in EcoSan, because they only had small pieces of land.

[38] The group who was not genuinely interested in EcoSan also indicated it had to be easy to apply and talked about a demonstration, not about experimenting themselves. It seems that if the urine of faeces are brought to them for free than it is acceptable, but they are not willing to do any efforts or investments themselves.

ANNEX 10 URINE - POSSIBLE COLLECTION AND TRANSPORT OPTIONS – ADDITIONAL INFORMATION

Pouring the small containers empty into a larger container on a vehicle
Another possibility is that the container is not emptied on the spot, but the full container is lifted on the vehicle and switched for an empty container. At the end of the trip the containers can be emptied in a transfer station. Advantage is that the visibility of the handling and the subsequent splashing is transferred from inside the community to a transfer station. However, this option is discarded:

- There are indications that this might not be culturally acceptable. When FODRA tried to distribute small water containers to the community in a few days fights started among people about the issue that their container was standing next to a container of a lower caste person. Urine is not the same as water, but this could pose similar problems.
- The handling of heavy containers is doubled; first loading it on the vehicle and then unloading at the transfer station.
- The necessary number of trips will probably also increase in this option, because a lot of empty space is taken up on the vehicle. The containers the collector picks up are in general only half filled or even less, because one should take into account a safety margin when designing the container in case collection does not take place one or even more days. This means that maybe fewer containers than the weight the vehicle can take can be fitted on the vehicle.

Emptying it at a transfer station also implies the containers should be cleaned before the containers are brought back to the households. When the containers are emptied in front of the house and returned to the same house it might be acceptable to only clean it quickly there where there is some liquid on the outside of the container.

This all means an increase of costs of the system and an increase of work that does not have good working conditions: it is heavy and the cleaning will smell. The positive public health implications by handling the urine at the transfer station are small compared to some alternative options where splashing of the urine during handling (in the community) is very little. This is strengthened by the limited risks associated with urine.

Using a vacuum pomp mounted on a tractor driven trolley with a vacuum tank
A vacuum pump is the standard to pump slurry. A vacuum pump can handle the viscosity of the slurry and solid parts, making it a robust pump. The urine however, is as liquid as water. One does not need an expensive vacuum construction to pump this. A centrifugal pump with a plastic tank as described in the previous option will do and is much more cost-efficient. A vacuum tank construction needs thick sheets of steel to be able to hold the vacuum build up in the tank. The cost of a 3000-litre plastic tank will come around 10.000 rs. and a vacuum tank around 100.000 rs. (5 mm thick plates), making vacuum tanks an inappropriate option.

Furthermore, knowledge on operation and maintenance on vacuum constructions is not readily available in this area. The extra weight of the tank is also a drawback in areas where roads are in bad shape, because the weight the tractor can pull is smaller in that case. Vacuum constructions will not have real advantages over other pump constructions from a health point of view. The handling is quite similar.

ANNEX 11 URINE - ASSESSMENT COLLECTION OPTIONS ON CRITERIA

Table 1 Health and environmental assessment

Policy criteria - The occupational and public health is safeguarded - Faeces and urine do not enter the direct living environment - Valuable resources are reused to the maximum extent				
Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
No direct contact of workers with urine	-	+	+	For all three options no direct contact can only be guaranteed if protective clothing and gloves are worn. In the pouring option the container can easily slip out of the hands of the collector when lifting the heavy container to pour it in the tank on top of the vehicle. Or, when pouring too fast, the urine can be spilled on the hands and body. Handlebars can make the containers more manageable. However, these mistakes will most likely still occur, especially when people get tired or when the containers or hands are wet from e.g. rain. Less contact will probably happen in case pumps are used. The storage tanks can be designed in such a way that hose does not need to enter the tank and if the pump is operated correctly there is no spillage.
Prevent contact with eyes	-	+/-	+/-	In all three options the urine is very unlikely to splash into the eyes. Contact with the eyes could be possible trough touching with the hands. As contact with the urine is more likely in the pouring option this option scores worse.
No or small occurrence of spillage during handling	-	+	+	As explained for the first criteria for the first option: with heavy lifting spillage through slippage or pouring too fast can occur. It can happen that the whole contents of the storage container ends at the ground. When the pump and hose is handled not too hasty there is no spillage. Otherwise a little bit of urine might be spilled on the ground. In the suction line a valve could be inserted to prevent back flow when the pump is not running to further minimize spillage. A valve can be added in the discharge line as well to close off the tank (when the transportation distance is long) to be on the safe side.

Table 1 Health and environmental assessment

Policy criteria
- The occupational and public health is safeguarded
- Faeces and urine do not enter the direct living environment
- Valuable resources are reused to the maximum extent

Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Spillage consequences of failures should be limited and easily cleanable	+/-	+	+/-	For all three options the urine will end up on the ground in case of failures. This is not easily cleanable. Maybe some detergent could be sprayed on it to prevent smell. The urine will not be hazardous in general if the toilets slabs are constructed properly. In the first option especially the household containers suffer from wear and tear, as they have to be switched each day. The tank on the vehicle also suffers as the containers are rested on the edge each time. Iron reinforcement on this spot could reduce this burden. However, the wear and tear means the plastic tanks are more likely to break at once. Since the volume of the tank is relatively small, the maximum spillage will be limited in case of failure. In the second option no pressure or wear or tear is practised on the containers and tanks. When not using the lowest quality plastic, breaking of the tank will not happen unless maybe the vehicle collapsed. However, the maximum spillage will be limited, since the volume of the tank is relatively small. In case of failure of the tank in the third option, the volume that is spilled is relatively large. However, this is very unlikely to happen as explained for option 2. A simple valve can also be added at the end of the discharge line to close off the tank for safety in case the discharge line or pump malfunctions.
Container and equipment is cleanable	+	+	+	Plastic is an easy to clean material. All tanks are made of plastic. The tank and pumps can be rinsed with some water and detergent, which can be removed just like the urine is removed from the tank.
Transport container is watertight	-	+	+	In the first option the tank is not likely to be closed between the consecutive collection points when collection takes place house-to-house, because the pouring is relatively quick and a lot of houses will have to be emptied in the tank. Closing the tank after each house will be considered impractical. This means the tank is left open during the whole collection. The tank will be closed when collection is finished, otherwise spillage will occur during transport. In option 2 and 3 both tanks are closed off by the pump

Table 2 Technical assessment

Policy criteria - The system is easy to construct and maintain in the local context - The system is robust enough to meet the exigencies of normal use - The system is safe, user friendly and reliable - The system is as cost efficient as possible				
Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Suitable to the physical conditions of the area	+/-	+/-	+/-	Both the tricycle and the tractor construction have difficulty with the physical conditions of the area. The tricycle mainly with the road conditions, which limit the weight the collector can take in one trip and the tractor with the width of the streets and the electrical poles. Solutions to cope with this are present in the form of taking less weight, connection the difficult to access streets and/or moving the centrifugal pump in the streets instead of the tractor/lengthening the hose
Vehicles and equipment are available on the local market and safe to use	+	+	+	The researcher had only difficulty locating a specific hand pump, which is found to be most appropriate for this job: the semi-rotary pump (capacity can be 35-50 litres/minute, suction lift can be 4-7 metres and the pump is very robust). In Delhi the hand pump or a good alternative was difficult to find on the local market, only one shop was found which provided them. Throughout Europe and other countries in e.g. Asia this pump is widely used e.g. as a reliable emergency backup to an electric pump during a power failure or to pump small amount of fuels. Directly coupling the centrifugal pump to the tractor can damage the pump in case of incorrect use of power-take-off of the tractor. The use of a generator avoids this.
Rely on locally widely available knowledge, skills, spare parts and materials for operation and maintenance	+	+	+	The tricycles (including the motor), the tractor and trolley, the tanks and hoses, the generator and pump are widely used. Repair can be done everywhere. The hand pump might prove to be not widely available (see previous criteria) although repair and maintaining skills should be no problem as the pump is very robust and simple. Importing the pump is in this respect not a problem probably.
Handling is easy and quick	+	+/-	+/-	Pouring is easy and quick if the containers are not too heavy, otherwise it a very heavy job. A hand pump cannot pump very fast, but is easy. In case the tractor cannot go into the street the pump has to be taken to the spot. This is easy but takes a little extra time. The suction hose on the centrifugal pump is a little more difficult to handle, as the hose needs reinforcement.
Service is performed in the way and at the time that is agreed upon	-	+	+	In the first option collection has to take place everyday. Currently, the solid waste collectors do not always show in case of e.g. rain or problems in the family. In the first option this can lead to overflowing of the system very quickly. The other two options have more room for margin, as the containers can be larger.
The total weight of vehicles does not exceed the maximum allowed axle weight	+	+	+	The tricycles where an engine is fixed on are reinforced with extra bars and a small-motor wheel is added in the middle, which will take most of the weight. The bad road conditions limit the weight the vehicles can take.

Table 2 Technical assessment

Policy criteria - The system is easy to construct and maintain in the local context - The system is robust enough to meet the exigencies of normal use - The system is safe, user friendly and reliable - The system is as cost efficient as possible				
Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Use of stainless steel, plastics or concrete (concrete needs to be rubbed down)	+	+	+	Plastic tanks are used in all three options. Stainless steel pumps are available, but when the pump is used everyday fulltime the parts wear out faster than they can corrode. Galvanised or unprotected iron might be a more cost-efficient solution.
Urine storage excluded, places where urine stands still are minimized (because of crystallising of urine)	+	+	+	In the collection tank, pumps and hoses the urine is only shortly present and moves during handling and transport.
Critical sections are easy reachable and replaceable	+	+	+	In the first option the containers and decoupling construction is critical. These are easy reachable and replicable, because this is located at the outer ends. In the other two options the hose is most critical. This is also very easy to replace and everywhere available. The pump is robust if operated correctly and in case of blockage are both repairable. Especially the hand pump is very easy to take apart.

Table 3 Social/Cultural Assessment

Policy criteria - The system is consistent with cultural and social values - The system is aesthetically inoffensive - The system meets the needs of all household members and workers considering gender, age and social status and caste - The system is acceptable to the users and waste workers				
Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Everybody has access to the service and feels safe using it	+	+/-	+/-	Investments necessary to participate in all three options do not differ substantially, because the construction of the slab and the labour for the piping account for most of the costs. The low-income users have access to micro-credit schemes. For the lowest-income people special arrangements might be necessary. The investments can be the smallest in the first option, because the storage tank will be the smallest. Handling has to take place every day; there is no need choice in this. For the other two options the size will probably be (a little) higher to be sensible. For all three options there is a need to construct piping between the storage containers in the difficult to access streets. In all three options defecation takes places in the house where every one will feel safe using it.
The fee for the service fits within the expenditure pattern of the households	See next Section	See next Section	See next Section	This remains to be seen from the costs calculation in the next section. However, a small fee per month could be charged in each option. A large amount per year does not fit in the expenditure pattern.

Table 3 Social/Cultural Assessment

Policy criteria - The system is consistent with cultural and social values - The system is aesthetically inoffensive - The system meets the needs of all household members and workers considering gender, age and social status and caste - The system is acceptable to the users and waste workers				
Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Potential users have identified the sanitation service as a necessity	+/-	+/-	+/-	As explained in the chapter on Saboli the potential users have difficulty accepting the urine collection, because they cannot relate to (separate) urine as a good fertilizer. On top of this it looks like more effort in general and the users do not exactly know how to relieve oneself on the urine separation toilet slab. However, urine separation can be tolerated to make double vault system possible. This feeling is the same for all three options as in all three options urine separation takes place.
Potential users are involved in selecting the option most appropriate for their community	+	+	+	Like an employee of WASTE put it: “Choosing is using”. In all three options the users have to freedom how much one want to spend on the container in term of the quality of materials, type of toilet slab and water seal and in the last two options there is the choice in size of the storage container as well.
Users feel responsibility to manage and maintain their toilet and corresponding storage	+/-	+	+	The toilet and construction in the house does not differ in the three options and in the house people will feel the need to keep it clean and maintain it. For the first option regular maintenance is needed, because the decoupling construction and the container undergo wear and tear everyday. People could stop maintenance if this happens too often. Maybe a certain arrangement can be made that the collection service takes care of this. In the last two options there is no or not much need for maintenance.
A complaint mechanism is present	+	+	+	This is in itself possible for all three options. In all three options the users can observe whether the collection is done correctly.
Operation is done in a way that preserves the dignity of the workers	-	+	+	In the first option as explained in table 4 the pouring is prone to spill over the workers. Furthermore, the pouring will smell for the collector, because they are very close by all the time. In this option the dignity of the worker is affected. This is not the case in the options with where a pump is used for handling, because this can be seen as a closed circuit with little spillage and smell.

Table 3 Social/Cultural Assessment

Design criteria	Option 1 **Pouring in tricycle**	Option 2 **Tricycle & hand pump**	Option 3 **Tractor & pump**	**Explanation / Remarks**
Policy criteria - The system is consistent with cultural and social values - The system is aesthetically inoffensive - The system meets the needs of all household members and workers considering gender, age and social status and caste - The system is acceptable to the users and waste workers				
No association with manual scavenging	-	+/-	+	During interviews with Indian people everyone pointed out the service should not be associated with the manually scavenging. The first option does evoke associations with the manual scavenging. Although the opening in the container and tank is smaller than a bucket e.g. which makes contact with the material less and the material is much less harmfull, it has many similarities with the manual scavenging. On the other hand, the use of pumps and hoses make the material invisible and have a more mechanised charm around it; more so in the third option as in the second option still a lot of manual handling needs to be preformed. The association with manual scavenging is not just a social/cultural issue, it is also a political/legal issue. The manual handling of excreta is forbidden to stop the dehumanising practice. As explained above Option 1 could be regarded as illegal more easily.
Storage container must be located outside the house and not visible to the eye.	+/-	+	+	In all three options the container can be stored outside. In the second and third first option the container can be located under the ground, making it invisible. In the first storage should be done above ground and easy accessible, because the container needs to be taken out completely. This makes coverage difficult.
Collection vehicle is closed to avoid spillage and to hide the urine from the public eye.	-	+	+	During pouring the urine is visible to the public eye and during collection the tank is probably not closed as explained in Table 4. Handling through a hose hides the actual material. Furthermore, in the first option collection has to take place everyday instead of e.g. once a week or once a month as in the other two options. This means the collection vehicle has to go through the streets every day in each area, making the collection system very present for the community.
The users can not handling the urine themselves in any way	+	+	+	In none the options the user has to perform any handling actions. Maintenance could possibly be done by the collecting service.
Collection must not create tension and hassle	-	+/-	+	The less frequent the storage container has to be emptied the less the collection is perceived as hassle. Also, in case the collector does not collect the urine at the agreed times this is a big problem in the first option as the safety margin in the size can only be small, because the size of the container has to stay manageable for the collector during lifting. In the other two options the container can be as big as the user wants allowing for safety margin.

ANNEX 12 URINE - CALCULATION OF NUMBER OF TRIPS

The following tables give an overview of the breakdown of the calculation of the possible number of trips per day for the tricycle (without and with engine), the tractor for secondary collection and the tractor for direct transport.

Tricycles for primary collection (without and with engine): Calculation number of trips

Activity in one trip	**Assumptions**	**Remarks**
Driving to first house	Without engine: 12 minutes With engine: 10 minutes	
Handling per house + Driving to next house	Scenario in which collection takes place at individual houses: - Participation < 1000: 4 minutes per ‘house covered’ - Participation >= 1000: 3 minutes per ‘house covered’ Scenario in which houses are connected: 3 minutes	A distinction is made between a participation level of less than 1000 households and more than 1000 households for the driving time per house to the next house with a tricycle. As participation grows, the time it takes to travel to the next house is reduced. ‘house covered’ = Rounded up # Households covered in one trip (Average) In the scenario in which houses are connected together, the collector only needs to stop once to fill his whole collection tank.
Filling of tank	Capacity collection vehicle / 25 litres per minute	Speed of hand pump is assumed to be on average 25 litres per minute (depends on the effort of the collector)
Driving to transfer point	Without engine: 12 minutes With engine: 10 minutes	
Unloading	Without engine: 3 minutes With engine: 5 minutes	
Duration of one trip	*Sum of the above*	
Working minutes a day	420 minutes	7 hours to allow for breaks
# Trips possible per day	Working minutes a day Duration of one trip	

Tractor for secondary collection: Calculation number of trips

Activity in one trip	**Assumptions**	**Remarks**
Handling at transfer station	4 minutes	
Filling of tank	Capacity collection vehicle / 250 litre per minute	Speed of centrifugal pump is assumed to be 15 m^3 per hour
Driving to farmers	40 minutes	
Unloading	Capacity collection vehicle / 250 litre per minute	
Returning to transfer station	40 minutes	
Duration of one trip	*Sum of the above*	
Working minutes a day	420 minutes	7 hours to allow for breaks
# Trips possible per day	Working minutes a day Duration of one trip	

Tractor for direct transport: Calculation number of trips

Activity in one trip	**Assumptions**	**Remarks**
Handling per house + Driving to next house	- No connection between houses: 2 minutes per 'house covered' with a second operator - Connection between houses: 4 minutes	'house covered* = Rounded up # Households covered in one trip (Average) A second operator is advisable when each house has to be covered individually to reduce the handling time per house. The second operator could handle the pump and e.g. close and open the containers. This is why the handling is reduced to 2 minutes.
Filling of tank	Capacity collection vehicle / 250 litre per minute	Speed of centrifugal pump is assumed to be 15 m^3 per hour
Driving to farmers	40 minutes	
Unloading	Capacity collection vehicle / 250 litre per minute	
Returning to Saboli	40 minutes	
Duration on one trip	*Sum of the above*	
Working minutes a day	420 minutes	7 hours to allow for breaks
# Trips possible per day	<u>Working minutes a day</u> Duration of one trip	

ANNEX 13 URINE - INVESTMENT AND OPERATIONAL COSTS OF VEHICLES AND EQUIPMENT

The vehicles are operating under different conditions: running reasonably fast, moving very slowly and carrying heavy loads and light loads. Therefore the fuel consumption per hour is estimated. Estimates are very rough and should be further analysed, because the fuel consumption accounts for a large portion of the total costs of the vehicle.

The numbers are an average of several inquires by researcher on local markets and operators.

Investment and yearly cost of tricycle without engine

Investment costs	**Value**	**Assumptions**
Tricycle	6.000	New
Tank plastic 100 litre	350	3,5 rs per litre (Best quality plastic)
Hand pump	2.000	
Hose	250	
Total investment costs per vehicle	***8.600***	
Yearly capital costs		
Unit price	8.600	
Depreciation	1.720	5 years economic lifetime
Interest on capital	1.032	12% per year
Total capital costs per vehicle	*2.752*	
Yearly operational and maintenance costs		
Maintenance cost tricycle	1.500	Which comes to 20% of investment costs
Maintenance cost pump / hose	700	
Total O&M costs per vehicle	*2.200*	
Yearly labour costs		
One operator	*48.000*	(4000 rs/month x 12 months)
Costs per vehicle per year	***52.952***	

Investment and yearly cost of tricycle with engine

Investment costs	Value	Assumptions
Tricycle with engine	12.000	New tricycle with second hand engine
Tank plastic 300 litre	1.050	3,5 rs per litre (Best quality plastic)
Hand pump	2.000	
Hose	250	
Total investment costs per vehicle	***15.300***	
Yearly capital costs		
Unit price	15.300	
Depreciation	3.060	5 years economic lifetime
Interest on capital	1.836	12% per year
Total capital costs per vehicle	*4.896*	
Yearly operational and maintenance costs		
Petrol tricycle	100.160	2 litre/hr for 4 hr/day (60% drive-time in 7 hrs) a 40 rs/litre for 313 days/year
Maintenance cost tricycle	2.500	Which comes to 20% of investment costs
Maintenance cost pump / hose	700	
Total O&M costs per vehicle	*103.360*	
Yearly labour costs		
One operator	*48.000*	(4000 rs/month x 12 months)
Costs per vehicle per year	***156.256***	

Investment and yearly costs of tractor for secondary transport

Investment costs	Value	Assumptions
Tractor	75.000	Second hand
Trolley	25.000	Second hand
Plastic tank 3000 litre	10.500	3,5 rs per litre (Best quality plastic)
Suction hose	700	70 rs per metre (Good quality)
Total investment costs	***111.200***	
Yearly capital costs		
Unit price	111.200	
Depreciation	11.120	10 years economic lifetime
Interest on capital	13.344	12% per year
Total capital costs per vehicle	*24.464*	
Yearly operational and maintenance costs		
Diesel tractor	154.935	3 litre/hr for 5,5 hr/day (80% drive-time in 7 hrs) a 30 rs/litre for 313 days/year
Maintenance cost tractor	11.000	Which comes to 10% of investment costs
Total O&M costs per vehicle	*165.935*	
Yearly labour costs		
One driver	48.000	(4000 rs/month x 12 months)
Costs per vehicle per year	***238.399***	

Investment costs and yearly costs of basic transfer station

Investment costs		
Tank plastic 6000 litre	21.000	3,5 rs per litre (Best quality plastic).
Generator set with build in centrifugal pump	10.000	To load the tractor trolley or to unload the tricycles, depending on the type of transfer station chosen.
Hoses	1.000	
Construction costs + hand pump	10.000	In most basic form construction is only digging a hole in the ground to fit the tank in and installation of hand pump.
Total investment costs	***42.000***	
Yearly capital costs		
Unit price	42.000	
Depreciation	4.200	10 years economic lifetime
Interest on capital	5.040	12% per year
Total capital costs per station	*9.240*	
Yearly operational and maintenance costs		
Kerosene generator set	23.475	5 ltr/day a 15 rs/ltr x 313 days/year
Maintenance cost generator set and hand pump	2.000	
Maintenance cost hoses	1.000	
Total O&M costs per station	*26.475*	
Yearly labour costs		
-		
Costs per station per year	***35.715***	

Investment and yearly costs tractor for direct transport

Investment costs	**Value**	**Assumptions**
Tractor	75.000	Second hand
Trolley	25.000	Second hand
Plastic tank 3000 litre	10.500	3,5 rs per litre (Best quality plastic)
Generator set with build in centrifugal pump	10.000	
Suction hose (new)	700	70 rs per metre (Good quality)
Total investment costs	***121.200***	
Yearly capital costs		
Unit price	*121.200*	
Depreciation	*12.120*	10 years economic lifetime
Interest on capital	*14.544*	12% per year
Total capital costs per vehicle	*26.664*	
Yearly operational and maintenance costs		
Diesel tractor	154.935	3 litre/hr for 5,5 hr/day (80% drive-time in 7 hrs) a 30 rs/litre for 313 days/year
Kerosene generator set	9.390	(30 rs/day x 313 days/year (2 ltr/day a 15 rs/ltr))
Maintenance cost tractor	11.000	Which comes to 10% of investment costs
Maintenance cost generator set	1.000	
Total O&M costs per vehicle	*176.325*	
Yearly labour costs		
Scenario: Houses connected - One operator	48.000	(4000 rs/month x 12 months)
Scenario: Individual collection - Two operators	96.000	A second operator is advisable to reduce the handling time per house. The second operator could handle the pump and e.g. close and open the containers.
Costs per vehicle per year - Scenario: Individual collection	***298.989***	
Costs per vehicle per year - Scenario: Houses connected	***250.989***	

ANNEX 14 URINE – ESTIMATION OF AVERAGE (UN)LOADING TIME AT THE TRANSFER STATION

To calculate the capacity of the transfer station one needs an indication of the average (un)loading time per vehicle. This is different for the two options described in Section 7.2.3 as the handling in each option is different:

- *Transfer in intermediate tank*

In this case the tricycles can be unloaded by parking the tricycle next to the intermediate tank and attaching the hose of the intermediate tank to the opening at the bottom of the tricycle tank and open the small tap on the tricycle tank; then the urine will flow into the intermediate tank when it is underground. To empty the next tricycle one can just hand over the hose to the next tricycle and couple it to that. This can go quickly. Therefore, the total 3 and 5 minutes for respectively the handling at the transfer station for the 100 litre and 300 litre tricycles as determined for the calculation of the required number of tricycles is reduced to 1.5 and 2.5 minutes; every 1.5 and 2.5 minutes a tricycle of respectively 100 litres and 300 litres can be emptied. After the hose is decoupled from the vehicle the collector can get ready to move out again; this is not part of the time between two tricycles that can be emptied at the transfer station. The tractor trolley has to be loaded at the transfer station as well. This has to be done with the generator. This will take around 20-25 minutes for a 3000-litre tank.

When calculating the capacity of the transfer station one needs to take into account to what degree vehicles can be (un)loaded at the same time. With one generator only one tractor can be loaded at the time. By making more connections for the tricycles to unload the average unloading time per tricycle can be reduced considerably. To determine whether the tricycles or the tractors are the constraining factor for the capacity of the transfer station and how many connections for the tricycles are sensible one must realise that for every tractor load 30 and 10 tricycle loads of respectively the 100 litres and 300 litres tricycles have to be emptied to fill one 3000 litre tractor load. This means that with one connection for the tricycles it takes 45 minutes (= 30 loads * 1.5 min) or 25 minutes (= 10 loads * 2.5 min) unloading time for the tricycles to fill one tractor load. For the tractor it takes 25 minutes. This makes the tricycles the constraining factor in case of the 100 litre tricycles. In case of the 300 litre tricycles both the tricycles and the tractor take the same amount of time to fill one trolley load. By making an extra connection in case 100 litre tricycles are used for primary collection the 45 minutes unloading time for the tricycles drops to 22,5 minutes (= 45 min / 2) making the tractor the constraining factor. In that case the tractors loading time is the constraining factor when only one generator is used. This means the transfer station, as is calculated in Table 11, can serve 2900-6400 households. This would mean 2 to 3 transfer stations are needed in case 8000 households participate. Further increasing the capacity of the transfer station by installing and using more generators and making more connections for the tricycles is considered of no use. Two to three transfer stations is already the minimum quantity that the researcher advises considering that the area is spread geographical in two areas (of which one area has considerably more inhabitants making use for a second transfer station in that locality) to limit the transport time per trip for the primary collection tricycles.

- *Transfer directly in trolley*

The handling at this type of transfer station is a little different. The tricycles need to be unloaded with a pump into the trolley. This can be very quick as a new tricycle can be parked next to the tricycle already loading and the suction hose can immediately be put into the new tank. There is no need to first move the tricycle out of the way; one can just hand over the hose to the next tricycle. Therefore, the same average unloading time as estimated for the other option can be used; the 1.5 and 2.5 minutes for respectively 100 litre and 300 litre tricycle.

The tractor does not need to be loaded in this option. The tractor only needs to decouple the empty trolley and couple the new full trolley and he is ready to leave again. This makes the tricycles the constraining factor and the situation the same as in the previous option. The average unloading time of the tricycles needs to be reduced by half to reduce the number of transfer station from 3-5 transfer stations to 2-3 transfer stations. In this case installing an extra generator can reduce the average unloading time for the tricycles by half. The extra costs of the generator are small compared to constructing one or two whole transfer sites.

ANNEX 15 URINE – RESULTS – REQUIRED NUMBER OF VEHICLES

The following tables list the results of the analysis of the required number of vehicles for each scenario and for different participating household levels. The numbers indicate the required number of full-time employed vehicles. A ‘0.5’ tractor means a tractor is needed 50% part time; either he can work every other day or half a day each day (for the tractors for secondary collection this depends on when the tricycles are working, otherwise the transfer station might not be able to receive new material).
For the tricycle options there are also tractors needed for secondary collection and transfer station. These can be found in the following tables and are the same for both options. For the tractor option no other vehicles are needed besides the tractors for direct transport.

Tricycles without engine – *Required number of vehicles*

# Households	**No Connection - No Water Added**	**No Connection - Water Added**	**Connection - No Water Added**	**Connection - Water Added**
Frequency collection	7 days	7 days	Not applicable	Not applicable
Container size	100 litre	200 litre		
100	0,9	1,9	0,8	1,6
200	1,9	3,8	1,5	3,3
300	2,8	5,5	2,1	4,9
400	3,6	7,4	2,9	6,5
500	4,6	9,3	3,6	8,1
600	5,5	11,1	4,4	9,6
700	6,5	13,0	5,1	11,3
800	7,4	14,8	5,9	12,9
900	8,3	16,6	6,5	14,5
1000	8,6	17,5	7,3	16,1
2000	17,1	35,1	14,5	32,3
3000	25,6	52,6	21,9	48,4
4000	34,3	70,3	29,1	64,5
5000	42,8	87,8	36,4	80,6
6000	51,4	105,4	43,6	96,8
7000	59,9	122,9	51,0	112,9
8000	68,5	140,5	58,3	129,0

Tricycles with engine – *Required number of vehicles*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
Frequency collection	14 days	14 days	Not applicable	Not applicable
Container size	150 litre	300 litre		
100	0,4	0,8	0,3	0,6
200	0,8	1,4	0,6	1,3
300	1,1	2,1	0,9	1,9
400	1,5	2,9	1,1	2,5
500	1,9	3,5	1,4	3,1
600	2,3	4,3	1,8	3,8
700	2,6	5,0	2,0	4,4
800	3,0	5,8	2,3	5,0
900	3,4	6,4	2,6	5,8
1000	3,5	6,8	2,9	6,4
2000	7,0	13,6	5,8	12,6
3000	10,5	20,4	8,5	19,0
4000	14,0	27,3	11,4	25,3
5000	17,5	34,0	14,3	31,6
6000	21,0	40,8	17,1	38,0
7000	24,5	47,6	20,0	44,3
8000	28,0	54,4	22,9	50,6

Tractors for secondary collection – *Required number of vehicles*

# Households	No Water Added	Water Added
100	0,1	0,2
200	0,1	0,3
300	0,3	0,5
400	0,3	0,7
500	0,4	0,9
600	0,5	1,0
700	0,5	1,2
800	0,6	1,4
900	0,8	1,5
1000	0,8	1,7
2000	1,5	3,4
3000	2,3	5,1
4000	3,1	6,8
5000	3,9	8,5
6000	4,6	10,2
7000	5,4	12,0
8000	6,2	13,7

Transfer stations – *Required number of stations*

# Households	No Water Added	Water Added
1000	1	1
2000	1	1
3000	1	2
4000	1	2
5000	2	2
6000	2	3
7000	2	3
8000	2	3

Tractors for direct transport – *Required number of vehicles*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
Frequency collection	14 days	14 days	Not applicable	Not applicable
Container size	150 litre	300 litre		
100	0,1	0,3	0,1	0,1
200	0,2	0,4	0,1	0,4
300	0,4	0,6	0,3	0,5
400	0,5	0,9	0,3	0,6
500	0,6	1,1	0,4	0,9
600	0,7	1,3	0,5	1,0
700	0,9	1,5	0,5	1,3
800	1,0	1,8	0,6	1,4
900	1,1	1,9	0,8	1,5
1000	1,2	2,1	0,8	1,8
2000	2,5	4,3	1,5	3,4
3000	3,8	6,5	2,3	5,1
4000	5,0	8,6	3,1	6,9
5000	6,3	10,8	3,9	8,5
6000	7,5	12,9	4,6	10,3
7000	8,8	15,0	5,4	12,0
8000	9,9	17,3	6,1	13,6

ANNEX 16 URINE – RESULTS – TOTAL INVESTMENTS COSTS PER OPTION

The following tables list the total investment costs for each of the three options. These numbers are a result of multiplying the required number of vehicles (Annex 15) and the investment costs per vehicle (Annex 13)

Option Tricycle without engine – *Total investments costs in rs.*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
1000	198.500	387.100	187.750	375.275
2000	356.075	719.375	333.500	694.650
3000	512.575	1.106.475	480.325	1.069.925
4000	684.050	1.452.650	639.975	1.403.200
5000	882.550	1.783.850	827.725	1.722.575
6000	1.040.125	2.172.025	973.475	2.097.850
7000	1.196.625	2.517.125	1.120.300	2.431.125
8000	1.354.200	2.849.400	1.266.050	2.750.500

Option Tricycle with engine – *Total investments costs in rs.*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
1000	178.950	339.875	169.388	334.138
2000	315.900	625.763	296.775	610.463
3000	452.850	965.638	422.250	944.600
4000	603.700	1.265.425	563.538	1.234.825
5000	782.650	1.549.400	732.925	1.513.063
6000	919.600	1.889.275	860.313	1.847.200
7000	1.056.550	2.189.063	987.700	2.137.425
8000	1.193.500	2.473.038	1.115.088	2.415.663

Option Tractor - Direct transport – *Total investments costs in rs.*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
1000	145.440	257.550	90.900	212.100
2000	303.000	515.100	181.800	409.050
3000	454.500	787.800	272.700	621.150
4000	606.000	1.045.350	378.750	833.250
5000	757.500	1.302.900	469.650	1.030.200
6000	909.000	1.560.450	560.550	1.242.300
7000	1.060.500	1.818.000	651.450	1.454.400
8000	1.196.850	2.090.700	742.350	1.651.350

ANNEX 17 URINE – RESULTS – TOTAL YEARLY COSTS PER OPTION

The following tables list the total yearly costs for each of the three options. These numbers are a result of multiplying the required number of vehicles (Annex 15) and the yearly costs per vehicle (Annex 13).

Option Tricycle without engine – *Total yearly costs in rs.*

# Households	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
1000	655.216	1.370.183	589.026	1.297.374
2000	1.290.727	2.690.861	1.151.728	2.538.624
3000	1.919.618	4.061.044	1.721.048	3.835.998
4000	2.584.928	5.411.521	2.313.549	5.107.047
5000	3.240.144	6.725.580	2.902.575	6.348.297
6000	3.875.654	8.102.382	3.465.276	7.645.671
7000	4.504.546	9.446.240	4.034.597	8.916.720
8000	5.140.056	10.766.917	4.597.298	10.157.969

Option Tricycle with engine – *Total yearly costs in rs.*

# House -holds	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added
1000	752.020	1.498.251	654.360	1.439.655
2000	1.477.716	2.959.910	1.282.396	2.803.654
3000	2.203.411	4.458.161	1.890.899	4.243.309
4000	2.958.906	5.949.619	2.548.734	5.637.107
5000	3.710.926	7.391.746	3.203.094	7.020.638
6000	4.436.621	8.889.997	3.831.129	8.460.293
7000	5.162.317	10.381.455	4.459.165	9.854.091
8000	5.888.012	11.823.581	5.087.200	11.237.621

Option tractor - direct transport – *Total yearly costs in rs.*

# Households	No Connection No Water Added	No Connection Water Added	Connection No Water Added	Connection Water Added
1000	358.787	635.352	188.242	439.231
2000	747.473	1.270.703	376.484	847.088
3000	1.121.209	1.943.429	564.725	1.286.319
4000	1.494.945	2.578.780	784.341	1.725.549
5000	1.868.681	3.214.132	972.582	2.133.407
6000	2.242.418	3.849.483	1.160.824	2.572.637
7000	2.616.154	4.484.835	1.349.066	3.011.868
8000	2.952.516	5.157.560	1.537.308	3.419.725

ANNEX 18 URINE – RESULTS – CALCULATION ON COSTS FOR HOUSEHOLDS AND FARMERS

	No Connection - No Water Added	No Connection - Water Added	Connection - No Water Added	Connection - Water Added	Remarks
Total yearly costs for 8000 households (rs/year)					
Tricycle without engine	5.140.056	10.766.917	4.597.298	10.157.969	See Annex 17
Tricycle with engine	5.888.012	11.823.581	5.087.200	11.237.621	
Tractor - Direct transport	2.952.516	5.157.560	1.537.308	3.419.725	
Costs per litre urine (rs/litre)					
Tricycle without engine	0,29	0,60	0,26	0,56	Total yearly costs / Total transported litres of urine*
Tricycle with engine	0,33	0,66	0,28	0,62	
Tractor - Direct transport	0,16	0,29	0,09	0,19	
Monthly costs per household (rs/household/month)					
Tricycle without engine	54	112	48	106	Total yearly costs / Total number of households / 12 months or **
Tricycle with engine	61	123	53	117	
Tractor - Direct transport	31	54	16	36	
Yearly costs per hectare (rs/ha/year)					
Tricycle without engine	11.014	23.072	9.851	21.767	Total yearly costs / 467 ha (see Table 6.2)
Tricycle with engine	12.617	25.336	10.901	24.081	
Tractor - Direct transport	6.327	11.052	3.294	7.328	
Costs per big farmer (6 ha) per crop (rs/farmer/crop)					
Tricycle without engine	22.029	46.144	19.703	43.534	= Yearly costs per hectare x 6 ha / 3 crops a year or ***
Tricycle with engine	25.234	50.672	21.802	48.161	
Tractor - Direct transport	12.654	22.104	6.588	14.656	
Costs per small farmer (1.75 ha) per crop (rs/farmer/crop					
Tricycle without engine	6.425	13.459	5.747	12.697	= Yearly costs per hectare x 1,75 ha / 3 crops a year or ***
Tricycle with engine	7.360	14.779	6.359	14.047	
Tractor - Direct transport	3.691	6.447	1.922	4.275	

* Total transported litres of urine per year = 18.000.000 = 450 litre per person a year x 8000 households x 5 persons per household

** Monthly costs per household = Costs per litre urine x 450 litre per person a year x 5 persons per household / 12 months

*** Costs per farmer = Yearly costs per hectare x (Size of land of farmer / 0.035 ha fertilized per person a year) x 450 litre urine excreted per person a year

ANNEX 19 URINE - ADDITIONAL POINTS OF ATTENTION FOR THE CONSTRUCTION OF THE HOUSEHOLDS STORAGE CONTAINERS

Some general points of attention:

- The diameter of the inlet pipe needs to be as small as possible (1 inch) to keep ammonia losses to a minimum and thereby avoiding smell and nitrogen losses. As all parts of the inlet pipe can be vertical or at a high inclination (the toilets are mostly constructed higher than street level), the small diameter will probably not pose problems with regard to blockages.
- The outlet pipe can be 1 or 2 inch. The end of the outlet pipe should be located above the highest point that the floodwater will reach in the rainy season to still be able to empty it and to prevent water from coming in if the pipe is not closed properly.
- The pressure should be equalized, but the tanks must not be ventilated. An airlock might not be necessary if enough air can go through the inlet pipe and the outlet might not be airtight in practice.
- Care should be taken that the containers and pipes are resistant to the lifting forces of the water in case of floods.
- The old toilet slab needs be replaced by a urine-diverting slab. This can be done in concrete or ferro-cement or prefabricated units could be used. Local masons, if provided with the dimensions, can make the concrete or ferro-cement slabs. The prefabricated units are not locally availably, but can be obtained for example by the local NGO FODRA through WASTE, the partner in The Netherlands.

Some attention points for the option in which houses are connected:

- Concerning the diameter of the pipe and the problem of forming of sludge in the pipes much can learned from the report of Johansson. Johansson reports of the experiences in a full-scale operational system in several housing estates in Sweden based on a pipe system with holding tanks that are also emptied by tank truck. After two to three years of operation the following conclusions have been drawn based on observations and measurement:
  - The long-term effect of the formation of sludge in the pipe systems is not fully understood yet. It is difficult to avoid the formation of sludge, but it should not cause a problem if the inclination of the pipe systems is at least 1% and the diameter of the pipes are at least 75 mm (or even better 110 mm) in the case of horizontal pipes. At the bottom of the tanks a thin layer of sludge is formed, but this has not affect the emptying of the tanks. Studies indicate that any future problems will not be significant.
  - Where the inclinations were less than 1%, where there were back falls or when the diameter was too small, heavy, viscous sludge formed on the bottom, and this was considered likely to present future problems for the flow. However, the sludge did not adhere to the pipes and could easily be flushed out with a garden hose.

  In the construction as suggested in Figure 6 the urine is standing still in the pipes most of the time. This might give worse results. It should be further analysed if this is a technically sound construction.
- The pipe system should facilitate inspection, cleaning and clearance of blockages. A hole in the containers could provide access to the pipe system or separate pipes under an angel of 45º in the direction of the flow could be added. If the pipes need to be flushed with water the water could probably be diverted to the drains.

ANNEX 20 URINE - ADDITIONAL ISSUES THAT NEED ATTENTION BEFORE IMPLEMENTATION

- The users should be given instructions on how to clean the toilet and how to deal with blockages. Maybe some products can be harmful in the crop production, such as chemicals. Johnsson reports that in their project most of the stoppages that occurred in the toilet seals were easy to clear with a mechanical snake or brush and the harder stoppages could be dissolved with caustic soda solution.
- In order to increase the amount of urine that is collected and to ensure as little liquid enters the faeces chamber and to increase a cooperative attitude the toilets must be designed in such a way that men can stand up when urinating. Austin (2002) shows how a urinal can be made easily and cheaply using an ordinary 50 litre plastic container.
- It is likely that the present sweepers will find hand pumps difficult to work with at first and it may take some time for them to develop the arm muscles required for the continuous moving of the handle. They should also be instructed how to operate the pumps, especially the centrifugal pump with generator, and the couplings. If this is done properly there is no need for spillage on the floor and on themselves. A holder with detergent could also be added to the standard equipment of the collectors.
- With regard to the construction of the vehicles and containers it keep in mind that the vertical distance of the liquid to be pumped up and the pump itself needs to be kept as small as possible. This is an important factor for the effort required in the suction process. The centrifugal pumps need to be of the type dirty water pump instead of clean water pump.
- It should also be noted that with the expanding cities the nearby farmers might have to sell their land for (housing) development in the nearby future. When this happens the transport distances increase to other farmers that are able to stay.

ANNEX 21 FAECES - ASSESSMENT COLLECTION OPTIONS ON CRITERIA

Table 1 Health and environmental assessment

Policy criteria • The occupational and public health is safeguarded • Faeces and urine do not enter the direct living environment • Valuable resources are reused to the maximum extent			
Design criteria	**Option 1 Wet collection**	**Option 2 Dry collection**	**Explanation / Remarks**
No direct contact of workers with fresh faeces	-	+/-	During the wet collection there is no pre-treatment realised at the household. With suction, wet faeces can be collected in such a way that contact of the workers with wet faeces is little to none. The hose does not need to enter the tank at the household and when the pump is operated correctly there is no spillage. However, there probably will be spillage occasionally due to improper handling of the equipment. During these occurrences the workers could come into direct contact with wet faeces. When the workers wear protective clothing this could be prevented, but it is unlikely everyone will wear this. As for the dry collection of faeces, most of the pathogens will have died or become ineffective after a retention period of one year. Contact with the dried faeces is therefore much less dangerous. However, the household members must use considerably less water than they are used to for the faeces to dry to such an extent that it becomes harmless. It is likely that not every household member will fully adhere to this rule; it needs a level of understanding and a long-term view and most of all it will be very uncomfortable for a time when getting used to the new habit of using less water. For this reason there is a real risk that workers will be handling faeces that still contain a non-neglectable pathogens concentration. Together with the fact that the workers have a lot of contact with the faeces when digging all day, the risk of contamination should not be underestimated, because protective clothing is unlikely to be worn by everyone.
No or minimal occurrence of fresh faeces spillage during handling	+/-	+	When the pump and hose are handled not too hastily there is no spillage. Otherwise a little bit of black water might be spilled on the ground. Technically, a valve could be inserted in the suction line to prevent back flow when the pump is not running to further minimize spillage. A valve can be added in the discharge line as well to close off the tanks (when the transportation distance is long) to be on the safe side. Social pressure by the inhabitants to keep their streets clean might make the workers work carefully. Because of the higher collection frequency that is necessary for wet faeces collection, the number of times spillage can occur is higher. For the dry collection of faeces, dried faeces will be spilled on the ground during digging out the chambers. This can be dug up, but some faeces will be left on the ground. When the dry faeces have undergone primary treatment properly they will be not be harmful to the community. To remove more faeces a plastic sheet large enough to cover the area between the household and collection vehicle which can be picked up and shaken in the collection vehicle might help to remove more material if this is needed. During transport the trolley and tricycle can be closed to prevent faeces being spilled on the ground.

Table 1 Health and environmental assessment

Spillage consequences of failures should be limited and easily cleanable	+/-	+	During normal spillage occurrences for wet collection the quantity will be little. Maybe some detergent could be sprayed upon it to make the faeces harmless. In case the tank breaks or bursts and the contents spills on the ground, there is a serious problem that can not be easily cleaned up. However, this is very unlikely to happen as the tanks are very strong and do not suffer from wear and tear that much. A simple valve can also be added at the end of the discharge line to close off the tanks for safety in case the discharge line or pump malfunctions. For the dry collection of faeces, a little spillage of dried faeces will likely occur at each house during the digging out the chambers. This can easily be dug up, but some faeces will be left on the ground. When the dry faeces have undergone primary treatment properly they will not be harmful to the community. When the tricycles and trolleys are properly closed, no spillage will occur during transport.
Container and equipment is cleanable	+	+	The tank and equipment for the wet faeces are easily cleanable. The metal with its smooth surface can be rinsed with some water and detergent. The trolley and tricycle for dried faeces collection can also be cleaned with some water and detergent, but because the material is of wood it might need a little more scrubbing.
In case of fresh faeces collection the storage and transport container is watertight In case of drying of the faeces a double vault pit latrine is used	+	+	This is both achievable. Both options require initial investments from households: making the current pits watertight and making an outlet that helps to proper handle and store the material.

Table 2 Technical assessment

Policy criteria

- The system is easy to construct and maintain in the local context
- The system is robust enough to meet the exigencies of normal use
- The system is safe, user friendly and reliable
- The system is as cost efficient as possible

Design criteria	Option 1 Wet collection	Option 2 Dry collection	Explanation / Remarks
Suitable to the physical conditions of the area	+/-	+/-	The tricycle, the mini-tanker and the tractor construction will have difficulty with the physical conditions of the area. The tricycle mainly with the road conditions, which limit the weight the collector can take in one trip and the tractor with the width of the streets and the electrical poles. The mini-tanker and the tractor with the vacuum tank should have better wheels to cope with the extra weight of the vacuum construction in the roads. Solutions to cope with this are present in the form of taking less weight, going in with a wheelbarrow and lengthening the suction hose.
Vehicles and equipment are available on the local market and safe to use	+/-	+	Tractors, tricycles and trolley are widely available on the local markets. Vacuum tanks are also manufactured locally, but the researcher has not located mini-tankers. However, as the technology is available this should be possible.

Table 2 Technical assessment

Rely on locally widely available knowledge, skills, spare parts and materials for operation and maintenance	+/-	+	The tricycles, the tractor and trolley are widely used. Repair can be done everywhere. Knowledge on operation and maintenance of vacuum constructions is not widely available in this area. However, vacuum pumps are robust and knowledge is available in the city.
Handling is easy and quick	+/-	+/-	Vacuumpumps are quick, but the suction hose is a little difficult to handle, as the hose needs reinforcement. The digging out of the dried faeces is easy, but takes time.
Service is performed in the way and at the time that is agreed upon	+	+	In both options when the collector is late a few days there is room for margin, as the containers are large. A large safety margin should always be included to prevent that people will have to overflow the faeces in the open drains when the container is full.
The total weight of vehicles does not exceed the maximum allowed axle weight	+/-	+	The bad road conditions limit the weight the vehicles can take. However, with the heavy vacuum construction overloading might occur more quickly.
Critical sections are easy reachable and replaceable	+	+	In both options the critical sections are easy reachable and easy replaceable. The tricycle, tractor and trolley do not require special equipment and for the vacuum tank the hose is most critical. This is also very easy to replace and everywhere available. The pump is robust if operated correctly and in case of blockage repairable.
Use of vent pipe	+	+	For both options this can be added to the construction.

Table 3 Social/Cultural Assessment

Policy criteria

- The system is consistent with cultural and social values
- The system is aesthetically inoffensive
- The system meets the needs of all household members and workers considering gender, age and social status and caste
- The system is acceptable to the users and waste workers

Design criteria	Option 1 Wet collection	Option 2 Dry collection	Explanation / Remarks
Everybody has access to the service and feels safe using it	+	+	The investments necessary for the household construction are a little in the advantage for the wet collection, because one needs two sized chambers and the outgoing construction is a little more elaborate with a door instead of a simple outlet pipe. In both options the tanks need to be made watertight. However, the low-income users have access to micro-credit schemes. For the lowest-income people special arrangements might be necessary. In all three options defecation takes places in the house where every one will feel safe using it.
The fee for the service fits within the expenditure pattern of the households	-	+	A costs calculation has not been preformed (yet). However, for the wet faeces, collection would take place every few weeks and for the dry collection each year. As the costs for the wet collection are many times higher (see financial assessment) these monthly costs will probably be substantial. The yearly costs for the dry collection can be limited. Therefore, the dry collection still fits better within the expenditure pattern, although more frequent expenses fits better in the expenditure pattern.

Table 3 Social/Cultural Assessment

Potential users have identified the sanitation service as a necessity	+/-	+/-	As explained in the chapter 5 the potential users easily accept the dry collection of faeces, because they can relate to the production of fertilizer easily. The wet faeces collection is also acceptable to them, if the costs are not too high, because this is the general practice and it happens in a mechanised way. However, both options require money to transform the current pits and a collection fee might have to be paid. When people are not satisfied anymore with the service, because in their view they feel it does not bring improvements and it only costs money, people can easily start to overflow the faeces in the open drains again. This is true for both options.
Potential users are involved in selecting the option most appropriate for their community	+	+	In both options the user has freedom how much one wants to spend in terms of the quality of materials, the type of toilet slab, a water seal, the size of the chamber if one chooses to adjust the current pits and the construction of the outlet for the dry collection of faeces.
Users feel responsibility to manage and maintain their toilet and corresponding storage	+	+/-	The toilet and construction in the house does not differ for both options (both options require to use as little water as possible) and in the house people will feel the need to keep the toilet clean. There is not much need for maintenance. However, managing the toilet in the sense of using little water, it is likely that not every family member will not fully adhere to this rule; it needs a level of understanding and a long-term view and most of all it means being very uncomfortable for a long time when people must use less water. For both options this is a problem as it increases the collection costs, but for the dry collection of faeces the consequences are larger. The dry collection will not be achievable in that case and the collector has to empty not fully dried faeces and/or people will start to overflow the faeces again in the drains.
A complaint mechanism is present	+	+	This is in itself possible for both options. In both options the users can observe whether the collection is done correctly.
Operation is done in a way that preserves the dignity of the workers	+	+/-	For the wet collection where a pump us used for handling, smell and spillage will be little, because of the closed circuit nature of pumping. Dried faeces do not smell and are not dirty to handle. In that way the dignity of the workers is not affected. However, people still have the tendency to associate the digging out of dried faeces with manual scavenging of fresh faeces and perceive it as an unclean thing to do. The dignity of the workers is affected in this way, because people will still disapprove of them as a result of this. Furthermore, when the workers come across a chamber that does not have completely dried faeces and they go ahead with emptying it, the situation is indeed going back to the manual scavenging.
No association with manual scavenging	+	+/-	The use of pumps and hoses make the material invisible. These mechanised ways of handling have no association with manual scavenging. The digging out of the dried faeces does evoke associations with manual scavenging. Although the faeces do not smell anymore and look very differently and are much less harmful, it has many similarities with manual scavenging in the minds of people. However, when people see with their own eyes what the dried faeces look like, this associated might lessen.

Table 3 Social/Cultural Assessment

Collection vehicle is closed to avoid spillage and to hide the faeces from the public eye	+	+/-	Handling through a hose hides the actual material and the tank is closed at all times as well. The dried faeces on the other hand, are visible during digging. The tricycle itself can have a covering.
The users can not handle the faeces themselves in any way	+	+	In both options the user does not have to perform any handling actions.
Collection must not create tension and hassle	+/-	+	The less frequent the storage container has to be emptied the less the collection is perceived as a hassle. The dry collection is therefore preferable, although a collection frequency of once a month is not too bad either. Furthermore, both options allow for building in safety margins in the size of the container which can limited the tension that is created when the collector does not show up at the agreed times.

Table 4 Financial assessment

Policy criteria

- The system is affordable to all households in the community
- The costs are affordable for the community as a whole
- Economic use of scare resource such as money, energy, space, land and water

Design criteria	**Option 1 Wet collection**	**Option 2 Dry collection**	**Explanation / Remarks**
Reasonable price for the service performance (price/quality performance)	-	+	The collection costs for the wet collection will be much higher than for the dry collection for two reasons: - the much higher collection quantity (generation quantity is more than 10 times as large); - the more expensive technology that has to be used for this (pumping with vacuum instead of digging with fawari; a vacuum tank construction needs thick sheets of steel to be able to hold the vacuum build up in the tank making it expensive)); Although the costs for collection have not been calculated yet, it is likely that the dry collection can be offered at an affordable price, because the equipment is similar to the solid waste collection and the collection quantity and frequency is smaller per year. When looking further to treatment and reuse the costs for wet collection are also much higher, because primary treatment has not taken place yet and the material to be treated is much more; now a huge amount of water has to be taken care of next to the faeces. Reuse of dry faeces can be done the traditional way with the bullock cart and fawaris and a tractor can be hired for ploughing as is already done. Reuse of wet faeces, if treatment does not deliver dry faeces, requires a new way of application that probably requires new equipment (maybe sludge spreader tanks and large watertight storage vaults at the farmers).
Affordable price for the users	-	+	See above, the collection costs will be much higher for the wet collection of faeces.
Affordable costs and reasonable benefits for the community (municipal)	-	+	See above, the collection costs will be much higher for the wet collection of faeces and the health risks for the community will also be equal or higher with the wet faeces collection (see health assessment).

Table 4 Financial assessment

Reasonable income for the employees	-	+	Because of the high costs of the wet collection there is not much room for the collector to have an (reasonable) income.
The advantages of the service should be competitive with existing practices	-	+	Although the current health problems could be reduced as a result of the wet collection of faeces, this will be at such high costs that one cannot consider it competitive with the existing practices probably. This is certainly true compared to the dry collection of faeces where the same or better health benefits can be attained at much lower costs.
Required initial investments should be limited	-	+/-	Both options need a tractor for secondary collection, a large investment. On top of this the vehicles for the wet collection need to be equipped with expensive vacuum technology. The mini-tankers are also much more expensive than a simple tricycle for dry faeces collection.

ANNEX 22 FAECES - CALCULATION OF NUMBER OF TRIPS

The following tables give an overview of the breakdown of the calculation of the possible number of trips per day for the tricycle (without and with engine), the tractor for secondary collection and the tractor for direct transport.

Tricycle for primary collection (with and without engine: Calculation number of trips

Activity in one trip	Assumptions		Remarks
	Without engine	**With engine**	
Driving to first house	8 minutes	5 minutes	Driving time is little as the trolley for secondary collection can be placed nearby.
Handling per house + Driving to next house	20 minutes per house		Depends highly on the design of the vault and the emptying mechanism: e.g. digging the faeces out or a easy container that can be pulled out. Chosen is a conservative handling time.
	22 minutes (1,1 houses per trip)	67 minutes (3,3 houses per trip)	
Driving to transfer point	8 minutes	5 minutes	See Driving to first house
Unloading	8 minutes	12 minutes	
Duration of one trip	*46 minutes*	*89 minutes*	
Working minutes a day	420 minutes		7 hours to allow for breaks
# Trips possible per day	*9.1 trips per day*	*4.7 trips per day*	= Working minutes a day / Duration of one trip

Tractor for secondary collection: Calculation number of trips

Activity in one trip	Assumptions	Remarks
Handling at transfer station	15 minutes	Manoeuvring at the transfer station, (de)coupling, covering the trolley if necessary, and driving the trolley to a new transfer point if necessary.
Driving to farmers	40 minutes	
Unloading	90 minutes	One persons shoving out the faeces.
Returning to transfer station	40 minutes	
Duration of one trip	*185 minutes*	
Working minutes a day	420 minutes	7 hours to allow for breaks
# Trips possible per day	*2.3 trips per day*	= Working minutes a day / Duration of one trip

Tractor for direct transport: Calculation number of trips

Activity in one trip	Assumptions	Remarks
Handling per house + Driving to next house	20 minutes per house Result: 667 minutes (33,3 houses)	A second operator is advisable to keep the handling time per house low. As not every house is accessible for the tractor construction, the second operator can operate the wheelbarrow and/or help with the baskets. The result is the same handling time as wit the tricycle collection.
Driving to farmers	40 minutes	
Unloading	60 minutes	
Returning to Saboli	40 minutes	
Duration on one trip	*807 minutes*	
Working minutes a day	420 minutes	7 hours to allow for breaks
# Trips possible per day	*0.5 trips per day*	= Working minutes a day / Duration of one trip

ANNEX 23 FAECES - INVESTMENT AND OPERATIONAL COSTS OF VEHICLES AND EQUIPMENT

The vehicles are operating under different conditions: running reasonably fast, moving very slowly and carrying heavy loads and light loads. Therefore the fuel consumption per hour is estimated. Estimates are very rough and should be further analysed, because the fuel consumption accounts for a large portion of the total costs of the vehicle.

The numbers are an average of several inquires by researcher on local markets and operators.

Investment and yearly cost of tricycle without engine

Investment costs	**Value**	**Assumptions**
Tricycle	6.000	New
Covering for tricycle	1.000	
Shovel + Basket	500	
Total investment costs per vehicle	***7.500***	
Yearly capital costs		
Unit price	7.500	
Depreciation	1.500	5 years economic lifetime
Interest on capital	900	12% per year
Total capital costs per vehicle	*2.400*	
Yearly operational and maintenance costs		
Maintenance cost tricycle	1.500	Which comes to 20% of investment costs
Total O&M costs per vehicle	*1.500*	
Yearly labour costs		
One operator	*48.000*	(4000 rs/month x 12 months)
Costs per vehicle per year	***51.900***	

Investment and yearly cost of tricycle with engine

Investment costs	**Value**	**Assumptions**
Tricycle with engine	12.000	New tricycle with second hand engine
Covering for tricycle	1.000	
Shovel + Basket	500	
Total investment costs per vehicle	***13.500***	
Yearly capital costs		
Unit price	13.500	
Depreciation	2.700	5 years economic lifetime
Interest on capital	1.620	12% per year
Total capital costs per vehicle	*4.320*	
Yearly operational and maintenance costs		
Petrol tricycle	36.960	2 litre/hr for 1.75 hr/day (25% drive-time in 7 hrs) a 40 rs/litre for 264 days/year
Maintenance cost tricycle	2.500	Which comes to 20% of investment costs
Total O&M costs per vehicle	*39.460*	
Yearly labour costs		
One operator	*48.000*	(4000 rs/month x 12 months)
Costs per vehicle per year	***91.780***	

Investment costs and yearly costs for transfer

Investment costs		
Trolley	25.000	Second hand
Covering + Bench/platform (two)	3.000	
Total investment costs	***28.000***	
Yearly capital costs		
Unit price	28.000	
Depreciation	2.800	10 years economic lifetime
Interest on capital	3.360	12% per year
Total capital costs	*6.160*	
Yearly operational and maintenance costs		
O&M costs trolley and equipment	3.000	Which comes to 10% of investment costs
Total O&M costs	*3.000*	
Costs per transfer per year	***9.160***	

Investment and yearly costs of tractor for secondary transport

Investment costs	**Value**	**Assumptions**
Tractor	75.000	Second hand
Trolley	25.000	Second hand
Covering + Bench/platform (two) + Shovel	3.000	
Total investment costs	***103.000***	
Yearly capital costs		
Unit price	103.000	
Depreciation	10.300	10 years economic lifetime
Interest on capital	12.360	12% per year
Total capital costs per vehicle	*22.660*	
Yearly operational and maintenance costs		
Diesel tractor	83.160	3 litre/hr for 3,5 hr/day (50% drive-time in 7 hrs) a 30 rs/litre for 264 days/year
Maintenance cost tractor	10.000	Which comes to 10% of investment costs
Total O&M costs per vehicle	*93.160*	
Yearly labour costs		
One person	48.000	(4000 rs/month x 12 months)
Costs per vehicle per year	***163.820***	

Investment and yearly costs tractor for direct transport

Investment costs	**Value**	**Assumptions**
Tractor	75.000	Second hand
Trolley	25.000	Second hand
Covering + Bench/platform (two) + Shovel	3.000	
Wheelbarrow (two) + Basket	4.000	
Total investment costs	***107.000***	
Yearly capital costs		
Unit price	*107.000*	
Depreciation	*10.700*	10 years economic lifetime
Interest on capital	*12.840*	12% per year
Total capital costs per vehicle	*23.540*	
Yearly operational and maintenance costs		
Diesel tractor	33.264	3 litre/hr for 1,4 hr/day (20% drive-time in 7 hrs) a 30 rs/litre for 264 days/year
Maintenance cost equipment	7.500	7% of investment costs (vehicle is standing still most of the time)
Total O&M costs per vehicle	*40.764*	
Yearly labour costs		
Two operators	*96.000*	
Costs per vehicle per year	***160.304***	