

Logistic Aspects of Ecological Sanitation in Urban Areas

Case study in Low-Income Community in Delhi, India



ISSUE Case Study



Marieke Slob

University of Twente
The Netherlands

Stan Maessen supervisor

October 2005



Nieuwehaven 201
2801 CW Gouda
The Netherlands

fax: +31 182 550313
e-mail: office@waste.nl
website: <http://www.waste.nl>

Logistic Aspects of Ecological Sanitation in Urban Areas

Case Study in Low-Income Community in Delhi, India

Type of report	Master Thesis
Author	Ing M. Slob
Supervisors University of Twente	Dr P.C. Schuur (Industrial Engineering & Management) Dr I. van der Molen (Technology and Sustainable Development Group) Enschede – The Netherlands
Supervisor WASTE	Ir S. Maessen (Sanitation Advisor) Gouda - The Netherlands
Period	September 2004 – October 2005



Copyrights

The research for this thesis received financing from the Netherlands Agency for International Cooperation (DGIS), Ministry of Foreign Affairs. The content of this thesis is fully the responsibility of the author. Citation is encouraged. Short excerpts may be translated and/or reproduced without prior permission, on condition that the source is indicated. For translation and/or reproduction in whole, WASTE, or the author should be notified in advance. This publication does not constitute an endorsement from the financier.

ACKNOWLEDGEMENTS

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 ($\pm \text{€}75$) 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.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	1
EXECUTIVE SUMMARY	3
LIST OF TABLES AND FIGURES	8
GLOSSARY	11
1 INTRODUCTION	13
1.1 Background	13
1.2 Problem definition	14
1.3 Research questions	18
1.4 Methodology	20
1.5 Scope and limitations	22
1.6 Outline report	22
2 FRAMEWORK – CRITERIA FOR A GOOD TRANSPORT SYSTEM	24
2.1 The Integrated Sustainable Waste Management concept	24
2.1.1 Principles of ISWM	24
2.1.2 Dimensions of ISWM	25
2.1.3 Usage of ISWM in this research	27
2.2 Specific characteristics of excreta removal in EcoSan projects	27
2.3 Context of India	30
2.4 Criteria logistics system	33
3 CURRENT SANITATION AND SOLID WASTE COLLECTION PRACTICES AND LOGISTIC ORGANISATION	36
3.1 Current sanitation practices	36
3.1.1 Current status and organisational structure	36
3.1.2 Current methods	38
3.2 Current solid waste collection practices	39
3.2.1 Current status and organisational structure	39
3.2.2 Methods	39
4 MAIN LOGISTIC SYSTEMS	43
4.1 Overview main logistic systems	44
4.2 Appropriateness of main systems and choice for system	45
4.3 Parameters of the chosen system	46
4.4 Factors to consider when selecting a collection and transportation vehicle	49
5 SOURCE OF URINE AND FAECES – HOUSEHOLDS IN SABOLI COMMUNITY	50
5.1 Context of Saboli	50
5.2 Current sanitation, solid waste disposal and health situation	54
5.3 Constraints and viewpoints of the Saboli community on EcoSan	57
5.3.1 Toilet and water use	57
5.3.2 Storage	58
5.3.3 Collection	59
5.3.4 Transfer	61
5.3.5 Financial aspect	61

5.3.6	Summary	62
6	DESTINATION OF URINE AND FAECES - FARMERS NEARBY SABOLI COMMUNITY	63
6.1	Context of nearby farmers	64
6.2	Current type of fertilizer usage, storage and application method	65
6.3	Basic research needed to be able to interview farmers	66
6.3.1	Amount of urine and faeces to apply to the field	66
6.3.2	Guidelines for (safe) use of excreta in agriculture	67
6.3.3	Options for application and storage	69
6.4	Constraints and viewpoints of the farmers on EcoSan	74
6.4.1	Application	74
6.4.2	Storage	75
6.4.3	Transport	75
6.4.4	Summary	75
7	LOGISTICS - URINE COLLECTION AND TRANSPORT	77
7.1	Different scenarios of collection situation	77
7.2	Possible collection and transport options	80
7.2.1	Handling options	80
7.2.2	Collection and transport means	80
7.2.3	Transfer options	82
7.2.4	Putting the options together - Summary	84
7.3	Comparison of the different options for collection and transport	84
7.4	Cost calculation acceptable options	86
7.4.1	Input	87
7.4.2	Analysis	90
7.4.3	Results	96
7.4.4	Financial assessment	101
7.5	Thoughts on the design of household urine container	103
7.6	Related issues that need attention before implementation	104
7.7	Summary	106
8	LOGISTICS - FAECES COLLECTION AND TRANSPORT	108
8.1	Dry and wet collection of faeces	108
8.2	Comparison of the two system: wet and dry collection	113
8.3	Possible collection and transport options for dry collection	116
8.4	Cost calculation	117
8.4.1	Input	117
8.4.2	Analysis	119
8.4.3	Results	125
8.5	Thoughts on the design of the double vault system at the household	127
8.6	Related issues that need attention before implementation	130
8.7	Summary	132
8.8	Integration of faeces, urine and solid waste collection services	132
9	CONCLUSIONS AND RECOMMENDATIONS	136
9.1	Conclusions	136
9.2	Recommendations	139
9.3	Recommendations for further research	140

REFERENCES	142
LIST OF ANNEXES	146

LIST OF TABLES AND FIGURES

List of Tables

Table 2.1	Generation quantities per person per year	21
Table 2.2	Characteristics of urine and its consequences for storage and handling	29
Table 2.3	Characteristics of faeces and its consequences for storage and handling	29
Table 2.4	Set of policy and design criteria for a good transport system	32
Table 4.1	Overview of main logistic systems	42
Table 4.2	Appropriateness of main logistic systems	45
Table 4.3	Basic parameters of logistic system	46
Table 4.4	Factors affecting vehicle selection	47
Table 5.1	Saboli community: general figures	51
Table 5.2	Saboli community: income level	52
Table 5.3	Saboli community: sanitation figures	53
Table 5.4	Saboli community: water use for toilet related activities	56
Table 5.5	Saboli community: summary of viewpoints, concerns and criteria for EcoSan	60
Table 6.1	Fertilizer usage of farmers	63
Table 6.2	Figures on the amount of urine, faeces and land required	66
Table 6.3	Practical handling guidelines for reuse in agriculture	67
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	70
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	70
Table 6.6	Farmers: summary of viewpoints, concerns and criteria for EcoSan	74
Table 7.1	Calculation of amount to be collected per day	77
Table 7.2	Possible scenarios for collection situation	77
Table 7.3	Characterization of remaining options for assessment	83
Table 7.4	Assessment of remaining options	84
Table 7.5	Input assumptions for costs calculations	86
Table 7.6	Overview of investment and yearly costs of the different vehicle combinations and transfer stations	86
Table 7.7	Analysis of required number of vehicles for collection from individual houses	88
Table 7.8	Analysis frequency of collection in case of individual house collection	90
Table 7.9	Analysis of required number of vehicles for collection at one spot	92
Table 7.10	Calculation of capacity of transfer station	94
Table 7.11	Insight in required size of the household storage container	94
Table 7.12	Total investment costs and number of vehicles and employees required	95
Table 7.13	Total yearly costs and costs per litre of the different options and scenarios	97
Table 7.14	Financial assessment of the different options	99
Table 7.15	Investment cost for installation of a urine-diverting toilet for a household	102
Table 8.1	Generation quantity for wet collection of faeces	107
Table 8.2	Generation quantity for dried collection of faeces	110
Table 8.3	Specific options for wet and dry collection of faeces	110
Table 8.4	Assessment of wet and dry collection of faeces	111
Table 8.5	Input assumptions for costs calculations	115
Table 8.6	Overview of investment and yearly costs of the different vehicle combinations and transfer stations	115
Table 8.7	Analysis of required number of vehicles when the vehicles/collectors work all year	118

Table 8.8	Required number of vehicles for different participation levels when the vehicles/collectors work all year	119
Table 8.9	Analysis of required number of workdays with a certain number of vehicle - collector combinations	119
Table 8.10	Required number of workdays when employing a certain number of vehicle collector combinations	120
Table 8.11	Total investment and yearly costs and size of fleet indicators for the different options	121
Table 8.12	List of factors that influence the required capacity of each vault	126
Table 8.13	Incoming volume into the vault	126

List of Figures

Figure 1.1	The waterborne sanitation system or “flush-and-discharge” model	11
Figure 1.2	The simple pit latrine or “drop-and-store” model	11
Figure 1.3	Closed loop diagram of EcoSan: linking defecation and agriculture	14
Figure 1.4	A house where faeces, urine and grey water are separated	13
Figure 1.5	Several examples of urine-diverting slabs	14
Figure 1.6	An example of a double vault system	15
Figure 1.7a	Schematic overview of transport requirements in an on-site system	16
Figure 1.7b	Schematic overview of transport requirements in a system where reuse takes place outside community	16
Figure 2.1	The ISWM model for Ecological Sanitation	24
Figure 2.2	Areas to investigate for each sustainability aspect in ISWM	25
Figure 2.3	Pictures of initial set-up of the Bangalore Public Toilet Project	27
Figure 3.1	A bucket latrine	36
Figure 3.2	A pit latrine with vent pipe	36
Figure 3.3	A septic tank	36
Figure 3.4	The solid waste collection process	39
Figure 4.1	Distinction between direct transport and transport with a transfer	42
Figure 4.2	Overview of logistic chain with primary and secondary collection	46
Figure 5.1	Location of Saboli within the State Delhi	49
Figure 5.2	Location of Saboli at edge of the city Delhi with farmland nearby	50
Figure 6.1	Different processes in a batch	68
Figure 6.2	Situation: Minimum batch period is shorter than or equal to period between two fertilizations	70
Figure 6.3	Situation: Minimum batch period longer than period between two fertilizations and shorter than two times the period between two fertilizations	70
Figure 7.1	Overview of collection and transport chain for the tractor and tricycle options	85
Figure 7.2	Trade-off for collection frequency in case of individual house collection	90
Figure 7.3	Monthly costs per household for the different options	96
Figure 7.4	Costs to fertilize one hectare of farmland per year	96
Figure 7.5	Side-view of an urine-diverting construction, an example	100
Figure 7.6	Side-view of how construction might be when the urine containers are connected to each other	100
Figure 7.7	Logistics – Urine collection and transport: A summary	105
Figure 8.1	Transfer with the help of a movable bench or platform	114
Figure 8.2	An example of a general double vault system when one chooses to dig the faeces out	124
Figure 8.3	Collection of faeces in containers	124
Figure 8.4	A carousel composting toilet	124
Figure 8.5	Logistics – Faeces collection and transport: A summary	129
Figure 8.6	Overview for which services each vehicle or piece of equipment can or needs to be employed	130

List of Photos

Photo 3.1 Street sweeping and primary collection	39
Photo 3.2 Different types of transfer points in Delhi and their handling methods	40
Photo 3.3 Sorting by waste pickers	41
Photo 5.1 The open drains in Saboli	51
Photo 5.2 Throwing of the waste and wastewater in nearby open plots	54
Photo 5.3 Collection vehicle of solid waste collector	55
Photo 5.4 The solid waste collector using a fawari to pick up some waste from the street	58
Photo 6.1 To irrigate the land, the land is divided in small plots separated by small earthen border ridges	62
Photo 6.2 Animal drawn cart that is used to apply the animal manure on the field	64
Photo 7.1 Constraining road conditions in Saboli	76
Photo 7.2 Example of tricycle with engine	78
Photo 7.3 Example of hand pump (semi-rotary pump)	78
Photo 7.4 Example of tractor with trolley	80
Photo 8.1 Wet collection of faeces: manually emptying of pits	106
Photo 8.2 Wet collection of faeces: use of vacuum tankers	107
Photo 8.3 Wet collection of faeces: an example of a mini vacuum tanker and transfer	108
Photo 8.4 Dried collection of faeces: use of double vault system and the result	108
Photo 8.5 A closed body tricycle and the heightened sides of a tricycle body	126

List of Boxes

Box 5.1 General reactions of sweepers to EcoSan	48
Box 6.1 Willingness of farmers to apply excreta	72
Box 6.2 Financially deprived	126