EAWAG
Swiss Federal Institute for Environmental Science & Technology

SANDEC News

Water & Sanitation in Developing Countries
Ueberlandstrasse 133 • CH-8600 Duebendorf/SWITZERLAND
Tel. +41-1-823 52 86 Fax +41-1-823 53 99

SANDEC News No. 2, October 1996
ISSN 1420-5572

CONTENTS

Non-Governmental Refuse Collection Systems

by Roger Pfammatter and Roland Schertenleib

Abstract

Although urban governments of low and middle-income countries increasingly acknowledge solid waste as an immediate and serious environmental health problem, it is mostly beyond their means to collect the growing amount of waste generated by the rapidly expanding cities. SANDEC therefore decided to review selected non-governmental schemes as alternative to municipal primary collection of household waste in unserved peri-urban areas. The lessons learned from the review of 18 operating systems have recently been published as SANDEC Report No. 1/96. This article is a summary of that report.

Door-to-door collection with manually operated handcarts, pushcarts or donkey carts is the most widespread and promising option for primary collection among the reviewed cases. (Photo: SANDEC)

Background

Solid waste is one of the most immediate and serious environmental problems confronting urban governments of low and middle-income countries. Although the responsible administrations increasingly acknowledge the importance of adequate waste collection and disposal, it is mostly beyond their means to handle the growing amount of waste generated by the rapidly expanding cities. Insufficient collection of household waste is thereby one of the most critical problem areas [1]. Many city administrations fail to provide this basic public service to a large section of the urban population, leaving often more than 50% of the households underserved.

As a result, tons of household waste are indiscriminately dumped on roads, into open drains, rivers and surrounding areas, thus posing a serious health risk to the population and leading to a general degradation of the living environment for millions of people. The problem is most acute in low-income peri-urban areas, and particularly impairs the quality of life of the poorer communities. However, indiscriminate dumping on a large scale is likely to affect the welfare of the entire urban population and to have negative impacts also on the national economies.

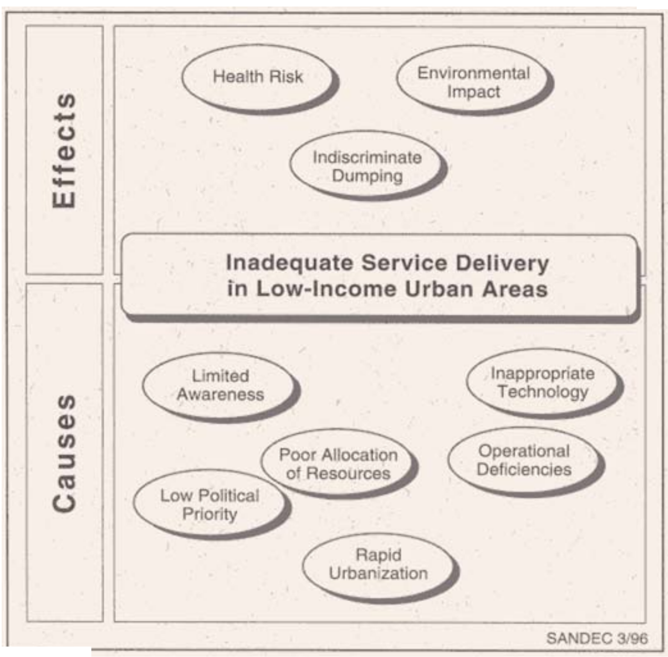


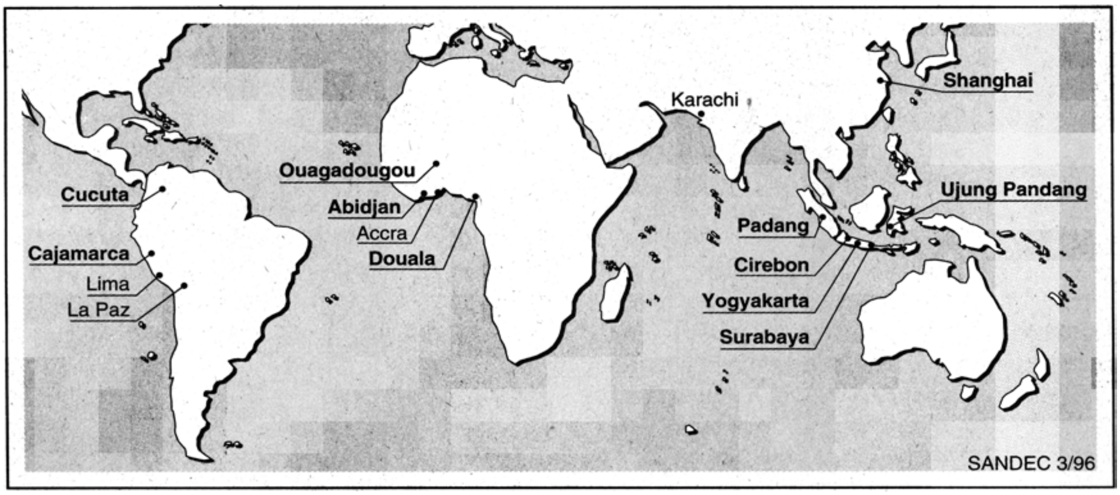
Figure 1: Causes and effects of inadequate service delivery in low-income urban areas

Rapid and often unregulated urban growth is the major cause for the inadequate service coverage (Fig. 1). Local authorities have difficulties in keeping pace with this development and meeting the growing demand for basic infrastructure and public services. As a result of continuous migration and insufficient planning, housing areas are often poorly accessible, and make the collection of waste with conventional trucks difficult or even impossible. Other reasons, which include deficiencies in the operation of SWM schemes and use of inappropriate technologies, lead to an inefficient use of time and resources. Since municipal authorities tend to allocate the available resources and services to the richer areas with higher income tax yields and greater political influence, mainly low-income peri-urban areas remain unserved with the aforementioned consequences. Finally, political priority and social prestige of those dealing with waste are still very low and limit rapid and sustainable improvements associated with SWM.

Alternative Approach

A realistic approach to improve this deplorable situation would be for the inhabitants of unreached areas to assume their own responsibilities with regard to waste handling. They could set up a collection system appropriate to their economic standing and adapted to the conditions of the area. This can take different forms; i.e., the community either pays private collectors from within or outside the neighbourhood to carry the waste to communal collection points, or the households assume responsibility for part of the work. Such types of non-governmental primary refuse collection schemes have been initiated and operated in different cities of Asia, Africa and Latin America over the past few years. Owing to the limited amount of literature on the experience gained, and to the great number of people and institutions looking for alternatives to improve solid waste collection, SANDEC decided to review a number of selected cases (Fig. 2) to assess the potentials and limitations of such non-governmental approaches based on practical experience [2]. The reviewed cases thereby range from community-based schemes in Indonesia, China and some parts of Africa (i.e., Burkina Faso, Ivory Coast and Cameroon), to schemes operated and managed by small private enterprises in Peru and Colombia.

Figure 2: Location of reviewed non-governmental refuse collection schemes



Operating Options

The main options for primary collection and communal storage observed in the reviewed cases include the following systems (Fig. 3):

Communal storage or bring-system (I)

Where households are willing to carry their waste to a communal storage point, the bring-system is an option requiring serious consideration. It is an institutionally uncomplicated system and the cheapest alternative in terms of cash requirements. However, considerable input from the inhabitants and an increased awareness of the population is a pre-condition for successful operation of this system. Furthermore, the communal storage points have to be sited within a reasonable distance from the households to be accepted by the users. According to observations in China and Africa [3, 4], the distance which most beneficiaries seem prepared to carry their waste is 50 m to max. 100 m.

Tricycles as mobile collection points (Ia)

A varied form of communal storage has been observed in Shanghai (China) where citizens carry the refuse about 50 m to a "mobile" collection point; i.e., a passing collector with handcart or tricycle. This system had to be introduced as larger communal storage facilities were used (steel containers of 10 m^3) to reduce the number of required collection points. This, however, increased the average distance from the households to more than the acceptable 100 m. "Mobile" collection points therefore offer a form of collection within the reach of the households.

Door-to-door collection with handcarts (II)

The door-to-door collection with manually operated carts is the most widespread and promising option among the reviewed cases. The household contribution is minimal and limited to carrying the refuse to the roadside. The waste is then collected by individual collectors with handcarts, tricycles (Indonesia), or donkey carts (Burkina Faso), and brought to collection points for transfer to larger transport vehicles. In serving households door-to-door, this system is likely to prevent people from throwing the garbage elsewhere. Use of handcarts has proved most suitable for conditions generally prevailing in low-income areas; i.e., with narrow streets, low generation rates and low wages. Carts are also cheap to manufacture and operate, quite simple in design, and can be produced and maintained locally - all of which are important prerequisites for a sustainable technology. Despite its simplicity, however, such schemes and the required equipment have to be designed with great care:

Attention should be paid to easy handling of the carts. The review suggests that the carts be operated in a team of two and with a volume ranging between 0.5 and 1.5 m^3.

Detailed design is dependent on physical characteristics of the area, such as surface and slope.
Dumping of the waste on the ground for transfer to a container or larger transport vehicle was frequently observed and should be avoided as it is messy, tiring, and exposes the operators unnecessarily to health risks. Where households have adopted plastic bags for storage, the problem is less significant. The placing of containers (bins, large bags) in carts which can be lifted out for transfer and/or unloading is yet another inexpensive solution to overcome the handling problem.
According to the review, about one collector hour is necessary to serve approx. 200 inhabitants with handcarts. Low participation of households, however, often hinders such high efficiencies as the distance between houses to be served becomes too big.

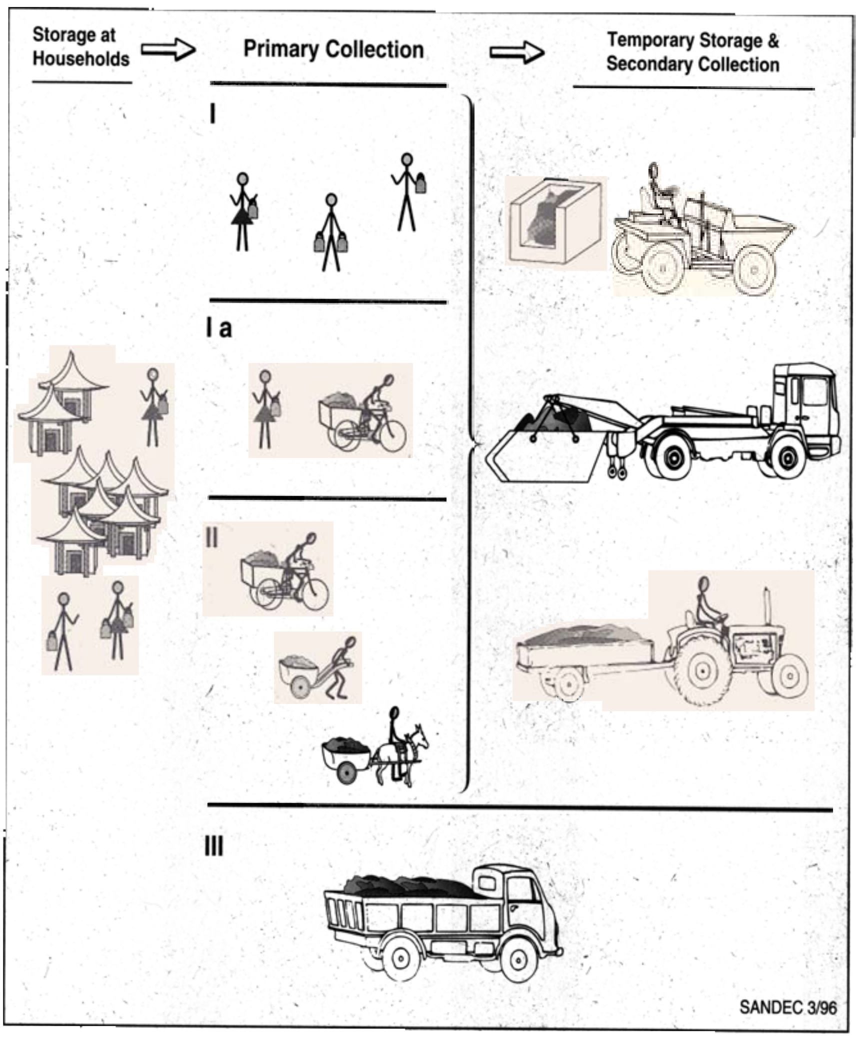


Figure 3:
Operating options for primary collection and communal storage

House-to-house collection with trucks (III)

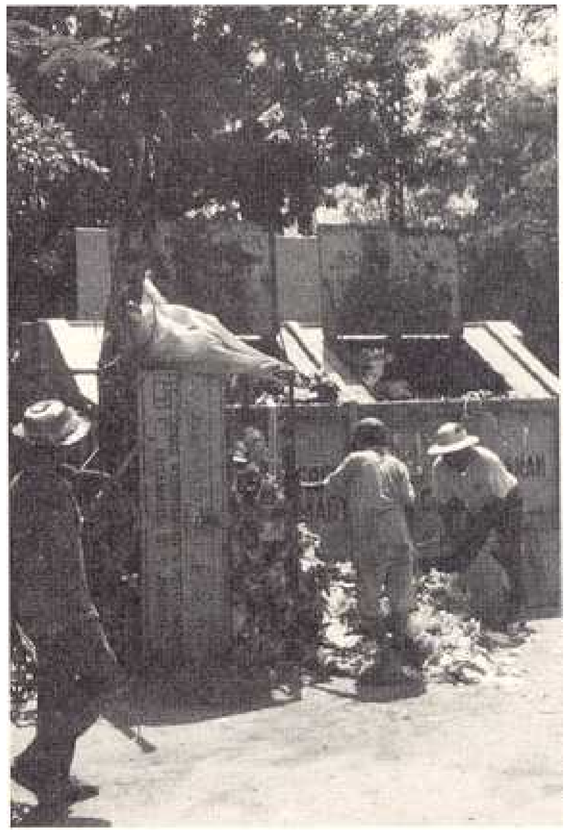
Where access roads are adequate, collection with trucks appears more efficient than with manually operated carts. The main advantage of such a system, observed only in Padang (Indonesia), is the fact that the waste can be transferred directly to a final disposal site (unless transport distances are too long), thereby avoiding the difficult interface with the secondary collection system. However, since roads are often inaccessible by trucks, even in upgraded areas, collectors may have to walk considerable distances to pick up the refuse from houses or lanes of difficult access.

Technical Interfaces

Primary and secondary collection are interdependent systems (Fig. 3) and do not function properly one without the other. The reviewed cases indicate that these interfaces between (community-level) primary collection and (municipal) secondary collection are very critical elements in most schemes. The waste is often not picked up regularly at the collection or transfer sites by the secondary collection system. The resulting accumulation of waste and mess at the collection points thereby discourage both residents and collectors from using the primary collection system. Although such interface problems may occur irrespective of the chosen collection method or transfer facility, use of passing trucks as transfer points is the least appropriate option. Truck delays force the collectors to wait around or even induce them to dump the collected refuse elsewhere. In any case, cooperation between the involved actors as regards timing of container collection or emptying of storage facilities is a pre-condition for successful interfaces.

Transport

To include transport of the waste to the final disposal site in the duties of the organisation in charge of primary collection could be an option to minimise interface problems. In the two Latin American schemes, Cucuta (Colombia) and Cajamarca (Peru), the operating micro-enterprises serve 50,000 inhabitants, which is equivalent to about half of the cities' population. The cooperatives are responsible for primary collection and also transport to the landfill. The applied tractor/trailer system thereby seems to work quite well. Such a system is only feasible, however, where transport distances are short as in the case of small municipalities. Thereby, the fact that direct participation of the households is generally limited to primary collection should also be borne in mind [5]. Earlier studies have shown that further steps within the SWM cycle, such as secondary collection and transport, are beyond the scope and potential of most communities.



The potential conflict between valuable scavenger activities at collection points and an efficient and safe transfer process is exemplified by collectors in Cirebon (Indonesia). They dump the waste on the ground for waste pickers to sort out recyclables. (Photo: SANDEC)

Scavenger activities

The activities of waste pickers looking for inorganic recyclable material, such as cardboard, glass, metal, and plastic, pose a widespread source of problems at collection and transfer points. Although these recycling activities have undoubtedly important advantages, such as the recovery of valuable resources, reduction of the waste quantities to be transported and disposed of, as well as generation of income for the poorest, they hinder an efficient and safe collection and transfer process. An interesting approach with regard to solving this problem has been observed in some parts of Indonesia. There, the scavengers have to pick up the waste dumped by the collectors and place it into the containers. They are only allowed to continue their activities if the transfer points are clean. However, the valuable contribution of scavengers to SWM must be recognised, and existing recycling activities should be taken into consideration when establishing collection schemes.

Organisational Models

Different institutional arrangements with inherent advantages and disadvantages have been identified. Despite the great variety of models, two main trends have been observed: a "community-based" and a "micro-enterprise" model (Fig. 4):

Community-based model

The first model, which has been working quite successfully in Indonesia for several years, includes systems operated and managed at community-level by community groups or individuals. According to the level of community involvement, various arrangements can be distinguished [5]. However, the organisational structure of most schemes is similar to the one presented in Figure 4a. The collectors are paid by the community organisation which recovers the service costs via a collection fee system (alternatively, fees are recovered by the collectors themselves). Financial and managerial support is often provided by formal and informal community leaders who work mainly on a voluntary basis. The institutional links with the municipal authority are often weak or non-existent, and public support is limited to the occasional provision of handcarts or loans. This model is thus not entirely reliant on a cooperating municipality and might prove advantageous where the contribution of the authorities is limited to secondary collection and transport of the waste. However, where only one motivated and voluntary individual is in charge of management (as often the case), the scheme is vulnerable and may rapidly collapse if the competent person withdraws from its responsibilities.

Micro-enterprise model

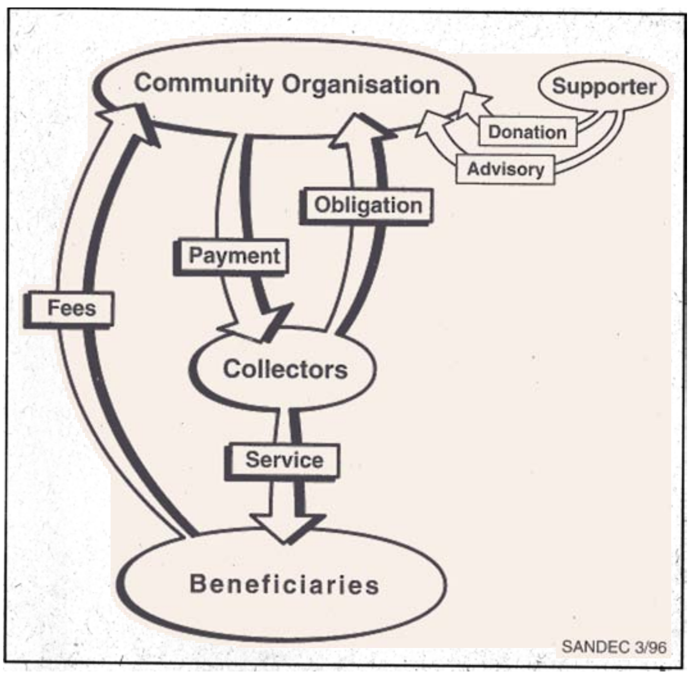
The second model refers to a specific "micro-enterprise" approach which finds increasing application in Latin American cities [6]. As shown in Figure 4b, the service, which is contracted out by the local government to a small private enterprise (with cooperative structure), is based on a written agreement which defines the tasks and duties of both actors. While the investment capital is covered by loans, operating costs are recovered through municipal taxes. Technical and financial assistance is provided by financial institutions and consulted NGOs. As successful implementation is dependent on the good cooperation between the small private enterprise and the local authority, the contract with the municipality is the key element of this approach. Once successfully established, this institutional link appears to facilitate dialogue between the actors and may have a positive influence on technical interfaces. However, as the business management principles are often not yet well understood among the new entrepreneurs, the commercial approach bears some risks, particularly for investment agencies.

Synthesis of the models

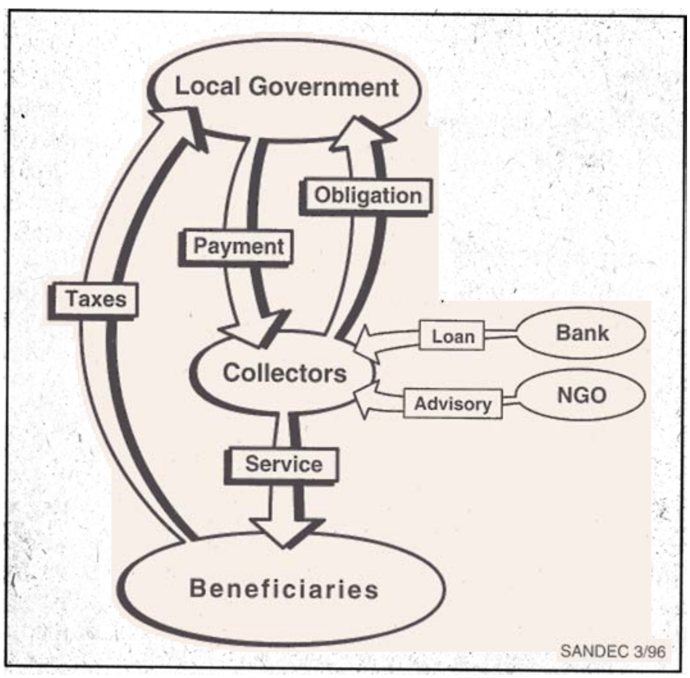
The models refer to specific and, as in the cases of Cucuta (Colombia) and Yogyakarta (Indonesia), successfully operating schemes. Nevertheless, the review indicates that the business management approach of the "micro-enterprise" model is likely to be more successful with regard to providing an efficient and reliable service. This can be partly explained by the positive effect which the contractual agreement and the preceding dialogue between involved actors have on the operation of the scheme. The commercially oriented behaviour which the micro-entrepreneurs have to adopt seems even more important. This approach generally improves operational efficiency of a scheme as the collectors are the direct beneficiaries of the acquired profit. The "community-based" models, operated without a commercial approach and dependent on voluntary management or external assistance, have failed or are bound to fail. It is clear, however, that both models can be combined, and that a wide spectrum of other approaches do exist, such as micro-enterprises contracted by capable community organisations.

Figure 4: Organisation charts of two main models

4a: Collectors managed and paid by community organisations



4b: Micro-enterprise contracted by the local government



Costs and Affordability

Most of the reviewed schemes revealed inadequate or a total lack of cost assessment and insufficient cost recovery. Costs for maintenance of equipment and management of the scheme are, for instance, often only partly taken into account and lead to a strong dependency on external financial assistance. Another observed characteristic of the schemes concerns the low wages of the collectors; i.e., they are often below the basic means of subsistence of a family. In labour-intensive systems where wages typically account for the largest sum of operating costs, low salaries certainly result in low service costs but fail to offer the collectors an incentive to perform a good and reliable job. As a consequence, many of the collectors perceive their employment as a temporary source of (additional) income, and most would immediately change it if given another job opportunity. Two aspects are thus of major concern for successful schemes: assessment of the expected costs (including fair salaries) and full cost recovery through fee collection.

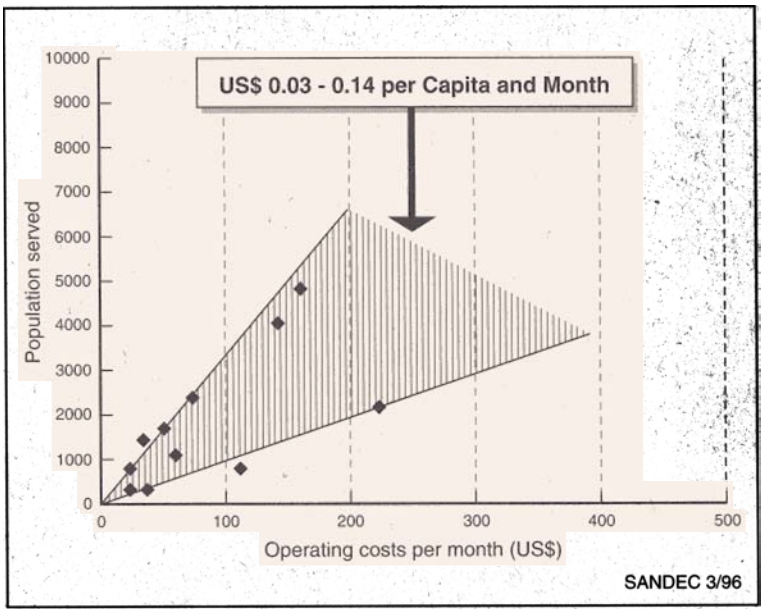


Figure 5: Served inhabitants vs operating costs

Service costs

Figure 5 presents the service costs per served inhabitant as estimated for the studied schemes operated with handcarts. These costs mainly include salaries paid to collectors and managerial staff and range between US$ 0.03 and 0.14 per capita and month (≈ up to US$ 0.70 per household). As a rule of thumb, about US$ 100 are thus necessary to cover the monthly operating costs of a manually operated house-to-house primary collection service of 1,000 inhabitants (US$ 0.10 per capita and month) - a sum which seems affordable. The figures are, however, only rough estimates since the cost structures of the studied schemes lack transparency. Many of the schemes have received capital and/or equipment in the form of grants from donors and municipal sources; "expenditures" which are not accounted for.

Affordability

Solid waste is certainly not given high priority by a low-income household. Particularly where the population is not aware of the consequences of inappropriate solid waste handling, households are rather reluctant to use their limited financial resources for solid waste services. Survey results from Indonesia suggest that in typical low-income areas about 60% of the income is spent on food, 20% on housing and education, and 15% on transportation, clothing and electricity [7]. The remaining 5% have to be shared between water, hygiene and solid waste services. Assuming an average household income of US$ 150, and 1% expenditure on SWM, the theoretical ability to pay is around US$ 1.5 per household and month. Although only an estimate, it clearly indicates that low-cost solutions, as described in this article, are a prerequisite for successful approaches.

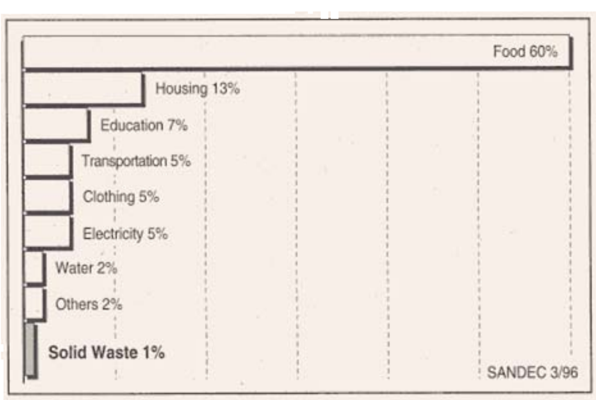


Figure 6: Distribution of expenditures; i.e., priorities in a low-income household

Conclusions and Recommendations

According to the review of selected schemes, non-governmental primary refuse collection is basically a suitable approach to increase service coverage in low-income urban areas. Small private enterprises and community organisations have an enormous potential in reducing part of the burden of the responsible public authorities. However, most schemes are still not self-sustainable and face problems which can and do lead to a breakdown of operation. The most important conclusions drawn from the reviewed schemes are described as follows:

Collaboration between public authorities and non-governmental actors

A common denominator of most schemes is the absence of a municipal framework which will adequately integrate community groups and the private sector in the delivery of a refuse collection service. Lack of cooperation between the actors results in operational difficulties, particularly at the interface between non-governmental primary collection and the required municipal secondary collection. Promising initiatives of motivated community organisations, NGOs and individuals are thus bound to fail if activities are not supported by and coordinated with public authorities. Establishment of a service oriented partnership between the key actors involved in such systems is urgently needed.

Selection of an affordable and sustainable technology

Most of the inhabitants in squatter settlements are poor, and their ability to contribute in cash is very limited. Low-cost technical solutions are thus a prerequisite for successful collection systems, and contributions in kind, such as carrying the refuse directly to communal containers, present an option requiring serious consideration. Where collection vehicles are necessary, manually operated handcarts or tricycles have proved most appropriate for the often poorly accessible areas. Apart from being non-polluting, these carts are cheap in manufacture and operation, and can be produced and maintained locally - all of which are important preconditions for a sustainable technology.

Orientation of the users and their involvement in decision-making

Primary refuse collection, particularly alternative approaches, require an important participation from the households. In addition to involving the future users in decision-making; i.e., in the choice of a system, scope and willingness of the beneficiaries to contribute in cash or kind are thus important factors to be considered. However, willingness to contribute is strongly dependent on the felt need of the population for solid waste collection and disposal. This need, however, often appears to be low. Enhancing people's awareness regarding the consequences of inappropriate solid waste handling, and providing information on possible improvements are thus crucial elements.

Assessment and transparent recovery of incurred costs

A lack of cost assessment and insufficient cost recovery are the major causes for a dependency on external financial assistance. Although donations and voluntary management may be a valuable contribution, particularly during the initial phase, operation and maintenance are likely to cease as soon as support is withdrawn. While the required investment capital may be covered through donations or loans, operating costs (including fair collector salaries) should be fully recovered from the beneficiaries via a simple and transparent fee collection system. A more commercial approach in managing non-governmental schemes may lead to the required accountability and improved motivation of its actors.

Acknowledgements

This work was carried out with the financial support of the Swiss Development Cooperation (SDC). As it is mostly based on information and experience gained by others, the research was only made possible with the commitment and collaboration of many people. SANDEC is especially grateful to the numerous organisations and individuals who helped develop the selected non-governmental refuse collection schemes and who shared their experience with us. The authors also wish to thank the following persons and institutions specifically involved in the review of the schemes and compilation of the acquired information: Werner Meyer (Nepal), Tore R. Semb (Norway), Yayasan Dian Desa (Yogyakarta), Mary Judd/RWSG-EAP (Jakarta), Dr Cheikh Touré/CREPA (Ouagadougou), Peter Hawkins (Recife), and Ricardo Giesecke (Lima). Finally, we should like to express our thanks to Lydia Zweifel for the drawings.

Cooperation between the actors with regard to container collection is crucial as overfilled storage units, such as these in Accra (Ghana), discourage both residents and collectors from using the primary collection system. (Photo: SANDEC)

References

[1] Schertenleib, R. and Meyer, W. (1992). Municipal Solid Waste Management in Developing Countries, Problems and Issues, Need for Future Research, IRCWD News No. 26, 2-8, Duebendorf, Switzerland.

[2] Pfammatter, R. and Schertenleib, R. (1996). Non-Governmental Refuse Collection in Low-Income Urban Areas, Lessons Learned from Selected Schemes, SANDEC Report No. 1/96, Duebendorf, Switzerland.

[3] Semb, T.R. (1992). Field Investigations on Community-Based Solid Waste Collection in Shanghai, China, IRCWD Field Report, Duebendorf, Switzerland.

[4] Hawkins, P. (1995). Primary Collection of Solid Waste at Community Level: A Summary of Case Studies from Five Developing Countries, IRCWD Internal Report, Duebendorf, Switzerland.

[5] Meyer, W. and Schertenleib, R. (1993). Community Participation in Solid Waste Management, Paper presented at the 18th WEDC Conference, Kathmandu, Nepal.

[6] Giesecke, R. et al. (1993). Microempresas de Recolección Manual y Transporte de Basuras Domésticas, Manual, APS/GTZ, Cúcuta, Colombia.

[7] Yayasan Dian Desa (1993). Study on Community-Based Primary Collection of Solid Waste in Indonesia, Dian Desa Field Report, Yogyakarta, Indonesia.

Pilot Projects on Community-Based Solid Waste Management

by Roger Pfammatter

In the course of the on-going research programme on alternatives for primary refuse collection and resource recovery in low-income urban areas, two pilot projects have been initiated with local counterparts in Pakistan and Indonesia.

Alternative Refuse Collection in a Typical Low-Income Urban Area of Karachi, Pakistan

This pilot project, which is carried out in collaboration with the NGO "Association for Protection of the Environment (APE)" in a typical urban slum in the 10-million city of Karachi in Pakistan, aims at gaining experience and acquiring knowledge on people's concerns in general and their attitude towards solid waste in particular. The final objective of the project is to formulate an approach to inform and motivate a community to participate in the establishement of a community-based SWM scheme, and to find a suitable technical, organisational and financial structure for alternative refuse collection schemes in low-income urban areas.

Resource Recovery in Community-Based Refuse Collection Schemes in Yogyakarta, Indonesia

This pilot project was initiated recently in collaboration with the NGO "Yayasan Dian Desa" in the city of Yogyakarta, Indonesia, and aims at finding an approach for combining existing community-based refuse collection schemes with on-going informal resource recovery activities. With regard to the recycling of inorganics, ways to improve the involvement of scavengers, hawkers and intermediary in a collection scheme are investigated. Furthermore, approaches for community-based small-scale composting of food and garden waste recycling shall be field tested.

Persons and institutions interested in collaborating with us in the elaboration of suitable options for SWM in low-income peri-urban areas are invited to contact:

Roland Schertenleib

Tel.: +41 - 1 - 823 50 18
Fax: +41 - 1 - 823 53 99
e-mail: schertenleib@eawag.ch

Roger Pfammatter

Tel.: +41 - 1 - 823 54 23
Fax: +41 - 1 - 823 53 99
e-mail: pfammatter@eawag.ch

Demonstration Projects on Solar Water Disinfection

by Martin Wegelin and Bernhard Sommer

Project Objectives and Research Background

Solar water disinfection (SODIS) may contribute to solving the water quality problems of those without access to reliably treated water in developing countries. This simple treatment process makes use of solar radiation to inactivate and destroy pathogenic microorganisms in the water. Water, flowing through a reactor (continuous flow system) or contained in transparent receptacles (batch process), is basically exposed to the sun for several hours. The continuous flow process could provide schools, hospitals or a larger number of people with about 100 litres (per square metre of solar collector and day) of drinking water. The batch process could be used to disinfect the drinking water of individuals and single families.

Specific research on SODIS was initiated by Prof. Aftim Acra at the American University of Beirut, Lebanon, in the late 1970s [1, 2]. Within the framework of a network programme, further field studies were conducted and reviewed in a workshop held at Brace Research Institute, Montreal, Canada, in 1988 [3]. Since the workshop revealed the need for additional research, SANDEC decided to embark on extensive laboratory and field test studies in order to identify the potential and limitations of the SODIS process. The results obtained were published both in IRCWD News and AQUA [4,5].

Laboratory Test Results

The aforementioned laboratory tests revealed that UV-A light is mainly responsible for the inactivation of microorganisms. A fluence (dose of solar radiation integrated in the 350-450 nm wavelength range) of approx. 2,000 kJ/m^2 or 555 Wh/m^2 is required to achieve a 3 log reduction of *E.coli* at water temperatures between 20 and 40 °C. The same *E.coli* reduction is achieved within 90 minutes at water temperatures above 50 °C. The recorded synergetic effect of solar radiation and thermal water treatment (at temperatures above 50 °C) favours a combined use of these two water treatment processes. The test with different microorganisms indicated that *E.coli* and bacteriophages are suitable indicator organisms to monitor the efficiency of SODIS with regard to the inactivation of bacteria and viruses.

Field Test Results

EAWAG's research work with SODIS was conducted under strictly controlled laboratory conditions. In order to assess the inactivation rates of faecal coliform bacteria under different climatic, physical, chemical, and microbiological conditions, the laboratory tests were complemented with field tests. They were run at CINARA (Instituto de Investigación y Desarrollo en Agua Potable, Saneamiento Básico y Conservación del Recurso Hídrico), Cali, Colombia [6, 7], at AyA (Instituto Costarricense de Acueductos y Alcantarillados), San José, Costa Rica [8,9], at the Renewable Energy Research Centre of the Royal Scientific Society in Amman, Jordan [10, 11], and at the Khon Kaen University in Khon Kaen, Thailand [12, 13].

Batch Process

Field tests [6, 7, 10, 12, 13] were conducted using test tubes, plastic bags (polyethylene) and bottles made of glass and plastic (polyethylene). The disinfection efficiency is significantly influenced by the specific properties of the material and shape of the water container. In addition, water depths beyond 10 cm strongly reduce UV-A irradiation. Therefore, the lower the turbidity the better the efficiency and reliability of the disinfection process.

As illustrated in Fig. 1, plastic bags have a better inactivation efficiency than bottles. The water depth in plastic bags placed on a flat and horizontal surface is small. Water heating and irradiation of the microorganisms are most effective

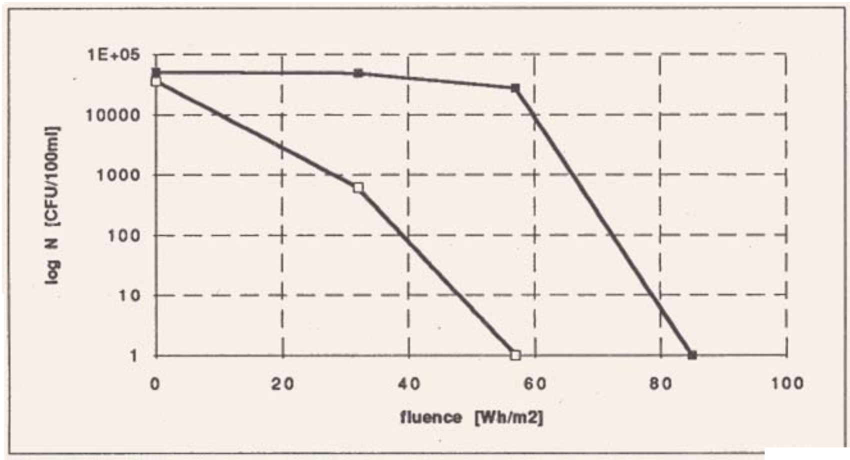


Figure 1: Inactivation curves achieved in plastic bags (❑) and in plastic bottles (■

at this depth, as the intensity of the UV-A radiation is not significantly reduced neither by turbidity nor by a great water depth. The fastest faecal coliform reduction (99.9 %) in a plastic bag occurred after 90 minutes of exposure at an UV-A dose of 16 Wh/m^2. This was sufficient to reach a water temperature of 47 °C.

Continuous Flow Process

The output of treated water can be increased significantly with continuous flow systems consisting of a raw and treated water tank, solar collector, exposure vessel, heat exchanger, and flow control device. The continuous flow process can be used for solar water disinfection - thermal and irradiation effect combined - or solar pasteurisation (SOPAS) - thermal effect only - [8, 9, 10, 11, 12, 13].

The most recently installed SODIS plant (photo: plant on the left side) in Costa Rica worked very well on sunny days. The required temperature of 50 °C was reached within 50 to 90 minutes, and a subsequent steady flow of half a litre (per minute and square metre of collector area) of completely disinfected water was achieved for several hours. The cloudier the weather the more difficult it is to maintain the required temperature. Nevertheless, the SODIS plant worked well also during cloudy days with only 60 % UV-A light and 70 % visible light as energy source. SOPAS (photo: plant on the right side) requires a working temperature of 70 °C, thus, it is more vulnerable to unfavourable weather conditions than the SODIS plant. The SOPAS plant is operational only on absolutely cloudless days.

Demonstration Projects

Successful and promising field test results of the batch and continuous flow processes now allow the starting of a limited and controlled dissemination of the methods. Over 700 households will participate in the batch process project at test sites in Africa (Burkina Faso, Togo), Asia (China, Indonesia and Thailand) and South America (Bolivia, Colombia). The SODIS continuous flow process will be applied in five test sites in Costa Rica and in five sites in Honduras for a period of at least one year.

The objective of the project is to test the method under various sociocultural conditions in order to assess its acceptance, suitability of equipment, costs, and problems encountered by the users in their daily water treatment practices. Production of the SODIS reactor will start in Costa Rica under the guidance of Swisscontact as soon as it has proved its suitability for daily use in developing countries.

EAWAG/SANDEC intends to establish an information network to coordinate the exchange of practical experience among institutions active in the field of solar water disinfection.

References

[1] Acra, A. et al. (1984). Solar Disinfection for Drinking Water and Oral Rehydration Solutions, UNICEF.

[2] Acra, A. et al. (1990). Water Disinfection by Solar Radiation, IDRC.

[3] IDRC (1988). Solar Water Disinfection, Proceedings of a workshop held at the Brace Research Institute, Montreal, Canada.

[4] Wegelin, M. (1993). Water Disinfection by Solar Energy, IRCWD News No. 27.

[5] Wegelin, M. et al. (1994). Solar Water Disinfection: Scope of the Process and Analysis of Radiation Experiments, AQUA, No. 3, pp. 154-169.

[6] Pfammatter, R. et al. (1993). Solar Water Disinfection: Evaluation of Field Tests Carried out at CINARA, Cali, Colombia, EAWAG Internal Report.

[7] Sommer, B. (1995). Solar Water Disinfection: Impact on *Vibrio cholerae* and faecal coliform, Results of a Practical Training at CINARA, EAWAG Internal Report.

[8] Mariño, A. (1996). Consulting Mission in Costa Rica, EAWAG Internal Report.

[9] Valiente, C. (1996). Proyecto Desinfección del Agua, Utilizando Luz Solar, SOPAS-SODIS, AyA Internal Report.

[10] Mariño, A. et al. (1995). Solar Water Disinfection: Evaluation of Field Tests Carried Out in Amman, Jordan, Monitoring Report, Part I, EAWAG Internal Report.

[11] Ajarmeh, H. and Al-Taher, A. (1995). Solar Water Disinfection Project, Final Report, Part II & III, Royal Scientific Society, Amman, Jordan.

[12] Mariño, A. et al. (1995). Solar Water Disinfection: Evaluation of Field Tests Carried Out in Khon Khaen, Monitoring Report, Part I, EAWAG Internal Report.

[13] Setter, P. (1995). Solar Water Disinfection: Evaluation of Field Tests Carried Out in Khon Khaen, Monitoring Report, Part II, EAWAG Internal Report.

Institutions working or interested in solar water disinfection are invited to contact:

Martin Wegelin
Programme Officer Water Treatment

Tel.: +41-1-823 50 19
Fax: +41-1-823 53 99
e-mail: wegelin@eawag.ch

SODIS and SOPAS Plant (Photo: SANDEC)

SOS - Management of Sludges from On-Site Sanitation

Faecal Sludge (FS) Treatment

Progress in Brief

by Martin Strauss and Udo Heinss

Foreword

In 1992, SANDEC initiated an R+D project on faecal sludge management, particularly on faecal sludge (FS) treatment processes and technologies. The rationale for the project is the lack of appropriate FS treatment options in most developing and newly industrialised countries. FS treatment plants have been installed in recent years in a few cities only, e.g. in Accra, Bangkok, and Jakarta.

The aim of the project is to develop **guidelines** for appropriate faecal sludge treatment options for planners, designers and technicians. Furthermore, the project also proposes to enhance the expertise of the collaborating institutions in the field of monitoring and control of wastewater and sludge disposal.

The **three phases** of the project include an identification, a field research and a synoptic phase. We are currently engaged in the field research phase and are also periodically publishing our findings (see "bookshelf").

1 Overview of our Field Research in FS Treatment

Our field research projects are listed in Table 1. In addition to these activities, SANDEC has recently embarked on a series of special tests to refine the biochemical oxygen demand (BOD) analysis of faecal sludges (see 2.1).

2 Findings

2.1 BOD Analysis and FS Classification

BOD Analysis

Special BOD monitoring activities were initiated as the 5-day BOD analysis using the traditional Winkler titration procedure was suspected to lead to an underestimation of the BOD values for FS. Undervaluing may cause an undersizing of those treatment works where process designs are based on BOD concentrations or BOD loading rates, such as anaerobic or facultative stabilisation ponds. Comparative analyses are conducted with the following methods and parameter variations over ten days instead of five:

- Traditional Winkler titration method with bottles that are not stirred
- Oxygen probe immersed in a stirred Winkler bottle
- Manometric BOD equipment
- Seeded vs unseeded samples
- Not stirred vs stirred samples
- Unsuppressed vs suppressed nitrification

Preliminary test results obtained by SANDEC at WRRI in Accra with septage and public toilet sludges (Stalder 1996), and at AIT in Bangkok with septage (Heinss 1996), led to the following conclusions: contrary to our assumption, seeding with aerobic bacteria does not appear to be meaningful. In some, though not all of the FS tested, the exertion of oxygen demand starts after about one day only, irrespective of seeding. Stirring appears to be of significance in samples of solid-rich (Type A) sludges (see FS classification below). Stirring of public toilet sludge increased the BOD_5 by a factor 1.4. For BOD_{10}, it increased by a factor 1.4 - 2, depending on the type of method used. Furthermore, stirring appears to be of particular importance in manometric BOD analysis. The respective equipment does, in fact, have built-in stirring mechanisms.

Additional BOD analyses, including a number of test runs where nitrification is suppressed, will be conducted to determine whether carbohydrates are decomposed and, thus, oxygen demand exerted beyond a period of five days.

Table 1 SANDEC's collaborative field research on faecal sludge treatment

No.	City (country)	Research partners	Treatment processes and technologies	Investigation period
	Completed and ongoing investigations			
1	Accra (Ghana)	Water Resources Research Institute (WRRI)	Settling/thickening + anaerobic ponds; composting of separated solids with sawdust	1993-94
2	Accra (Ghana)	----"-----	Settling/thickening + anaerobic + facultative ponds Drying beds + settling columns	1996-97 1995-97
3	Bangkok (Thailand)	Asian Institue of Technology (AIT)	Planted sludge drying beds Attached growth WSP	1996-98 1997-98
4	Manila (Philippines)	National Engineering Centre, University of The Philippines	Use of septage for land reclamation	1996-98
5	Wuhan (China)	Wuhan Urban Construction Institute Wuhan, Hubei Pvce.	Co-composting of faecal sludge + domestic/municipal refuse	1995-96
	Planned investigations			
6	New Delhi (India)	Sulabh International Inst. of Technical Research & Training	Dewatering/drying beds for sludges from nightsoil biogas digesters	

FS Classification

After reviewing a large number of data on FS characteristics, we decided to classify faecal sludges into two broad categories. **High-strength sludges** from bucket privies or non-flush and pour-flush public toilets have been characterised as "Type A". They have generally undergone little fermentation and exhibit COD, ammonium and solids concentrations of 20, - 50,000 mg/l; 2, - 5,000 mg/l; and ≥ 3.5 % respectively. In contrast, sludges of relatively **weak strength**, such as septage, have been classified as "**Type B**". Their COD, ammonium and solids concentrations amount to < 10,000 mg/l; < 1,000 mg/l; and < 3 % respectively.

Truncating FS into two broad categories is important, particularly when treating sludges in ponds as described in Chpt. 2.3.

2.2 Solids/Liquid Separation

The findings of solids/liquid separation of FS in settling/thickening tanks and in conventional beds (**unplanted, sludge drying beds**) are based on field research conducted by WRRI in Ghana (Larmie 1994), and on research carried out by Pescod and co-workers at AIT in Bangkok in the late 1960s (Pescod 1971). The information on **planted sludge drying** beds[1] is based on a literature review of the use of reed beds for treating sludges from sewage treatment plants (STP). Research at AIT will be focusing on planted drying beds as the process has not been used yet for faecal sludges, except in some preliminary pilot studies carried out by CEMAGREF in Lyon, France (Payrastre 1995). Solids/liquid separation may prove particularly useful as pretreatment step in pond treatment of FS. A substantial solids elimination can thus be achieved and allow a reduction of the specific technical and operational problems associated with the emptying of large quantities of sludge from primary ponds. Reduction of the solids load discharged into the ponds will also decrease the organic load and, thus, lead to considerable land savings. Solids/liquid separation is strongly recommended if FS is to be co-treated with

Since reeds are generally applied in planted sludge drying beds, the process is often called "reed bed treatment". The term "constructed wetlands" is also used. The German terminology uses "Schlammvererdung" and the equivalent English translation is "sludge humification".

wastewater in existing waste stabilisation ponds (WSP) or conventional STP which have not previously been designed to receive FS.

Settling/Thickening

Mechanised sedimentation tanks are normally used in continuous flow/continuous sludge removal solids/liquid separation processes. However, such equipment intensive installations may not be appropriate in most developing countries. Use of batch-operated FS settling/thickening tanks with sludge removal by front-end loaders, such as the ones installed in two faecal sludge treatment plants (FSTP) in Accra, Ghana (Annoh 1989 and 1994), is a possible alternative to the problem where front-end loaders are either used at municipal administrations or can be hired from private construction firms.

The required storage volume for the separated solids is the decisive design variable for batch-operated FS settling/thickening tanks. The tank volume thus calculated has to be verified to guarantee a minimum liquid retention time of three hours in the clear/settling zone. The sludge storage volume for the type of tanks used at the Achimota FSTP, Accra (rectangular tanks; access ramp for accumulated sludge removal by front-end loader), can be calculated on the basis of the attainable thickening concentration of the settled and floating sludge (≤ 14 %), and on the desired length of the operating cycle (e.g. 2-4 weeks).

Sedimentation and thickening tests using 1 or 2-litre cylinders should be performed, whenever possible, with the type of sludge mixture expected to be delivered to the plant. This would not only indicate the achievable degree of thickening and the relative amounts of scum and settled solids to be expected, but would also help design the settling/thickening units.

Figure 1 shows a batch-operated settling/thickening tank as used in Accra, Ghana, with a ramp for front-end loader for removal of the separated solids.

Unplanted and Planted Sludge Drying Beds

Two processes are responsible for the dewatering and drying of sludges in unplanted sludge drying beds: gravity percolation and evaporation. Evapotranspiration is a supplementary process in planted drying beds.

First published experiments on faecal sludge treatment in unplanted sludge drying beds were conducted by a group of researchers at AIT, Bangkok, in the late sixties (Pescod 1971). A sludge depth of 20 cm was found to give maximum allowable solids loading rates. The drying periods to achieve 25 % solids content required 5 to 15 days, depending on the varying total solids (TS) loading rates (70 - 475 kg TS/yr·m^2) and on climatic conditions (rainfall).

Results obtained from the first monitoring phase of the pilot sludge drying beds in Accra/Ghana (Larmie 1995 and 1996) revealed that this treatment option is applicable to septage, public toilet sludge and primary pond sludge (TS = 1.6-7 %). Experiments were conducted during the dry season with sludge depths of ≤ 20 cm. A 1:4 mixture of public toilet sludge and septage was dried to over 70 % TS in nine days at a solids loading rate of 130 kg TS/yr·m^2. A significant and persistent helminth egg removal in the sludge could not be observed during the one to two weeks drying

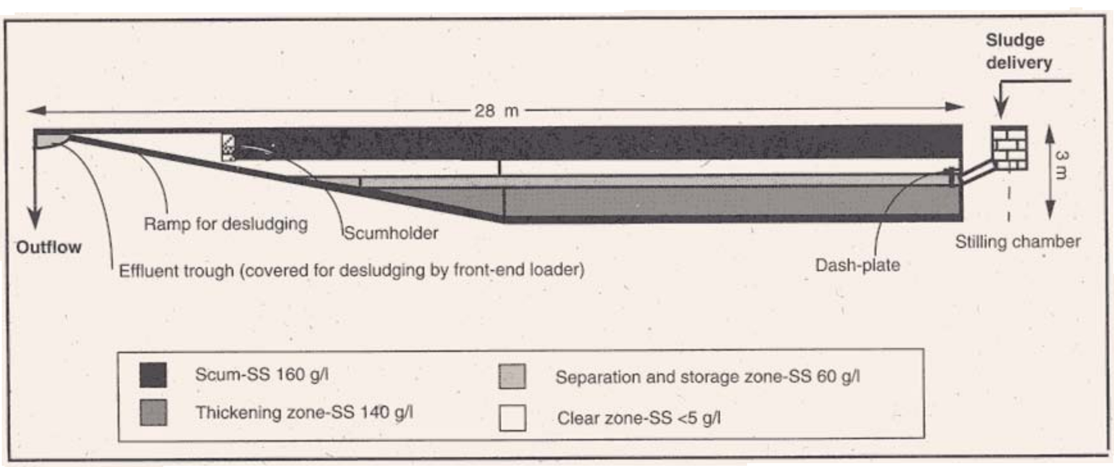


Figure 1: Improved design of a sedimentation/thickening tank providing storage for approx. 50 tons of separated solids (desludging by front-end loader)

period. A 95 % suspended solids (SS) and a 100% helminth egg elimination in the percolating liquid was achieved. Public toilet and primary pond sludges were dried to almost 40 % TS in 12 days at a solids loading rate of 200 kg TS/yr·m^2. Further sludge drying experiments will be conducted to substantiate these findings.

Removal of the dewatered or dried sludge from unplanted sludge drying beds is labour intensive or requires mechanical equipment. **Planted** sludge drying beds could minimise the need of frequent dried sludge removal as sludge withdrawal becomes necessary only after several years of operation. A considerable number of reed beds treat sludge mainly from smaller STP in Europe and North America. Since the applicability of reed beds for faecal sludge treatment remains to be tested, the process will be investigated in the collaborative field research of AIT and SANDEC.

The monitoring results from planted and unplanted drying beds treating sludges from activated sludge treatment plants reveal that the **percolating liquid** is significantly nitrified. The toxic effect of ammonia on algae in facultative ponds (see also 2.3 below) is therefore unlikely, and makes the drying bed effluent particularly suitable for pond treatment.

Sedimentation/Thickening vs Drying Beds

Table 2 contains the per capita surface area required for the two solids/liquid separation processes, viz. sedimentation/thickening and drying beds, which was determined by the monitoring data obtained to date. FS treatment in a sedimentation/thickening tank requires a significantly (approx. seven times) smaller area than treatment in a sludge drying bed. However, FS treatment in dewatering/drying beds yields a final sludge product of TS ≤ 70 %, whereas the achievable TS concentration in settling/thickening tanks amounts to ≤ 14 % only. The thus obtained sludge requires further dewatering or co-composting. Since the COD, SS (suspended solids) and helminth egg concentrations in the effluent of drying beds are substantially lower than in the effluent of sedimentation/thickening tanks, they require less polishing. In choosing between settling/thickening and drying bed treatment, careful attention should be paid to factors such as required surface area, quality of the liquid effluents and sludges produced, and requirements for further treatment.

2.3 Pond Treatment

Separate Treatment of FS and Wastewater

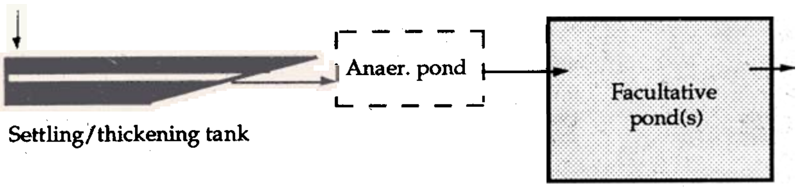
Based on the knowledge acquired to date, we recommend that high- and low-strength sludges (see 2.1 for the respective classification) be treated in separate pond systems. This would be beneficial as highly loaded, multistage **anaerobic ponds** are particularly suitable to achieve an efficient treatment of the more concentrated "Type-A" sludges. High loading rates lead to higher volumetric BOD removal rates and, hence, to less overall pond surface or volume than in diluted faecal sludge treatment. Since high ammonia concentrations inhibit algal growth, Type A or mixtures of Type A and B sludges containing high nitrogen loads are not amenable to **facultative pond** treatment. In contrast, septage is likely to be treatable in facultative ponds as its ammonia contents are relatively low.

	Attainable TS %	Loading Cycle	TS Loading kg TS/m^{2}yr	Area Required m^2 /cap.1)
Sedimentation Tank	≤ 14	8-week cycle (4 weeks loading + 4 weeks resting) with two parallel settling tanks	1,000	0.007
Sludge Drying Bed (unplanted)	≤ 70	10-day cycle (loading, drying, removing)	100 - 200	0.05

1)Assumed parameters: FS quantity = 1 litre/cap · day; TS of the untreated FS = 20 g/l

Table 2: Comparison of settling/thickening and drying bed treatment for solids/liquid separation of faecal sludges

Figure 2 provides design guidance for treating septage in a facultative pond system in warm climates, preceded by a settling/thickening unit and an optional anaerobic pond.



Sedimentation/ Thickening	Anaerobic pond	Facultative pond(s)
• Batch-operated • Attainable TS: 15% • Liquid retention ≥ 3 h in the clear / settling zone • Attainable elimination: BOD and COD: 50 % SS: 60-80 % Helminth eggs: 50 %	• The need/benefit of anaerobic ponds for treating septage is still uncertain. It is likely to be advantageous if a BOD elimination of ≥ 40 % can be achieved. • $L_V \leq 350$ g/m^3·day, depending on temperature	• BOD elimination 80% • Retention time > 5 days • $L_a \leq 350$ kg/ha·day, depending on temperature
L_V = Volumetric organic loading rate L_a = Aerial organic loading rate		

Figure 2: Functional sketch and design guideline for pond treatment of septage *

Field research is conducted by WRRI at the Teshie FSTP in **Accra**, Ghana, on **treatment of septage** in a **pond** system comprising five ponds in series and preceded by settling/thickening. The monitoring programme will determine whether and to what extent septage is amenable to **anaerobic** pond treatment. The data generated from the first monitoring phase in May 1996 (Larmie 1996) indicate that BOD removal in the primary anaerobic pond following settling/thickening was in the order of **50 %**. The monitored volumetric and surface loading rates of this pond amounted to 100 g BOD/m^3·day and 1,300 kg BOD/ha·day respectively.

Co-Treating FS and Wastewater in Waste Stabilisation Ponds

The organic loading rate, the solids load and the ammonium/ammonia nitrogen concentrations are critical variables to be considered when co-treating wastewater and faecal sludges in waste stabilisation ponds. Their relevance is outlined below.

Organic loading rate: anaerobic and facultative ponds are sensitive to excessive organic (BOD) loading. The most serious symptomatic effect in overloaded anaerobic ponds is odour. In facultative ponds, overloading will impair the development of aerobic conditions and algal growth. The permissible additional faecal sludge load is dependent on the organic load already exerted by the wastewater, and on the loading rates for which the ponds were originally designed.

- **Solids load:** ponds may fill up at undesirably fast rates as a result of high solids contents in FS. Separating the FS solids in solids/liquid treatment (e.g. settling/thickening or dewatering beds), and treating the liquid in wastewater stabilisation ponds is, thus, the recommended option which is likely to lead to a reliable and long lasting WSP operation. A 60-80 % removal of suspended solids can be achieved in well-designed and operated settling/thickening tanks. A ≥ 90 % removal of suspended solids and a 100 % removal of helminth eggs from the FS liquid can be attained in dewatering/drying beds.

Ammonia nitrogen: the permissible ammonia (NH_3) concentration in the facultative pond is a further factor influencing the permissible FS load in a WSP system. Excessive ammonia levels may cause a suppression of algal growth. This, in turn, reduces the supply of oxygen required by the aerobic bacteria for the decomposition of organic matter, and by nitrifiers for the oxidation of NH_4. For the conditions prevailing in facultative ponds in tropical climates, the permissible NH_4 concentration in the influent of the combined waste has been established at 400 mg/l, or 500 mg/l if the waste is pretreated in an anaerobic pond. The FS:wastewater load ratio may be calculated on the basis of these critical concentrations.

3 References

Annoh, C. (1989 and 1994). Project Designs for the Koforidua and Teshie (Accra) Faecal Sludge Treatment Plants.

Heinss, U. (1996). Back-to-the-Office Report of a Mission to Thailand and the Philippines, September. SANDEC.

Larmie, S.A. (1994). *Sedimentation Tank Sludge Accumulation Study.* Field Report, WRRI.

Larmie, S.A. (1995 and 1996). *Drying Bed Experiments.* Field reports on pilot treatment of faecal sludges in unplanted drying beds. WRRI/ SANDEC. Unpublished.

Payrastre, F. (1995). *Pilot Treatment of Faecal Sludges in Reed Beds.* Report by CEMAGREF, Water Quality Division (Head: A. Liénard), P.O. Box 220, F-69336 Lyon Cedex 90, France). In French.

Pescod, M.B. (1971). Sludge Handling and Disposal in Tropical Developing Countries. *Journal Water Pollution Control Federation*, **43** (4), 555-570.

Stalder, I. (1996). BOD Analyses of Accra Septage and Public Toilet Sludges. Internal Report, SANDEC.

For further information on SANDEC's FS treatment activities you may contact:

Martin Strauss Tel.: +41-1-823 50 20
Fax: +41-1-823 53 99
e-mail: strauss@eawag.ch

or

Udo Heinss Tel.: +41-1-823 50 25
Fax: +41-1-823 53 99
e-mail: heinss@eawag.ch

On the Bookshelf

Reports on Solid waste

- **Non-Governmental Refuse Collection in Low-Income Urban Areas.** SANDEC Report No. 1/96, by Roger Pfammatter and Roland Schertenleib, March 1996, 70 pages, 27 photos, 11 figures.
  The leading article of SANDEC News No. 2 is a summary of this publication.
  Available free of charge from SANDEC, Ueberlandstrasse 133, CH - 8600 Duebendorf, Switzerland, fax: +41-1- 823 53 99.

  Valorisation des Déchets Organiques dans les Quartiers Populaires des Villes Africaines. SKAT Publication (ISBN: 3-908001-53-6), by Alter Ego/CREPA/IAGU and SANDEC, March 1996, 143 pages, 8 photos, 21 figures.
  This publication, available so far only in French, is the result of a collaborative research project between Swiss (Alter Ego and SANDEC) and African (CREPA and IAGU) institutions on decentralised composting in peri-urban areas of West African cities.
  Following an extensive bibliographic research on the subject of composting in general (part A), the results of pilot projects in four West African cities (Ouagadougou, Abidjan, Bamako, and Cotonou) are summarised (part B), and conclusions and perspectives given (part C). The Annex finally comprises a bibliographic list of publications on the subject.
  Available (in French only) from Intermediate Technology IT Publications, 103-105, Southhampton Row, London WB1B4HH, England. Price: Sfr. 25.-.

- **Community-Based Solid Waste Management and Water Supply Projects: A Survey of Literature.** UWEP /WASTE Working Document 2, May 1996, by Justine Anschütz, 103 pages.
  Available from WASTE, Advisors on urban environment and development, Crabethstraat 38F, NL-2801 AN Gouda, The Netherlands, fax: +31-182 584 885, e-mail: alrisseeuw.waste@nld.toolnet.org. Price: US$ 10.-.
- Options for Small Scale Resource Recovery. WASTE Urban Solid Waste Series No. 1-4, No. 1: **Organic Waste**, 132 pages; No. 2: **Plastic Waste**, 112 pages; No. 3: **Rubber Waste**, 126 pages; No. 4: **Hazardous Waste**, 71 pages; 1993-96, by Arnold van de Klundert and Inge Lardinois (eds.).
  The aforementioned publications can be ordered from TOOLBooks, Warmonderweg 80, 2341 KZ Oegstgeest, the Netherlands, fax: +31-71-517 1856, e-mail: backhuys@euronet.nl.

SANDEC Reports on Faecal Sludge Treatment

The following reports have been prepared or will be finalised shortly. They are available from SANDEC upon request and free of charge.

- **Anaerobic and Facultative Ponds for Treatment of Septage and Public Toilet Sludges in Tropical Climates - A Discussion Paper and Preliminary Guidelines**, by Udo Heinss and Martin Strauss, EAWAG/SANDEC, (1996), (in press).

Use of Reed Beds for Sludge Dewatering - A Literature Review, by Udo Heinss, EAWAG/SANDEC (1996).

Co-Treatment of Faecal Sludges and Wastewater in Tropical Climates, by Udo Heinss, EAWAG/SANDEC (1996).

Treatment of Sludges from On-Site Sanitation - Low-Cost Options, by M. Strauss, S.A.Larmie, U. Heinss, (1996). In: *Water Science & Technology* (in press) (Proceedings, 3rd International Specialised Conference on Design and Operation of Small Wastewater Treatment Plants, Kuala Lumpur, Malaysia, 30 Oct. - 1 Nov. 1995).

Conclusions Drawn by EAWAG from the Second Monitoring Cycle in Accra, Ghana, (Based on the Field Report Entitled "Sedimentation Tank Sludge Accumulation Study", prepared by S.A. Larmie, WRRI), by Udo Heinss, (1995a), WRRI and EAWAG/SANDEC.

Preliminary Designs of Improved Sedimentation Tanks for Sludges from On-Site Sanitation Based on Examinations in Accra, Ghana, by Udo Heinss, (1995b), EAWAG/SANDEC.

Miscellaneous

- **Guidelines for Drinking-Water Quality. Volume 2: Health Criteria and Other Supporting Information** (second edition), World Health Organization. Available from WHO, Distribution and Sales, CH-1211 Geneva 27, fax: +41-22-791 4857. Price: Sfr. 260.- or US$ 234.- (developing countries Sfr. 182.-).
- **Hygiene Education in Bangladesh**, by Marieke Boot, International Water & Sanitation Centre, IRC, P.O.Box 93190, NL-2509 AD The Hague, The Netherlands. Tel.: +31-70-331 4133, fax: +31-70-381 4023.
- **On-Plot Sanitation in Low-Income Urban Communities. A review of literature**, by Andrew Cotton, Richard Franceys, John Pickford and Darren Saywell, September 1995.
  Available from WEDC, Water, Engineering and Development Centre, Loughborough University of Technology, Leicestershire LE11 3TU, UK, fax: +44(0)1509 21 1079. Price: UK£ 7.14.

➨ NOW IN PRESS:

Surface Water Treatment by Roughing Filters - A Design, Construction and Operation Manual, 1996, by Martin Wegelin.

The new and comprehensive manual replaces the old publication: Horizontal-flow Roughing Filtration (HRF) - A Design, Construction and Operation Manual, IRCWD Report No. 06/86.

The new manual will appear in December 1996 and may be ordered from IT Publications, 103-105 Southampton Row, London WC1B 4HH, U.K., fax: +44-171 436 2013, e-mail: itpubs@gn.apc.org. Price: approx. US$ 20.-.

Editors
Brigitte Hauser and Sylvie Peter
"SANDEC NEWS"
Swiss Federal Institute for Environmental Science and Technology (EAWAG)
SANDEC/EAWAG
Ueberlandstrasse 133
CH-8600 Duebendorf / SWITZERLAND

Layout
Gianin Rageth, Creative Atelier Schwellbrunn, and Brigitte Hauser

Publication
SANDEC News appears on an irregular basis and is free of charge

Printed
by Truninger Kopie-Repro-Druck, Zurich

New subscribers to SANDEC News please contact: EAWAG/SANDEC, fax: +41-1-823 5399, e-mail: speter@eawag.ch
www. eawag.ch/pub/