Division 44
Environment and Infrastructure

Module 1: Technical Concepts

Improvement of Sanitation and Solid Waste Management in Urban Poor Settlements

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

commissioned by:

Federal Ministry
for Economic Cooperation
and Development

Division 44
Environment and Infrastructure

Module 1: Technical Concepts

Improvement of Sanitation and Solid Waste Management in Urban Poor Settlements

Eschborn 2005

Published by:
Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH
Postfach 5180, 65726 Eschborn, Deutschland
Internet: http://www.gtz.de

Sectoral Project
"Improvement of Sanitation and Solid Waste Management in Urban Poor Settlements"

Division 44 - Environment and Infrastructure
OU 4412 - Water, Wastewater and Solid Waste Management

and Division 42 - Governance and Democracy
OU 4223 - Regional and Local Governance, Urban Development, Decentralisation

Responsible:
Sandra Spies und Klaus Weistroffer

Authors:
Dr. Heino Vest, Franziska Bosch

with Contributions from:
Harald Kraft, Frank Samol

Advisory Team:
Franziska Bosch, Martina Craemer-Moeller, GTZ, Elke Hüttner, GTZ
Hans-Joachim Hermann, GTZ, Prof. Peter Herrle, Alexander Jachnow
Prof. Burkhard von Rabenau, Frank Samol, Heike Santen, GTZ, Sandra Spies, GTZ
Klaus Weistroffer, GTZ, Dr. Heino Vest

Conceptualisation, Lay-out and Editing:
Frank Samol, B.U.S. – Büro für Umweltplanung und Stadtentwicklung

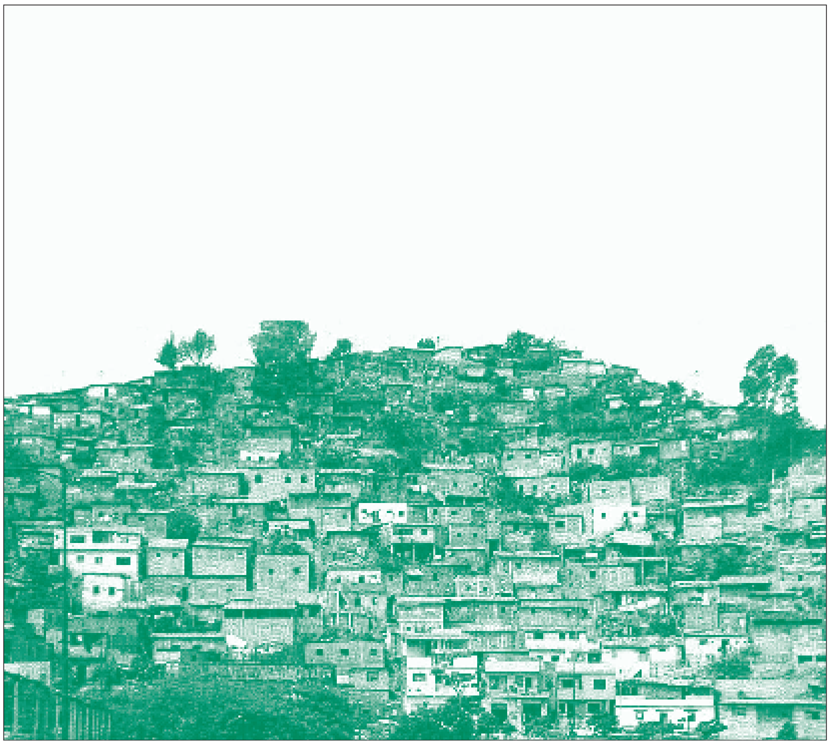
Translation from the German version published by GTZ in 2002 by:
Frank Samol, Ben Kern

CONTENTS

0 INTRODUCTION

0. INTRODUCTION

BACKGROUND AND CONTEXT



Fast growing informal settlement /1/

City planning, as a mechanism for controlling spatial development, is not feasible in poor districts. In these areas, land is traded illegally and built on without permission, and existing buildings are often extended or altered over long periods of time, with no official authorisation. To "formalise" these settlements completely would entail costs that neither municipalities nor inhabitants could handle. Restrictive policies (when applied) have done little or nothing to change the precarious living conditions of the poor. At worst, they have inhibited rather than supported legal, economic and infrastructural improvement. The need for policies of decentralisation and the strengthening of local self-government have therefore been voiced with ever increasing intensity ever since the 1996 United Nations Conference on Human Settlements in Istanbul (Habitat II).

Challenges of Urbanisation

Today, worldwide urbanisation is thought of as an unstoppable characteristic of global societal change. According to predictions, by the year 2025 at least two thirds of the world's population will live in cities. Most of this urban growth is taking place in the developing world where two billion people already live in cities - about twice as many as in industrialised nations.

The dynamics of the urbanisation process, and especially its economic, social and spatial consequences, are amongst the greatest challenges of our time. While cities offer an enormous and indispensable potential for the economic growth of developing countries in an increasingly globalised economy, the negative effects of urbanisation are also alarmingly apparent, and these include increasingly inadequate housing and working conditions for the poor and the ecological impact of virtually uncontrollable urban sprawl.

Failure of Conventional Urban Planning and Management Instruments

The emergence and expansion of poorly serviced illegal and informal settlements in peripheral areas within and outside urban agglomerations, have shown that conventional means of city planning and management are not able to cope with conditions of accelerated social change, high demographic growth rates and increasing urban poverty.

The Need for Flexibility and Pro-active Solutions

City planning, as well as the management of housing and urban services, demand pro-active, financially feasible strategies adapted to real conditions in order to take advantage of existing potentials; they need to be replicable, to show immediate effects and be sustainable. Although it is obviously not possible to equip informal settlements with extensive infrastructures overnight, they can be upgraded gradually. This requires procedures that take into account the potential for further future improvements.

0. Introduction

New Partnerships between the Public and the Private Sector

The supposed dominance of public sector agencies in the supply of social and technical services, no longer holds true. Apart from partnerships with the private sector, often the only sensible alternative for achieving sustainable improvements depends on the cooperation of various different stakeholders, including the local population and non-governmental organisations (NGOs).

For this reason, the significance of the diverse local stakeholders as well as the variety of possible organisational and financial structures should be seriously taken into account during the conception of urban management projects.

Problem: Precarious Living and Housing Conditions in Urban Poor Settlements

Poor settlements, in their various forms, are especially vulnerable to the negative impacts of urbanisation. In many cases, exclusion from legal protection, urban services and infrastructure leads to extremely unhealthy living conditions resulting in high child mortality rates, widespread epidemic illness and chronic disease.

The Lack of Waste Management Systems in Poor Settlements

The neglect of poor settlements by city administrations is often justified by the fact that they are “informal”. The term is used to describe not only their combination of uncertain legalities, ownership rights and illegal construction activities, but also their economic structures, which yield hardly any tax or revenues. City administrations cite these factors to explain their lack of input in social and technical infrastructure.

Whatever the case, the consequence is that in many African, Asian and Latin American cities, barely a third of the population is connected to municipal waste management systems, while the rest of the population relies on private contracts or self-help.

Importance of Housing Rights as against Waste Management

Infrastructure, waste management and sewerage systems are usually of secondary importance to the inhabitants during the initial phases of informal settlement. Securing a plot with a right to stay there, and establishing networks for income generation are the primary concerns. Inward migration and continuous construction quickly lead to rising population densities. This establishes and consolidates the social structure and built environment of a settlement, but also inevitably results in increased refuse and sewage management problems. In settlements with population densities of more than 2000 inhabitants per hectare, uncollected garbage, stagnant water and lack of sanitary facilities can create serious health hazards, especially for women and children.

Settlement without security of tenure /2/

0.
Introduction

Danger of Social and Economic Disintegration

Neglect can lead to social and economic disintegration, which can result in the area becoming marginalised as the better-off inhabitants try to leave.

In addition, there is the problem of deficient technical infrastructure and services, such as drainage or sewage disposal systems, which cannot be effectively tackled by public or self-help initiatives alone. Solutions often require intervention at many different operational levels and involvement across various existing areas of activity.

Potential: The Resourcefulness of the Urban Poor and their Commitment to Self-help

Despite the relatively unattractive living conditions they provide, poor settlements, particularly in cities, continue to grow in size and density. The social and economic value attached to an urban location apparently outweighs the numerous disadvantages. Moreover, people born and raised in an urban poor settlement frequently have no other option. Today's generation of urban poor has lost its ties to the countryside and survives, physically and economically, within the boundaries of the city or district.

Various Forms of Organisation

The majority of settlements, even including temporary settlements, possess some sort of waste disposal management. These range from individually arranged rubbish removals, to area-wide servicing through private contractors, to complex neighborhood organisations.

However, these organisational possibilities only operate within the narrow confines of each isolated local situation, and this can produce problems. For example, a drainage facility that is not connected to the main sewage system may easily intensify potential flooding in adjacent districts. Many issues related to infrastructure and waste management can therefore only be resolved in a suitable and sustainable way, when they are coordinated in an overall system.

Decentralised Methods of Waste Management

During the past twenty years, a variety of methods for decentralised waste management have emerged out of pure necessity - and, in part, without expensive subsidies. They have generally been characterised by their ability to adjust to specific social,

Refuse as a source of income /3/

0. Introduction

economic and cultural situations. Some were initiated within the context of international development co-operations; many innovative approaches were devised jointly by inhabitants and NGOs; and others were implemented through city administrations.

Alliance and Cooperation of Different Stakeholders

What these approaches have in common is that they not only pursue technical solutions, but they also incorporate organisational and financial aspects, and involve a variety of local interest groups.

Housing conditions without adequate waste management /4/

Future Challenges: The Improvement of Waste Management in Urban Poor Settlements

The improvement of technical and social infrastructure is of key importance in consolidated low-income settlements. Many such areas that originated in the 1950's and 1960's now have populations similar to those of a medium sized city, and yet their infrastructures remains rudimentary. With steadily growing populations and increasing building densities, health hazards have increased disproportionately and living standards have plummeted.

The Importance of Improving Technical and Social Infrastructure for the Consolidation of Low-income Settlements

Nowadays, many of the urban poor have access to potable water, although they usually pay more for it than middle-class citizens. Nonetheless, hygienic conditions in low-income settlements have become critically important to the quality of life of their inhabitants. In the long run, any advantages of location will not outweigh the lack of basic services in these areas.

The standard of supply and disposal systems tends to rank only third on the priority lists of inhabitants, behind income generation and security of tenure. Even so, the extent of under-serviced areas and the high proportion of the urban population affected have made the absence of functional systems the number one obstacle to overall development.

Integration of Poor Settlements into the Urban Fabric

Finding solutions for waste management deficits in low-income settlements has become a main element in strategies aimed at improving the general functionality of cities and developing their economic potential. The sustainable management of waste has acquired a significance that reaches far beyond its technical or sanitary dimensions. It encompasses fiscal aspects as well as the reorganisation of the relationship between a city's administration and its people. What is required are, on the one hand, new forms of managing increasingly heterogeneous urban structures in an economically sound, yet fair and balanced way, and on the other, the effective coordination of the very diverse stakeholders involved in the development process.

0.
Introduction
Objectives and Target Groups

This publication intends to combine the scattered theoretical and practical knowledge acquired in the field of decentralised waste management, and make it available for practical use in development cooperation projects. The listings of waste management projects and the numerous individual project profiles available on the internet are not able to communicate the innovative core, nor the basic parameters of novel approaches in ways that enable comparisons and encourage their application in other contexts. Moreover, the practical experience gained in individual GTZ projects has not, as yet, been systematically brought together.

A treatment that deals only with the technical aspects of waste management in low-income settlements, will not tackle the issues effectively. In order to achieve the sustainable improvement of people's lives, financial and organisational factors must be considered as equally important. Moreover, without the extensive participation of affected inhabitants in the planning, implementation, and maintenance of systems, sustainability cannot be achieved. Seemingly marginal themes, such as the organisation of campaigns or the pricing of local services, are therefore also dealt with in this publication in so far as they relate to the main topic.

All volumes of this publicaton series focus more on the content matter and operational requirements of innovative approaches, and less on easily replicable formulas. The examples given are intended to encourage the search for new solutions in specific situations.

While the first volume presents the topic of waste management in urban poor settlements in general, the subsequent three modules offer more issue-specific recommendations for the development of local project approaches.

The technical solutions described in the present volume, Module 1, of this publication series are intended as a guide and only provide basic background information on the main issues to be considered in identifying appropriate waste management solutions. The length of this document is limited, and hence technical aspects have been described as concisely as possible, and should not be taken as a comprehensive basis for detailed technical planning and implementation.

For these purposes, it will therefore be indispensable to draw on specialised expertise and advisory assistance.

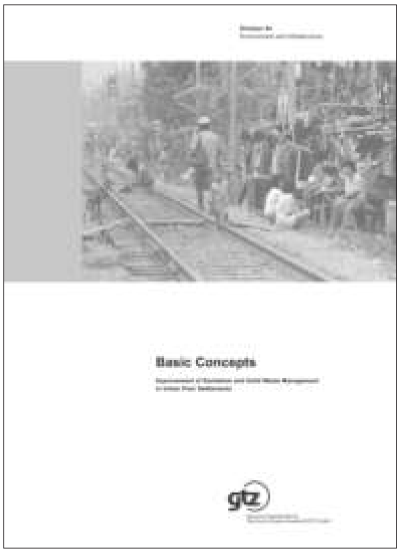
Objectives of this Publication

- **To appraise and document experience gathered in sectoral and cross-sectoral development cooperation projects**
- **To provide an overview of current international discussions on improving waste management in urban poor settlements**
- **To offer orientation and support for the initiation, planning and implementation of measures and activities for the improvement of waste management at the urban district or residential quarter levels**
- **To present exemplary solutions and their institutional, organisational, and financial contexts**

Target Groups

- **People working on projects dealing with housing supply, city development, and refuse and waste water management**
- **Interested laypersons and professionals from NGOs, local community initiatives and other grass roots organisations**
- **Professionals and decision -makers in communal and other responsible institutions involved with waste management in poor areas.**

CONTENTS OUTLINE



Basic Concepts:

The introductory volume describes the basic information necessary for the conception, planning and implementation of measures to improve waste management in urban poor settlements. Sample case studies and their concrete experiences are used as references.

Module 1: Technical Concepts

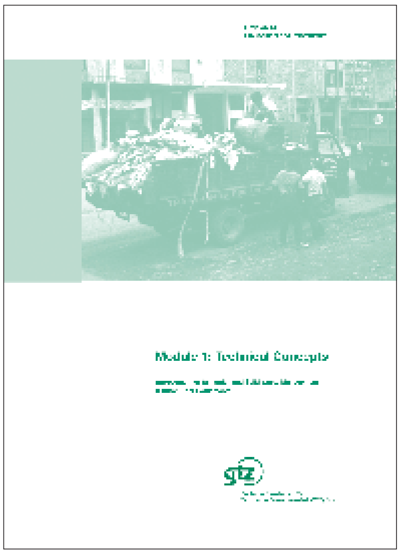
This first module documents proven technical solutions and develops criteria for assessing their suitability for use in different types of housing areas, and for dealing with different conditions and problems.

Module 2: Participation, Self-help and Public Relations

The second module is concerned with procedures, instruments, and methods for encouraging participation and self-help among inhabitants of urban poor settlements during waste management upgrading.

Module 3: Organisation of Operations and Financing

The third module describes and evaluates possible approaches to the organisation, maintenance and financing of waste management systems at the housing area level.



0.
Introduction

Module 1 Overview

The present volume deals with the following topics, and, where possible, these are illustrated by short summarised case studies and examples of technical waste management solutions.

1. Technical Aspects of Waste Management

The introductory chapter of this module outlines the main framework conditions and the most important aspects that need to be considered in the design and implementation of technical solutions to waste management problems. It also gives an overview of the basic information needed for selecting suitable technologies and approaches, and indicates appropriate selection criteria.

2. Solid Waste

A first part of the second chapter describes the main problems, potentials and challenges of solid waste management in urban poor settlements and provides information on tools and instruments for assessing solid waste generation. The most relevant technical solutions and procedures for solid waste collection and transport, sorting and recycling, and final disposal are then presented and assessed in more detail.

3. Wastewater

As an introduction to wastewater management tasks and functions, the first section of this chapter outlines the main problems and challenges to be confronted in urban poor settlements, and describes basic concepts for assessing the amounts of wastewater to be disposed of and treated. More detailed descriptions and evaluations of technical options follow in two main parts: on-site (i.e. settlement level) solutions for collecting and treating wastewater, and solutions for wastewater disposal and treatment both on-site and off-site.

4. Rainwater

As in chapters 2 and 3, an initial overview of the problems and challenges for rainwater management and erosion control in urban poor settlements is given. Against this background, the most relevant technical approaches and solutions for drainage systems, erosion control measures and rainwater harvesting are presented and assessed.

Annex

The annex comprises:

- checklists, tables and design parameters for solid waste and wastewater management;
- a list of literature that can provide more detailed information on the technical solutions and approaches presented;
- photo and illustration credits.

1 TECHNICAL ASPECTS OF WASTE MANAGEMENT

1. TECHNICAL ASPECTS OF WASTE MANAGEMENT

Introduction

Depending on the specific context and the resources available, various technical solutions, procedures and forms of organisation can be used to process and dispose of solid waste (refuse), wastewater and rainwater in urban poor settlements. In general, the technologies involved are only one aspect in assessing whether a particular waste management solution is appropriate.

In most cases, social, cultural, financial or institutional aspects will be more relevant than specific technical measures, the choice of which are usually unproblematic. As a rule, the long-term viability and sustainability of waste management projects and initiatives depends more on factors such as social acceptance, the capabilities of target groups and users to operate and maintain equipment and installations, the necessary institutional and organisational arrangements, and economic efficiency, in particular the possibilities of cost recovery.
Thus, the selection of appropriate technologies normally requires a careful assessment of the prevailing socio-cultural, institutional, organisational and financial conditions, and the possible scope of action will need to be based on these findings.

However, there may be situations in which the particularities of various technical solutions of waste management tasks do become important. In such cases, it will not be sufficient to assess their advantages or disadvantages primarily on the basis of the general conditions. A comparison of specific technical aspects, such as efficiency, quality, ease of maintenance, durability and environmental impact will then have to be used to select the most favourable option.

A broad spectrum of appropriate and well-tested technical solutions and procedures for waste management in urban poor settlements has developed over time, and an assessment of the applicability of any of them requires specific technical know-how and practical experience.

This chapter therefore, first outlines the basic information that will be needed to select and plan appropriate technical waste management solutions, and how to collect and compile this information. It then presents the most important technical assessment criteria that will need to be considered in selecting a particular technical solution in a specific context.

As far as is possible and useful, the presentation also describes important non-technical aspects, or provides references to their detailed description in other modules of this publication. Respective references are indicated by an arrow, thus:

▶

The technical or technological aspect is only one of the factors in assessing whether a waste management solution is appropriate. Social, cultural, financial or institutional issues are often more important than any specific technical solution.

The viability and sustainability of a technical waste management solution mainly depends on:

- **its social and cultural acceptance;**
- **the capabilities of target groups and users to operate and maintain technologies and equipment;**
- **the institutional and organisational set-ups required;**
- **its economic efficiency and level of cost recovery.**

Technical Aspects of Waste Management

Type of Information Needed to Select Appropriate Technologies and Procedures

Since different urban quarters and settlements may have considerably different characteristics and problems, it will usually be necessary to analyse the prevailing development conditions and problems carefully in order to identify and develop waste management measures that reflect each settlement's particular situation.

Densely built-up innercity areas need technical solutions different from those for peri-urban settlements /5/6/

Technical Aspects

The following technical aspects and information will be important inputs in analysing development conditions:

- data on residential densities, housing conditions and public open space;
- information on topography and geology (terrain profiles, slopes, soil conditions);
- existing waste management solutions, and the quality and conditions of their respective technical solutions:
  - method of collection and disposal of household and commercial refuse,
  - condition of latrines, septic tanks, sewage pipes and treatment plants (as relevant),
  - condition of possible open sewerage canals,
  - type of rainwater and other surface water drainage,
  - risk of land slides and flooding.
- existing initiatives to improve waste management;
- data on refuse and wastewater produced, on rainwater yield and on the corresponding needs for disposal;
- possibilities of connecting to existing municipal waste management systems or networks;
- possibilities of recycling and marketing solid waste components (compost, scrap metals, glass, paper, etc.).

▶ *More detailed information on the kind of basic data needed for different waste management tasks can be found in the corresponding chapters on refuse management, wastewater management, and rainwater drainage.*

Social, Institutional and Financial Aspects

The following social, institutional and financial information is indispensable for the selection of appropriate solutions:

- problem perception and requirements of target groups and users; where relevant, considering socio-cultural or gender-specific factors;
- interests, willingness and possibilities of target groups and users to participate in waste management activities (e.g. through self-help and mutual help, financial contributions, payment of user charges);
- existing community based organisations (CBOs) and non-governmental organisations (NGOs), which can be used as starting points for waste management initiatives;
- interests, capacities and capabilities of public sector (municipal or governmental) institutions responsible for waste management services;
- existing fee and tariff systems for waste managements services; possibilities of recovering service costs;
- possibilities of support from governments or administrations, such as local governments, governmental sector institutions, etc..

▶ *More detailed information on the kind of basic data needed for these aspects can be found in Modules 2 and 3, and in the first volume "Basic Concepts".*

1. Technical Aspects of Waste Management

Criteria for Selecting Appropriate Technologies and Processes

Participatory methods of information collection and problem analysis can facilitate early target group and user involvement in the planning process. In particular, they can allow residents and target groups to voice their demands, concerns and expectations with regard to improved waste management, and thus ensure that planned measures take these interests into account.

In addition to cooperation and interaction with target groups and users, special analyses or studies (e.g. on soil conditions, topographical and cadastral surveying, etc.) will usually be necessary to provide a sound basis for decisions on possible technical solutions.

Because of the potentially wide range of activities and requirements that can be derived from information collection and data analysis in the planning phase, it will usually be necessary to prioritise measures for improving hygienic conditions, and use this as a basis for selecting appropriate technical solutions.

▶ *Tools and instruments for participatory information collection and planning are presented in more detail in Module 2 - "Participation and Self-Help".*

Costs

Waste management in urban poor settlements will usually require low-cost or relatively cheap solutions in order be affordable to target groups and public sector service providers. Hence, one of the most important selection criteria will be the costs involved in a particular technical solution.

In addition to net investment costs, the long-term costs of operations and maintenance will be of particular importance:

Investment Costs

The investment costs of a particular technical solution depend on a number of factors:

- The level of technological complexity: Considering the conditions in developing countries, which are usually characterised by low labour costs and high capital expenditure, sophisticated, automated and labour saving equipment and processes will generally be less appropriate than simple, labour intensive technologies.
- Physical factors, such as topography, geology, residential density or accessibility (e.g. latrines need to be regularly emptied and sludge transported when the absorption capacity of the soil or space is limited).
- Possibilities for financing and capital costs: financing of investment costs by government subsidies or external donor grants is usually "cheaper" than loan financing.

A good indicator for comparing the costs of different technical solutions is the investment cost per household or user.

Operating Costs

In previous practice, the importance of the operational costs of technical solutions as a selection criterion has often been neglected. These are mainly determined by:

- salaries and wages of operational and administrative staff;
- energy consumption and costs;
- other necessary consumables (lubricants, spare parts, cleaning agents, etc.);
- the expected life span of equipment or system components, and the resulting depreciation;
- the needs for regular maintenance and repair works.

▶ *More detailed information on this topic can be found in Module 3 - "Organisation and Finance"*

1.

Technical Aspects of Waste Management

Efficiency and Quality

In addition to cost aspects, the efficiency and quality of technical solutions are other important criteria for assessments.

The need for low-cost solutions and affordability often calls for compromises and/or cuts in quality. In general, waste management measures in urban poor settlements will provide less quality or convenience than those in better-off, formal urban quarters. Nevertheless, even simple low-cost solutions can lead to significant improvements. Important selection criteria for technical solutions are:

- the amount of hygienic and environmental improvement that can be achieved with the financial resources available;
- the possibilities of gradually improving and further developing initially simple low-cost solutions.

Interfaces with Networks and Systems beyond Settlement Level

Closely related to quality and efficiency, the necessities or possibilities for interfacing with networks and systems outside the settlement or quarter are further important criteria in assessing waste management solutions. In this, a distinction should be made between:

- "Technical" interfaces that are the result of the technical solution selected, such as the connection of local sewers to municipal or public sewerage networks or the collection of refuse by municipal refuse departments or enterprises.

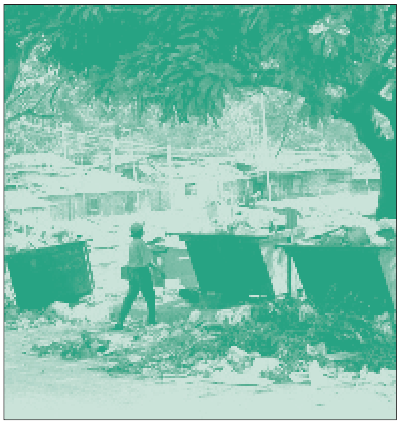
  Such technical interfaces usually require close collaboration with the responsible public or private services providers from the outset of planning and preparation.

  Moreover, they usually mean that at least part of services at settlement level will later have to be taken over by the public (municipal) or private sector operators who are responsible for waste management operations at city-wide level.

- "Systemic" (institutional) interfaces, resulting from the necessity to coordinate projects or particular measures with public or municipal institutions responsible for waste management services.

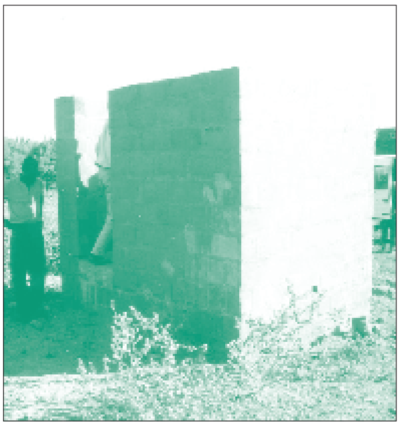
  For technical on-site solutions that do not need to connect to overall systems (e.g. the construction of latrines), coordination or cooperation with responsible sector institutions may, in any case, be necessary or useful, e.g. to obtain official approval of a waste management measure. The need for such coordination and cooperation should thus be carefully assessed, even when it seems not to be required by the technical option selected.

Simple but efficient: Refuse containers /7/



Connection to municipal system: Sewerage /8/

Simple localised solution: Latrine /9/



1.

Technical Aspects of Waste Management

Ease of Operation and Use

The ease of operation and use of a technical solution or process is mainly determined by two factors:

- its level of complexity and the skills needed to make it function;
- the capabilities and skill levels of users and target groups.

In the selection of technical equipment, solutions or processes, the relationship between both factors should be adequately considered. For more complex solutions, or in cases where user skills and capabilities are inadequate, complementary training and advisory assistance will be needed. This should be considered in planning and preparation.

Maintenance Requirements and Durability

Maintenance requirements and durability of materials, equipment and system components are further important assessment criteria.

Maintenance requirements and durability largely depend on the complexity of a technology:

- Simple technical solutions often require less maintenance or have longer maintenance intervals. Moreover, their maintenance usually needs relatively less skill and technical know-how, and can thus be secured more easily; this, if necessary, can be supported by complementary training.
- More complex technical solutions generally present a higher challenge for maintenance and repair work. On the other hand, they are often more efficient and can provide a better service quality.

Requirements for Operations and Organisation

Different technical solutions generally call for different operational and organisational set-ups. Operational forms and organisational structures also relate closely to some of the aspects described above, including:

- ease of operation and use;
- maintenance requirements and durability;
- technical and systemic interfaces with networks and institutions beyond settlement level;
- costs of operations, maintenance and asset depreciation.

In most cases, the operational and organisational challenges increase with a technical solution's level of complexity. However, even simple technical solutions require a minimum of stable organisational or institutional structures in order to be sustainable.

▶ *Module 3 - "Organisation and Finance"*

Simple technology: Manual push-carts for refuse collection in Benin /10/

Complex technical solution with a higher need for maintenance: Waste compactor truck in Aqaba, Jordan /11/

High organisational challenge: Operations of sludge pumping trucks /12/

1.

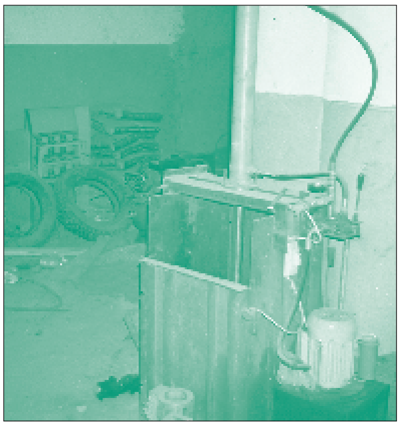
Technical Aspects of Waste Management

Accessibility of Technical Solutions and Technologies

As a consequence of economic globalisation, most up-to-date technologies for urban waste management are available almost everywhere (albeit at very different costs). Theoretically, they could therefore also be used in urban poor settlements. However, due their technical complexity, maintenance requirements or costs, many technologies and related equipment are only partially appropriate or even completely inappropriate in this context.

On the other hand, importing technologies can make sense if it helps achieve technically and institutionally sustainable improvements at reasonable costs. Machines, equipment and technologies from countries with similar development levels that correspond to specific local conditions (e.g. with regard to labour and capital costs or soil conditions) can be applied. The needs and costs for spare parts, repairs and staff training will, however, have to be considered.

Reasonable import of technology: Machine for paper pressing in Egypt /13/



Possibilities for Self-help

The possibilities for target group and user self-help (e.g. in form of labour or other contributions in kind) are largely determined by the ease of operations and use of a technical solution.

But even more complex technical solutions, such as the construction of sewerage networks or retaining walls against soil erosion or landslides, can at least partially be done through self-help (e.g. digging trenches or other earthworks).

Basing an assessment of self-help possibilities on technical aspects alone however, will usually be insufficient. Poor target groups often have to fight for their livelihood on a daily basis, and this has to be taken into consideration. Thus the possibilities and scope for self-help can be limited.

▶ *Module 2 - "Participation and Self-Help"*

Self-help in the construction of a sewer network /14/

Social and Cultural Acceptance

Specific social, cultural, religious or ethnic factors can have a considerable influence on a technical solution's level of acceptance and willingness to be involved in self-help and participation. In many cultures, the handling and collection of refuse is seen as a low status activity, which is often designated to disadvantaged social groups, e.g. to Coptic Christians in Islamic Egypt or to members of special castes in Hindu countries. The handling of human excrement is often subject to similar taboos.

Specific socio-cultural conditions should thus be identified in the planning and preparation of waste management initiatives, and be adequately considered in the selection of technical options. On the other hand, existing prejudices against specific technical solutions can be overcome by information, awareness raising campaigns and public relations efforts.

▶ *Module 2 - "Participation and Self-Help"*

Limited social acceptance: Refuse collection and recycling - the Zabaleen of Cairo

1.
Technical Aspects of Waste Management

Environmental Impacts and Environmental Balances

In the past, the environmental impacts and the environmental balances of technical solutions have often been neglected in the assessment of waste management solutions.

Although the overall objective of most waste management projects is to improve hygienic and environmental conditions for residents, problems are often transferred elsewhere, that is, they are "externalised". This is particularly true where solutions at settlement level are not fully integrated into functioning city-wide waste management systems, e.g. sewerage systems without final sewage treatment facilities, or refuse collection without suitable landfills or dumping sites.

The selection of appropriate technical solutions should thus also consider the following:

- In cases of interfacing with or connection to city-wide systems (off-site solutions): the existence of sustainable solutions for waste disposal outside the settlement, or the possibilities of creating or introducing environmentally sound final disposal options over time.
- In cases of local solutions at settlement level (on-site solutions): their impact with regard to soil contamination, vegetation, pollution of ground and surface water, and other emissions.

Criteria for selecting technical waste management solutions for urban poor settlements:

- **low investment and operational costs; saving of energy and other consumables**
- **efficiency: possibility of significant improvements even through technically simple solutions**
- **appropriate consideration of technical and systemic interfaces with city-wide networks and systems**
- **ease of use and operations corresponding to the skills and capabilities of users and target groups**
- **low requirements for maintenance and repair; durability with a long functional life span**
- **requirements for operational organisations that correspond to the capacities of local stakeholders, organisations and institutions**
- **locally or regionally produced or purchased technologies**
- **adequate consideration of self-help potentials and possibilities of user and target group participation and/or contribution**
- **social acceptance**
- **positive environmental impacts and balances**

Problems transferred "externally": Dumping refuse at the urban fringe /16/

2 SOLID WASTE MANAGEMENT

2.1 Solid Waste Management

Challenges and Conceptual Approaches

Basic Concepts of Solid Waste Management in Industrialised Countries

Refuse is generally perceived as material that the owner no longer needs and wishes to dispose of. The traditional form of refuse disposal is to just throw it away and/or have it transported by a refuse collection service to a landfill or dumping site.

Today, this form of disposal (end-of-pipe technology) has not yet completely vanished, but has generally become less acceptable. Simple refuse disposal has developed into solid waste management, a complex system, involving various measures and activities which increasingly focuses on the reduction and recycling of refuse material. Environmentally sound, resource-conserving waste management aims to recycle the largest possible number of waste components and reintroduce them into the economic cycle in order to reduce the consumption of valuable material resources and energy.

From refuse disposal to solid waste management as part of a recycling economy

Solid waste management, as applied in most industrialised countries today, prioritises the reduction and recycling of refuse over its final disposal. Environmental laws or other regulations aim at only allowing final disposal after all possible means to reduce or recycle waste material have been made use of.

Hierarchy of Solid Waste Management

1. First priority: avoidance and reduction of waste

- **avoidance of waste in production processes**
- **use of products with a low waste constituents or that generate low amounts of waste**
- **reduction of hazardous waste materials by sorting and separation**

2. Second stage: waste reuse and recycling

- **reuse of goods or products**
- **recycling of material**
- **composting of organic waste**
- **energy recycling**

3. Only then, final stage: end disposal

- **sanitary landfill sites**
- **waste incineration**

Solid Waste Management in Developing Countries

This new understanding of solid waste management has only slowly taken hold in developing countries.

In most of these countries, governments, political bodies and institutions responsible for solid waste management still perceive waste as refuse to be disposed of, rather than as a resource that supplies, among other things, reusable materials. Traditional methods of refuse disposal still largely prevail, and, in most cases, they function badly. Even in mega-cities, such as Cairo, Caracas or Manila, well-managed sanitary landfill sites are still an exception, and refuse collection and disposal are often erratic and of bad quality. In parallel to formal refuse collection and disposal services, a huge informal sector for refuse collection and recycling has developed in many cities which provides income and jobs for some of the poor population.

More recent initiatives to privatise or license waste management in the form of concessions, which have emerged in many larger cities or metropolitan areas over the past 10-15 years, have had little impact so far on the low quality of waste management services. Part privatised waste management services, which largely remain publicly organised and regulated, still tend to be only available to the formal parts of cities and to rich or middle-income residential areas.

CHALLENGES AND CONCEPTUAL APPROACHES

Solid Waste Management in Urban Poor Settlements

Problems

In urban poor settlements, well-organised solid waste management is rare. In most settlements, residents have no alternative other than to dispose of household and commercial refuse in streets and alleys, in public open spaces, in valleys or creeks, or in sewage or rainwater drainage canals. Informal dumping sites at the fringes of settlements are common, resulting in serious environmental hazards (from smouldering fires, the pollution of surface water, breeding vermin, etc.).

Where public waste management services are at all available in urban poor settlements, they are usually limited to the collection of refuse from central collection points, often at the fringes of settlements which can easily be accessed from the urban street network. Typical solutions consist of the installation of containers or walled transfer stations where residents can discharge their refuse. In the best case, containers or other collection points are regularly emptied by municipal refuse collection services; more frequently however, such services can be rather unreliable, and serious health hazards, as with informal dumping sites, can arise from these intermediate collection points.

As for private refuse collectors, who often collect and recycle refuse in wealthier formal residential areas, they have little interest in extending their services to poorer areas, where recyclable waste materials are difficult to find.

Dumping of waste in river beds or creeks /17/

Dumping of waste in streets /18/

Irregularly emptied refuse containers /19/

Limiting factors for efficient solid waste management in urban poor settlements:

- **missing formal recognition of settlements by responsible public sector institutions (in most cases, municipalities)**
- **limited capacities of public waste management services; caused in particular by insufficient refuse collection cost recovery through user charges**
- **limited willingness and capacity of residents to pay user charges for refuse collection**
- **difficult accessibility in many settlements (narrow streets in bad condition)**
- **few incentives for private informal refuse collection due to limited recycling possibilities of waste material**

Challenges and Conceptual Approaches

Potentials

Due to the economic situation of residents, the amount of waste generated in urban poor settlements is usually significantly lower than in formal, wealthier parts of cities: all materials with any possible economic value are usually separated and recycled. Organic matter, for example, is used to feed domestic animals, or the animals "separate" it themselves from the accumulated refuse.

In extremely poor settlements: high level of recycling and low amounts of waste generated

In less consolidated poor settlements, recycling of waste generated inside the settlement itself is usually an exception. Instead, residents of poor settlements often collect recyclable materials from wealthier urban areas. Sorting and preparation for recycling is then done inside poor settlements, where often highly specialised informal recycling economies have developed. In a few cases, whole urban quarters have specialised in the collection and recycling of waste, for example, the Zabaleen settlements in Cairo, or the waste collector neighbourhoods in Metro Manila (Smoky Mountain and Payattas).

With the consolidation of settlements, waste composition changes and opens up new possibilities for internal recycling

With increasing consolidation of an informal settlement, which is usually accompanied by growing wealth of its residents, the composition of waste changes: changes in consumption patterns usually produce a higher proportion of recyclable waste components as well. Even in formerly poor residential quarters, e.g. in the older, more consolidated *favelas* in Brazil, basic internal recycling methods have developed.

Informal Markets for Recycled Waste

Typical informally recycled materials are metals (in particular non-ferrous metals and large scrap items), reusable glass bottles and plastic containers, and, to a lesser extent, paper and cardboard.

Organic waste, plastic bags, thin sheet iron and steel scrap, and paper and textile off-cuts are generally more difficult to recycle.

As a rule, the development of private initiatives for recycling waste depends less on the material available and its suitability for recycling, than on the practical possibilities of selling recycled materials to intermediate agents, or of reusing or further processing them within the settlement itself.

Recycling of organic waste components /20/

Living and working on a refuse dump site /21/

Informal recycling enterprise in Manshiet Nasser, Cairo /22/

Challenges and Conceptual Approaches

Conceptual Approaches

The characteristics of urban poor settlements described earlier, largely define the possible scope for initiatives and projects to improve solid waste management. For very poor and vulnerable target groups, whose main interest is to secure a livelihood, increasing their awareness of the necessities of protecting their health and the environment will generally not be enough. It will usually be more important to provide economic incentives as well.

Taking into consideration such factors as poor target groups' limited capacity to pay, the general inefficiency of public sector waste management and the difficulties of achieving complete cost recovery for solid waste management services, only few basic approaches will be realistically feasible. As far as possible, they should be combined or applied in a complementary way:

- to further reduce amounts of waste by promoting better sorting and recycling;
- to demonstrate the economic feasibility of waste recycling, supported by training and advisory assistance;
- to mobilise the potentials for resident self-help and initiatives by other civil society stakeholders (e.g. NGOs) to solve the most urgent and obvious solid waste management problems;
- to promote and support informal sector micro-enterprises who are interested in the business opportunities offered by refuse collection and recycling activities;
- to enable public sector institutions responsible for solid waste management to cope with their tasks better, particularly with regard to supervising and controlling solid waste management initiatives at settlement level;
- to introduce consumption-oriented user charges as incentives to reduce refuse. Such user charges should be introduced in a careful and gradual manner in order not to put too much financial pressure on residents of poor neighbourhoods.

There is a wealth of examples and positive experience of solid waste management initiatives in urban poor settlements worldwide, and a variety of feasible and realistic technical approaches and solutions for the collection, sorting, recycling and final disposal of waste have been developed. Some of these exemplary solutions as applied in particular cases, are described in the following sections.

Self-help: clearing refuse from a canal /23/

Private refuse collectors in Kenya /24/

▶ *The following sections of this chapter provide summary overviews on technical solutions and processes that can be applied in urban poor settlements. In addition to a description of their main features and characteristics, their appropriateness is assessed based on the criteria presented in chapter 1.*

Where possible, the overviews are complemented by concrete examples.

Waste Generation

TOOLS AND INSTRUMENTS FOR ASSESSING WASTE GENERATION

Basic Concepts

The planning of solid waste collection and disposal measures, and the identification of waste sorting and recycling options will usually have to be based on a careful analysis of both the amounts of waste generated and of its composition.

This is particularly relevant in urban poor settlements, where the amounts of waste and its composition are normally considerably different to that in formal, wealthier urban quarters. In urban poor settlements, refuse typically consists of organic waste (up to 60-70 % vol.), paper (2-5 % vol.), plastics (mainly foil material, 2-5 % vol.), low-quality scrap (predominantly tin plate containers; 2-4 % vol.) and a mix of stones, bones, textiles, broken glass, batteries, etc. (20-25% vol.).

Given these general characteristics, amounts of waste and its composition can, in fact, vary considerably between different urban poor settlements in different regions or countries. They may be influenced by a settlement's location and other specifics, e.g. if it is centrally located, or is relatively consolidated compared to a peri-urban settlement at the urban fringe, or by its climatic conditions, e.g. arid or tropical etc. Other factors, such as ways of life, nutritional habits, religion, seasonal differences etc. may also impact on waste amounts and composition.

Tools and Instruments

In order to conduct an analysis of waste generated and its amounts that reflects settlement-specific characteristics clearly, the following aspects should be considered:

- The sample of households should be large enough to derive sufficient representative information. Depending on settlement size and characteristics, generally 10-20% of all households should be included (however, in extremely heterogeneous settlements, the sample may have to be significantly larger). In addition, the selection of households to be included in the sample should adequately reflect the neighbourhood's social and economic conditions.
- In order to achieve an appropriate quality of fractioning, the sorting of waste components should be done manually.
- Sample waste collections should be done for different weekdays; to obtain reliable results, at least 4 sample collections will be necessary for each weekday.
- To take seasonal differences in waste amounts adequately into account, waste samples should, if possible, also be collected for different seasons.
- The information on waste fractions compiled can either be presented as volume or weight percentages, the latter being the most common form.

Determining Factors for Waste Amounts and Composition

- **geographical location**
- **ways of life and nutritional habits**
- **cultural and religious characteristics**
- **urban or rural setting**
- **levels of income**
- **background**
- **timing (season, weekdays or holidays)**

▶ *More detailed information on tools and instruments for identifying and analysing waste amounts and composition can be found in, for example: in: Jaradat, Isam Sabri Yousef: Municipal Solid Waste Management in Jordan/Aqaba (International Institute for Infrastructural, Hydraulic and Environmental Engineering – IHE, Delft, 1999)*

Waste Generation

The table below shows examples of waste amounts and fractions in different countries.

The figures relate to the average waste amounts generated by households in residential areas in the corresponding countries or cities.

It should be noted that waste composition can change significantly in residential and industrial or commercial mixed uses areas.

Manual sorting to identify waste composition and fractions in Cotonou, Benin /25/

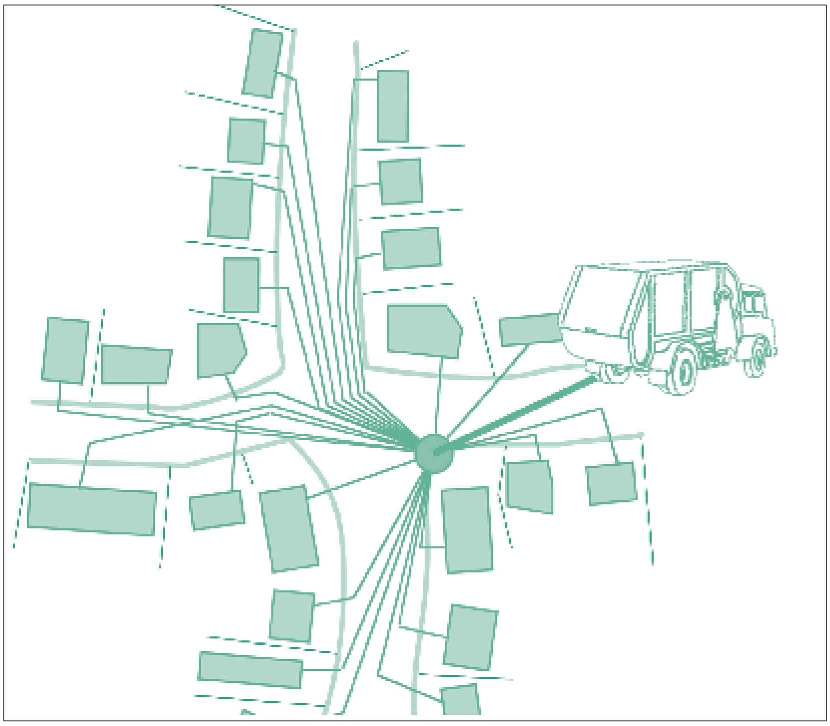
Examples of Waste Amounts and Fractions in Different Countries

country	characteristics of sample area	total amount	organic material	paper	plastics	metal	glass	other	source
		t/p/a	weight %	weight %	weight %	weight %	weight %%	weight %	
Jordan	Aqaba, high income	0.11	61.4	13.6	9.7	7.9	4.9	2.5	(1)
Jordan	Aqaba, low income	0.05	70.1	9.2	8.1	2.4	2.1	8.1	(1)
Mali	Koulikoro, city centre	0.12	93.1*	1.2	2.2	0.6	0.4	2.5	(2)
Mali	Koulikoro, urban fringe	0.41	95.9**	0.8	1.2	0.6	0.2	1.3	(2)
Argentina	urban	0.18	55.4	10.8	6.0	4.8	11,4	11.6	(3)
USA	average	0.73	30.0	38.0	10.0	8.0	6.0	18.0	(4)
Cyprus	average	0.41	35.0	25.0	13.0	4.0	3.0	20.0	(5)
Malaysia	urban	0.34	48.0	30.0	9.8	4.6	n.a.	7.6	(6)
Malaysia	rural	0.23	63.7	11.7	7.0	6.4	n.a.	11.2	(6)
Brazil	Rio de Janeiro	n.a.	34.0	27.0	13.0	3.0	2.0	11.0	(6)
India	Bangalore	n.a.	42.6	16.5	6.7	1.5	2.9	29.8	(7)
India	Dehli	0.17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(8)
Vietnam	Ho Chi Minh City	n.a.	77.5	0.6	0.5	0.3	0.02	20.9	(7)

* 60% sand
** 74% sand

Waste Collection and Transport

DROP-OFF SYSTEMS



Schematic sketch drop-off system

Because waste is brought to collection points by users themselves, and removal is reduced to a few centralised locations, drop-off systems have proved themselves many times in poor settlements, and often are the most suitable solution. In many cases, it is possible to achieve significant improvements to existing, but badly functioning drop-off systems, with relatively minor effort.

Application

Drop-off systems are to be understood as methods of waste collection in which involved households bring either mixed or pre-sorted waste to centrally located containers or transitional storage places. These collection points are emptied at regular intervals either by municipal or or other public sector institutions, or by private waste management companies acting on behalf of municipal or public institutions.

Drop-off systems are especially suitable in districts that are difficult to access by vehicle: for example, on steep gradients, with narrow, winding alleys or unpaved roads.

They have also established themselves in places where for ethical-religious (e.g. in Islamic countries), climatic (in hot regions) or spatial reasons (high population density, multi-storey housing), it is not possible to store waste in the home or on the property. In principle, drop-off systems also enable recyclable material, such as paper, glass or metal, to be collected separately from other waste. In fact, waste separation already occurs informally in many poor settlements, but this depends on whether a suitable market for sorted waste exists.

In most poor settlements, if an arrangement for waste collection is available at all, simple drop-off systems are the typical method, although in most cases it is carried out very erratically and unreliably.

▶ *Further information on sorting and recycling waste can be found in section 2.4*

Waste collection point in an in inner-urban informal settlement in St. Rita, Cotonou /26/

Waste Collection and Transport

Organisation and Structure

Collection points should be set up in places that can be approached easily by collection vehicles, for example on main roads or central public open spaces.

They can be installed as either permanent (e.g. brick or concrete) or mobile containers. The latter are either emptied into refuse lorries at the location or are replaced with empty containers and then driven to waste disposal sites.

Design and Implementation

Numbers and sizes of containers depend on three key factors:

- the quantity of waste accumulated daily in the collection area;
- the extent to which recyclable material is reclaimed by waste collectors;
- the intervals between emptyings.

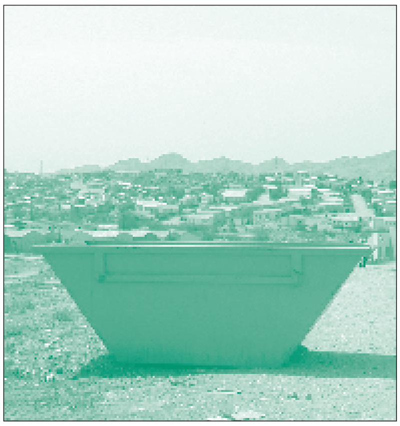
Containers should be dimensioned in such a way that they do not spill over during the times between emptyings. In hot regions, daily emptying is advisable. Since waste can self ignite, and is also often set on fire by residents and youths, containers should be made only from fireproof materials, such as metal, stone or concrete.

To avoid waste being spread by animals or the wind, containers should have lids that shut properly, but that can also be opened easily by children or elderly people. In some countries (India for example), animals are even given access to collection points deliberately: the organic waste there provides them with fodder. This reduces the volume of waste and thereby the disposal costs. An obvious disadvantage is that the animals spread residual waste around.

As a rule, residents should be able to access a collection point within 50-100 m, or at the most, 250 m. If there are not enough containers or they are too far away, there is a danger that waste will be deposited in other places, for example, at the roadside, in drainage canals, on empty sites, etc.

Various container types

/27/



/28/

/29/

Waste Collection and Transport

DROP-OFF SYSTEMS

Limitations and Restrictions

Waste containers that are open to the public are usually dirty and unhygienic. This is caused, among other things, by users dumping their waste carelessly, and animals, especially cats and dogs, spreading waste around while they forage for food.

Moreover, waste that is stored for too long produces smell nuisances and attracts vermin, such as flies and rats. Frequent fires in containers and at collecting points are another reason for smell nuisance and also damage the environment.

Suitability for Self-help

Drop-off systems need the support of local residents. The system as a whole can only work if individual users are willing to go to the nearest container instead of throwing their waste over the walls of their property or disposing of it in some other random way.

In many places, it is first necessary to motivate people and foster a sense of personal responsibility. This is where community associations and self-help groups play an important role.

Yang Pu, Shanghai, China

Waste collection organised by neighbourhood committees and local government

Residents bring their waste to collection points, where collectors pick it up for final disposal. A feature in Yang Pu is the use of bicycle-rickshaws or push-carts as "mobile collection points". This service is being financed by user charges, which households pay directly to neighbourhood committees.

Lakeview Estate, Nakuru, Kenya

Drop-off system organised by women's groups

The informal settlement, "Lakeview Estate", is located in the immediate neighbourhood of the Nakuru National Park, which is famous for its millions of flamingos. Separated from the park only by a fence, the settlement has about 20,000 inhabitants. As the municipality of Nakuru was not able to collect the waste generated in the settlement, residents had begun to dispose of refuse along streets and on public open spaces. Wind and torrential rainfalls also dispersed the refuse into the adjacent National Park.

The Usafi Women Self-Help Group was founded to improve these unhygienic conditions and the pollution. Its members began to collect the refuse from streets and open spaces. Its organic fractions were composted. To facilitate more organised waste collection, five central collection points were established with support from World Wild Life Fund for Nature - WWF: these are small roofed buildings that are accessed from staircases (see picture). This design was chosen to prevent refuse being blown away and to facilitate loading onto collection vehicles.

Central waste collection point in Nakuru, Kenya /30/

Waste Collection and Transport

Assessment of Costs

Costs for a drop-off system arise from:

- purchasing the containers or constructing collection points, and the capital cost of collection vehicles;
- repairs and maintenance of containers or collection points;
- personnel costs of the assigned waste management companies and / or organisations;
- costs of waste removal and dumping (vehicle operating costs, dump fees, etc.).

The total costs of the system depend eventually on the density of the container network, the materials used and the amount of maintenance involved, e.g. for emptying and cleaning.

Brick and concrete waste containers are cheaper than metal containers. But they can only be emptied by hand and not by mechanical lifting and tilting devices.

In many developing countries, wage levels are not very high, so personnel costs are often not a significant factor. Because there is no way to verify how much waste individual households deposit in containers, it is very difficult to introduce volume-linked charges in drop off systems.

Therefore, it is only possible to charge flat rates.

Main Features

Individual transport of household refuse to central collection points or containers; collection and emptying by service providers

Application

Settlements with difficult access conditions (bad road networks, narrow alleys, steep slopes, etc.)

Costs

Low (no house-to-house collection)

Operations

Transport to collection points organised individually; onwards transportation usually organised by self-help groups or local government

Interfaces

Central collection points for transferring refuse for final disposal

Advantages

Relatively inexpensive and affordable; applicable even in poor areas; largely independent of street conditions; suitable for self-help approaches;
later development of sorting and recycling possible

Disadvantages

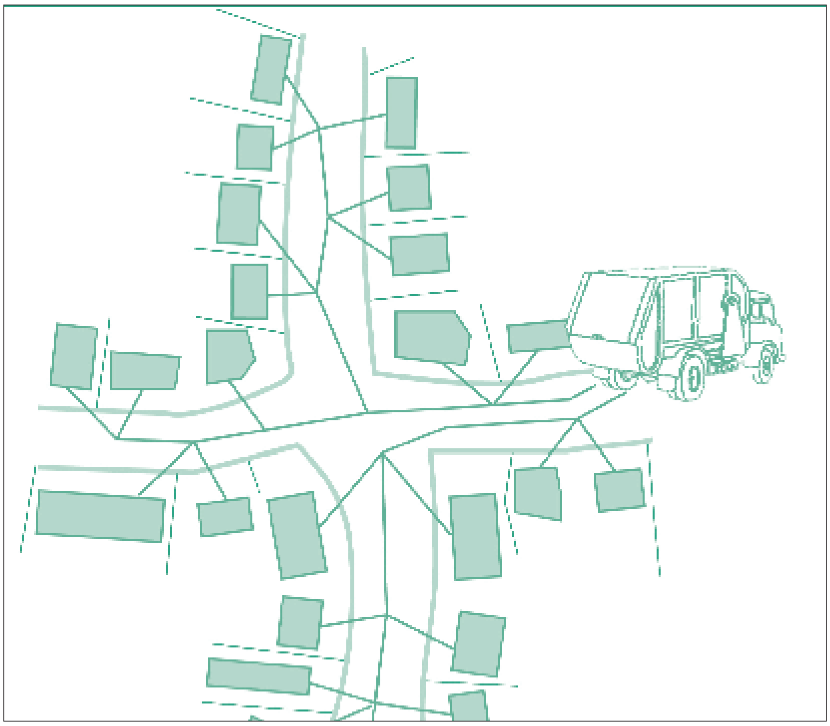
Highly dependant on the participation and support of individual households; volume-related user charges not possible (no incentives for waste reduction); no control of waste and disposal quality at central collection points (individual responsibility usually ends at the collection point)

To be Considered

Maximum distances to collection points; regular and reliable emptying of collection points or containers is indispensable to avoid negative hygienic and environmental impacts.

Waste Collection and Transport

PICK-UP SYSTEMS


Schematic sketch pick-up system

Application

Pick-up systems are methods of waste collection in which involved households collect and temporally store their refuse in appropriate containers, either inside the house or on the plot. The household waste collected and stored individually is then picked-up door-to-door by municipal or other public or private service providers.

Pick-up systems are the most typical and wide-spread form of waste collection in industrialised countries. In developing countries, pick-up systems are usually only applied in formal upper and middle-class residential areas. Due to their higher costs and organisational requirements compared to drop-off systems, fully fledged pick-up systems are rare exceptions in urban poor settlements. However, there are few examples of simplified pick-up systems which demonstrate that they can be a valid option for waste collection, even for poor target groups, particularly in more densely built-up settlements.

Organisation and Structure

Pick-up systems can use both motorised or non-motorised forms of transport.

They need appropriate household refuse containers, which can either be provided by the service operator or purchased individually by the users themselves. If household containers are provided by the service operator, they can be a basis for introducing volume-related user charges. Standardisation of household containers also allows for the use of collection vehicles equipped with suitably corresponding lifting gear.

However, in urban poor settlements standardised household refuse containers are rather the exception. Residents normally collect their refuse in any possible receptacle, e.g. old oil barrels, unused washtubs, plastic bags, etc. An interesting example in Thailand is rubber waste bins made from old truck tyres. They come in near standardised sizes, and are manufactured by enterprises specialising in tyre recycling; they can be seen outside almost all houses in Thailand's urban poor districts.

As a rule, refuse containers are normally put out on the street to be emptied or picked-up once or twice a week. In some cities, refuse is even collected on a daily basis.

► *A more detailed description of motorised and non-motorised systems is given in the following sections.*

Waste Collection and Transport

Design and Implementation

The design of pick-up systems should be based on actual waste amounts to be collected door-to-door. The carrying capacity of motorised or non-motorised vehicles (e.g. push-carts, donkey carts etc.) should be sufficient to pick-up all waste in the particular district or area to be serviced. The dimensions and carrying capacities of motorised vehicles will also have to allow for whether refuse will be transported loosely or compacted.

Standardised household refuse containers will have to dimensioned according to the waste amounts generated and temporarily stored by households prior to pick-up. Different sizes combined with volume or weight-related user charges can provide incentives for reducing waste and for sorting out recyclable material. The collection frequency will have to be coordinated with the households involved, taking into account household storage capacity and hygienic aspects.

Limitations and Restrictions

Any pick-up system will need a suitable standard of street network to allow adequate access to involved households. As a minimum, households should at least be accessible by push-carts or donkey carts. In more densely settled areas with more developed internal street networks, the use of motorised vehicles may be an option, depending on street conditions and the financial capacities of residents. In most cases, however, these conditions do not exist. It will thus be generally difficult to connect urban poor settlements to formal municipal pick-up systems, which usually use motorised vehicles.

Pick-up systems can only function when collection is reliable. Only then will users be willing to temporarily store their refuse rather than dumping it informally outside their plot or neighbourhood. If refuse collection is organised as a private subscription service, only subscribing households will be serviced. But even then, fluctuations in payment patterns or outstanding user charges can severely affect the economic viability and sustainability of such services.

Suitability for Self-help

In urban poor settlements that are not covered by municipal waste management services, self-help initiatives will be necessary to improve sanitary and hygienic conditions. Generally, such initiatives will aim to link local waste collection to city-wide collection and disposal systems.

A valid and well-tested option for such initiatives is subscription based settlement level pick-up systems that can be operated by local NGOs, neighbourhood committees or small-scale enterprises.

To encourage participation in such initiatives, and to create sufficient awareness of the financial and operational aspects, self-help groups and community-based organisations will usually have to take an active role.

Rubber refuse containers made from truck tyres, as widely used in Thailand, China and Laos /31/

Waste in various receptacles deposited for street collection in St. Rita, Cotonou, Benin /32/

Refuse collection in plastic bags in Windhoek, Namibia /33/

2.3 Solid Waste Management

Waste Collection and Transport

PICK-UP SYSTEMS

St. Rita, Cotonou, Benin

Door-to-door collection with push-carts

St. Rita is a neighbourhood in the City of Cotonou with a predominantly poor population. Due to its location close to the lagoon and at almost sea level, parts of St. Rita are regularly flooded. The settlement is not supplied with Cotonou municipal waste management services. Residents thus deposited their refuse on streets, public spaces or vacant plots. Some even used it as fill for their house foundations or to elevate their plot for flood protection. This resulted in extremely precarious hygienic conditions with a high incidence of illnesses.

A local hospital, with financial support from external donors, therefore took the initiative and established an NGO with the objective of developing a door-to-door refuse collection system. In addition to establishing technical and administrative structures, the mobilisation of residents through training and awareness raising campaigns was an important part of the project. As far as possible, the project was built on existing organisational structures (neighbourhood committees, assemblies of elders, political bodies, women's groups and youth associations). With the help of all stakeholders, it was possible to introduce a monthly user charge of FCFA 1,000 (USD 1.5) for households that were willing to subscribe to the waste collection service.

The settlement was then divided into different “collection districts”, in which refuse is collected by a team of two workers with push-carts. The teams then bring the collected refuse to central transfer stations, where recyclable materials are partly separated out; the remainder is then transported to a central landfill site outside the urban area. The collection of monthly user charges was organised by resident committees in each collection district.

Once the system was established and operational, with 90% of households subscribing in some areas, the second step was privatisation of the collection districts: i.e. the refuse collectors were encouraged to work on their own account. With the prospect of increasing their income, the refuse workers, who now had to collect user charges themselves, were motivated to increase the number of subscribers and improve the efficiency of fee collection. The NGO continues to supervise the quality of waste collection, facilitates the provision of push-carts and takes over the collected refuse at the central transfer stations for sorting and final disposal.

High costs for transport from transfer stations to the landfill site remain a major problem. In a further phase, efforts to recycle waste components more systematically, and to reduce the amounts of waste to be transported for final disposal are to be increased.

Refuse collection in Cotonou, Benin /34/

Badge indicating that the household is a subscriber to refuse collection services in St. Rita, Cotonou, Benin /35/

Waste Collection and Transport

Assessment of Costs

If no standardised domestic refuse containers are provided by service operators, which is usually the case in urban poor settlements, the following costs will have to be considered in order to develop and establish a simple pick-up system:

- purchasing costs for collection vehicles;
- energy/fuel and other operating costs of collection vehicles;
- personnel costs of refuse workers and fee collection staff;
- costs of refuse transport and final disposal.

To be financially sustainable, these costs will have to be covered by corresponding user charges.

The marketing of sorted and recycled waste components may provide additional revenue: but it may also entail additional costs, e.g. for sorting and storage of recyclable materials.

Main Features

Door-to-door collection of refuse; transport to landfill site directly or from transfer station using larger trucks

Application

Settlements with minimum accessibility (or at least accessible for push-carts)

Costs

Relatively high (due to individual door-to-door collection)

Operations

private enterprises, self-help initiatives or municipal

Interfaces

Transfer of refuse collected locally by private enterprises or self-help groups to municipal or private operators for further transport and final disposal

Advantages

Can provide job opportunities; volume or weight-related user charges are possible; efficient control of final waste disposal; temporary storage of refuse by individual households facilitates sorting, separation and composting

Disadvantages

Needs a minimum of infrastructure; needs sufficient space for and social acceptance of refuse storage inside houses or on plots; requires willingness to pay for collection service

To be Considered

Regular refuse pick-up is indispensable to maintain the trust of users in the system and their willingness to pay

Waste Collection and Transport

NON-MOTORISED SYSTEMS

Application

Non-motorised vehicles are used when insufficient capital and bad street conditions limit the use of motorised collection vehicles. Non-motorised systems are a simple solution appropriate for most urban poor settlements (and also for rural and peri-urban areas). There is a wealth of examples and practical experience of their application.

Non-motorised systems can contribute to job creation and income opportunities since they are labour intensive and the payloads of the individual collection vehicles are small and manageable. Consumables needed for operations (e.g. fodder for draught animals) are usually locally available and can often be obtained free of charge. The usually simply constructed vehicles have low investment costs, can be manufactured locally, and are easy to repair and maintain.

Manual push-cart in Cotonou, Benin /36/

Design and Implementation

The kind and number of collection vehicles needed mainly depends on residential densities, the amounts of refuse generated, the condition of the internal street network and the distance to transfer stations or landfill sites. Payloads and distances should not exceed the capacities of men and beasts. Particularly during rainy seasons, when streets are muddy and wet refuse is heavier, the risk of overburdening is high.

Manual push-carts have a limited scope because they can only cover short distances. Bicycle rickshaws or animal drawn carts, on the other hand, can allow for larger transport distances, possibly even to landfill sites, although considerable time-input may be needed due to their low speed.

Collection districts or areas should thus be designated in ways that enable them to be adequately covered by the types of vehicle available.

Donkey cart in Manshiet Nasser, Cairo, Egypt /37/

Operations and Maintenance

Even the life span of simple, non-motorised collection vehicles will be defined by their mode of operation and the quality of their maintenance. Their life span can be considerably extended if overloading is avoided, and when moving parts and bearings are regularly lubricated. Small damages should be repaired quickly before they lead to major problems and long downtimes.

When animals are used, special care should be taken to maintain their health and strength. Good fodder, correct treatment of illnesses or injuries and sufficiently long regeneration periods will be essential. Unfortunately, draught animals are often held in low-esteem and ill treated. In Mali, for instance, it is common knowledge that donkeys, once they are used to pull waste carts, do not normally survive for more than two years.

Limitations and Restrictions

Small payloads and short ranges limit the possibilities of using non-motorised vehicles for waste collection, particularly when heavy or bulky materials (e.g. cartons, plastic sheets or bulk rubbish) need to be transported. Moreover, in settlements with steep slopes, the physical strength of men or beasts can often be not enough to move a loaded waste collection vehicle.

Waste Collection and Transport

Suitability for Self-help

Due to their comparably low investment and operating costs, their labour intensive operation and the possibilities for local repair and maintenance, non-motorised vehicles are especially suitable for use in self-help initiatives. Moreover, they are often the first step towards the mechanisation of locally organised waste management systems. Their potentials can be demonstrated by the fact that, until a few years ago, all the refuse in the metropolis of Cairo was transported by donkey carts.

Assessment of Costs

Necessary initial investments will largely depend on the kind of vehicles to be used and their technical standards. When they can be produced locally, they will usually be affordable to individual private refuse collectors, local self-help groups or small-scale enterprises. In addition to initial purchasing costs, operating costs will normally consist of maintenance and repair costs, costs for fodder and animal care, and staff wages. Depending on the refuse collection system, other expenses may occur for final disposal at a landfill site or for the use of transfer stations.

Koulikoro, Mali

Modification of donkey carts to deal with particular waste components

In the municipality of Koulikoro in Mali, which has 20,000 inhabitants, a small local enterprise collects household refuse with donkey carts. Commissioned and licensed by the municipality, the enterprise collects user charges directly from the households its serves.

Due to the lack of an organised landfill site, the refuse is dumped on the banks of the river Niger outside the town. In the search for ways to reduce the amount of residual waste to be finally deposited, an analysis of waste composition was conducted.

The result of the analysis was that the refuse consisted of 60-75% sand. Separating the sand from the collected refuse could, therefore, considerably reduce the weight and volume of waste to be deposited, and, at the same time, relieve the strain on animals and collection vehicles. Because of the arid climate, the easiest way to separate the sand was to sift the refuse.

To do this, a funnel with a sieve insert was designed that attached to the back of the donkey cart. The sifting process begins once the refuse is loaded into the funnel, and increases when the cart moves forward. Since most urban roads and streets are unpaved, the sand can usually be left where it where it has been sifted.

Main Features
Transport of refuse with simple vehicles like push carts, animal drawn carts or bicycle rickshaws in a labour-intensive way;

Application
Settlements with minimum infrastructure: in cases where there is a lack of capital for larger investments or insufficient street networks for motorised vehicles

Costs
Low: local production; possibility of local repair and maintenance; manageable investment and maintenance costs

Operations
Self-help possible; individually owned vehicles and self-employed or employed personnel

Interfaces
Temporary or final disposal needs to be within the reach of vehicles; otherwise risk of uncontrolled dumping

Advantages
Low investment and operating costs; simple operations; flexible; first stage of a more complex solid waste management system; well-suited for self-help

Disadvantages
Low payload capacity, limited range

To be Considered
Loads and transport distances should be carefully adjusted to the capacities of men and beasts

Waste Collection and Transport

MOTORISED SYSTEMS

Application

Motorised vehicles are particularly useful when larger amounts of waste have to be collected and transported over longer distances.

For refuse collection purposes, there is a large range of possible solutions: from simple motor rickshaws or tricycles, to small trucks, up to technically sophisticated compactor trucks.

Larger vehicles with higher payload capacities can increase collection efficiency considerably. On the other hand, they usually need technically qualified staff and an appropriate street network. Costs for investment, operations and maintenance generally grow in line with the increasing size and technical sophistication of vehicles, while costs for personnel usually decrease. However, since salaries and wages are relatively low in most developing countries, possible savings on personnel costs do not normally compensate for higher investment costs.

For refuse collection in urban poor settlements, the use of smaller motorised vehicles is often a valid option, and a wealth of practical experience and proven technical solutions are available.

Design and Implementation

The selection of appropriate vehicles will mainly be determined by the financial capacities of their operators and the quality of the existing internal street network. In most cases, especially in typical urban poor settlements with narrow and winding alleys and rough street surfaces, inexpensive and sturdy motorised vehicles will be the solution of choice.

Since the transport distance and the time needed to get to landfills or dumping sites are often decisive factors for operating costs, larger vehicles with higher payloads will usually be given preference.

If street conditions inside a settlement prevent the use of larger vehicles, reloading refuse from smaller to larger vehicles may have to be considered. This will require the establishment of appropriate transfer stations, usually at the settlement fringes.

Small refuse collection truck, Ecuador
/38/

Operations and Maintenance

The use of large, modern equipment normally requires specific technical know-how on its operation, maintenance and repair. Hence personal skills will have to built up and suitable garaging and workshop premises will need to be found.

To extend vehicles' life spans, it will be important not to exceed their maximum payloads and to service them regularly (renewing coolants, oil, hydraulic liquids, etc.). If second hand vehicles imported from industrialised countries are to be used, special problems often arise with regard to the supply of spare parts and with technical skills needed for maintenance. In addition, such vehicles would, in some cases, have to be suitable for particular climatic conditions (e.g. with sufficient engine cooling in extremely hot climates).

For hygienic reasons, a regular and comprehensive cleaning of the loading spaces or holds of vehicles will be necessary.

Limitations and Restrictions

The main factors limiting the use of motorised collection and transport vehicles are usually the bad street conditions in urban poor settlements, the lack of qualified maintenance and repair staff, and difficulties with obtaining spare parts.

Due to the comparatively high costs involved in the purchase and operations of motorised vehicles, their economic feasibility, including factors such as the financial capacities of operators, can also restrict their use.

Waste Collection and Transport

Suitability for Self-help

Budget classes of motorised vehicle can be appropriate for self-help initiatives, as investment and operating costs will be more manageable.

Buying larger, more modern vehicles can easily exceed the financial capacities of self-help initiatives. Since modern compactor trucks can often cost hundreds of thousands of Euros, they would in most cases have to be financed with support from external resources. However, due to the follow-up costs involved, their use in urban poor settlements should be considered very carefully, even when such resources are available.

Assessment of Costs

Necessary initial investment costs will generally increase with size, payload and the technical equipment of vehicles, and will be disproportionate to any resulting savings in personnel costs. Overall economic feasibility will thus be mainly determined by the fixed costs of initial investments (interest payment, depreciation, discounting of equity). In comparison, salaries and wages, which are usually low in developing countries, will be less important.

Increases of efficiency expected from more sophisticated equipment should therefore be really significant, and higher investment costs should not be justified by savings in comparatively inexpensive labour costs.

Lokossa, Benin

Motorised pick-up system operated by a cooperative

In the provincial capital city of Lokossa in West African Benin, a waste management cooperative picks up household refuse in a door-to-door collection system, using a mini tractor and trailer produced in China. A monthly user charge is collected from all involved households, but the charges do not completely cover the service costs.

Refuse can be transported with the mini tractor to a central collection point outside the city boundaries, where it is sorted. Recyclable materials, such as plastics, paper and metal, are sold. Organic waste components, which constitute 40-50% of the total refuse, are composted and then used for gardening and urban agriculture. Yields can thus be improved considerably, and sales of fruit and vegetables at local markets have become a new source of income. Without the mini tractor, this would not have been possible.

Mini tractor in Lokossa, Benin /39/

Main Features
Transport of refuse with motorised vehicles with higher payload and transport capacity

Application
In settlements accessible for motorised vehicles; particularly applicable for large amounts of refuse or for transporting refuse from drop-off system transfer stations to final disposal sites

Costs
High costs for investment and operations

Operations
Simple or budget class motorised vehicles possibly suitable for operation s by self-help organisations or small-scale enterprises; larger, more modern vehicles usually require more professional organisational set-ups and operations

Interfaces
Operations of small-scale enterprises or self-help initiatives at settlement level will usually have to be complemented by city-wide (municipal) operations with larger vehicles and higher payload and transport capacities

Advantages
Efficient transport of larger amounts of waste over longer distances

Disadvantages
High initial investment and long-term operational costs; requires skilled personnel and minimum street network s quality

To be Considered
Regular maintenance; avoidance of overloading

Handling of Refuse and its Further Treatment

RECYCLING OF HOUSEHOLD WASTE COMPONENTS: BASIC CONCEPTS

In urban poor settlements, dealing with household refuse appropriately and its further processing can be a practical option and complement conventional collection, transport and final disposal. Refuse sorting and separation can considerably reduce the amount of waste to be expensively transported for final disposal. Moreover, recyclable material can be further processed inside the settlement, thus helping create new job opportunities and income.

Household refuse in poor residential areas often contains few recyclable components, as any material of any value has usually been separated out of it. Recycling initiatives will therefore have to focus on those materials that are actually present in the household refuse of urban poor settlements. These are mainly organic matter, and paper and plastic components. Metal and glass are quantitatively and qualitatively less significant, since large metal parts, non-ferrous metals and intact glass bottles have usually already been separated out. Waste generated by local small-scale enterprises, industries or transport services (waste oil, tyres, batteries, metal scrap, textiles, wooden parts) can, in some cases, be a basis for recycling and further processing.

In most urban poor settlements, recycling and processing of waste materials, when it occurs, is generally part of the informal sector economy.

Unfortunately, due to lacking financial resources, technical know-how and awareness, many of the processes and techniques practiced by informal enterprises seriously affect both the environment and the health of people involved in recycling activities. Any plans to promote recycling initiatives should therefore, on the one hand, avoid damaging existing economic structures and markets, and on the other hand, strive to limit or alleviate possible threats and hazards for people and the natural environment.

The economic success of recycling initiatives will largely depend on specific local conditions (e.g. markets or demands for recycled materials), which should be carefully analysed and assessed in early preparatory stages.

▶ *for check list for planning recycling measures, see Annex*

Sorting refuse in an inner-city informal settlement in Cairo, Egypt /40/

SORTING

Application

Refuse sorting can be applied in urban poor settlements when household refuse contains sufficient quantities of recyclable materials, and when residents are interested and willing to embark on sorting and recycling initiatives.

Ideally, refuse sorting should be done directly at its source in individual households or commercial enterprises; but, for various reasons (lack of space, insufficient acceptance, cultural reservations, ignorance, etc.), this will often not be practical, or only be possible when appropriate incentives are available (e.g. payment, marketing possibilities for secondary raw materials, etc.). Even when household level separation and sorting does function, an amount of mixed refuse will always remain to be sorted and further processed in order to separate recyclable material from more hazardous components and other residuals.

Although significantly more challenging, sorting and separation of refuse after household collection is also possible. This is usually done at central locations or sorting stations especially established for the purpose.

Sorting of waste enables:

- **the extraction of recyclable and marketable material from refuse (secondary raw materials);**
- **the separation of hazardous waste components (e.g. batteries, chemicals, etc.)**
- **the minimising of the amount of residual waste to be deposited**

Handling of Refuse and its Further Treatment

Organisation and Structure

Depending on the daily amounts and volumes of refuse generated, sorting can be done manually, be partly mechanised or be completely mechanical. In urban poor settlements, partly mechanised sorting will, in most cases, be the maximum feasible option. But because labour costs are low, it will usually make sense for sorting to be done as much as possible by hand.

The following main processing steps will be necessary:

- sieving, to separate coarse and fine waste fractions;
- manual sorting of coarse and fine fractions with the objective of:
  - extracting recyclable material from coarse fractions (paper, plastics, metal, glass),
  - cleaning organic fractions (which are usually the major parts of the fine fractions).

Effective sorting can reduce the amount of residual waste to be finally deposited to less than 20% of the original volume. A recycling of organic fractions and of paper and plastic components will be particularly important.

Quantities, Design and Implementation

Household refuse of up to 5 tons per day (from a catchment area of 15,000 - 20,000 inhabitants) can be sorted and separated completely manually. Apart from a paved surface (e.g. a concrete slab with an area of ca. 10x10 m), the only equipment needed will be a large sieve. Ideally, the sorting area should be fenced or walled to prevent refuse being blown away or the theft of valuable waste components. Containers to store different recycled materials will be useful. Five people will be needed to separate and sort this quantity of refuse.

For up to 20 tons of refuse per day (from a catchment area of roughly 60 - 80,000 residents), a partly mechanised sorting system may be more appropriate. Its main elements are a conveyor belt to transport the refuse to a drum sieve, and two other belts for manual separation of coarse and fine fractions. Moving both incoming refuse and the extracted fractions can be done by a motorised shovel. Again, the sorting installations should be fenced, or, even better, be located inside a work hall. To operate the equipment and to sort this amount of refuse, about 10-12 persons will be needed.

Operations

To avoid nuisance from smells, incoming refuse should be processed on the same day, or, at the latest, on the following day. Residual refuse should be transported for final disposal immediately. In most cases, the extracted materials will need further procession, which can be done either at the sorting area or at other suitable locations.

To protect staff, the sorting area and its premises should be well-aired. Protective clothing, including gloves and dust masks, should be provided, as should basic washing facilities. Eating should be prohibited inside the sorting area.

The sorting area should be fenced or walled to avoid refuse being blown away or dispersed by animals.

▶ *Further information on different recyclable materials are provided in the following sections*

Handling of Refuse and its Further Treatment

SORTING

Limitations and Restrictions

To avoid long transport distances, sorting should preferably been done where the waste is generated. This often conflicts with a limited availabilities of space or the wishes of residents, who often do not want refuse sorted in their immediate neighbourhood. In many countries, the handling of refuse has a negative image; in others, this work is restricted to certain ethnic groups or castes.

In general, negative impacts and nuisances of refuse sorting and processing cannot be completed avoided. Thus speedy processing and appropriate protection measures will be important.

Suitability for Self-help

In general, individual sorting at household level has considerable self-help potential. Negative environmental impacts and nuisances often caused by central waste sorting can thus be avoided, and households can benefit directly from the possible revenues from selling of recycled refuse components. Moreover, costs for the collection and disposal of residual refuse can be significantly reduced, again to the direct benefit of individual households.

Initiating and promoting waste sorting at household level will generally require educational or awareness raising activities. Community based organisations, environmental initiatives or self-help groups can be instrumental in this. Often a practical demonstration of sorting possibilities will have to be given before they will be adopted by individual residents and households.

In most cases, both individual awareness raising and practical demonstrations of refuse separation, will have to be undertaken in parallel.

Cairo, Egypt

Waste sorting by Coptic refuse collectors - the Zabaleen of Cairo

A part of Manshiet Nasser, with roughly 400,000 inhabitants, is one of the largest informal settlements in the Egyptian capital Cairo, and is located close to the historic Islamic city. It is populated almost exclusively by Coptic Christians. Most of its residents make a living by collecting, sorting and processing household refuse from wealthier parts of Cairo. In total, about 10,000 people in this particular part of Manshiet Nasser are working and living with refuse. In addition to raising fees from households, the recycling of refuse, which used to be collected with donkey carts, and today is done with small trucks as well, is traditionally their most important income source. Over time, a whole economy, with complex sorting and recycling systems, has developed, which nowadays is even used by public sector refuse collection providers. In addition to refuse delivered by donkey carts and small trucks, even large municipal collector trucks discharge their loads for sorting and recycling.

Incoming refuse is usually manually sorted by women and children. Organic components are fed to pigs and goats kept by the Christian residents. Paper, plastics, textiles and metals are sorted by material, colour and quality, and then sold to other families who have the necessary equipment and technical skills to further clean, shred, ameliorate and process bulk recycled materials. In this way, the neighbourhood not only produces intermediate products, such as bundled paper and sorted plastic waste, but also final products like metal cast goods, die-cast plastic parts or cushions made from textile waste.

Even machines and equipment needed for recycling and processing (baling presses, shredders, plastic extruders, die-casting machines, etc.) are nowadays partially or completely produced inside the settlement.

HANDLING OF REFUSE AND ITS FURTHER TREATMENT

Assessment of Costs

Individual household refuse separation does not normally entail any significant costs. It only requires a little time input, and can even generate additional income.

Completely manual sorting of mixed household refuse needs only minor investment for installations and equipment - a sorting area, fencing or walling, sieves, shovels and some containers or bags for the different recycled fractions. Basic equipment, space or premises are, moreover, often readily available inside settlements, thus reducing, or doing away with some of the initial investments needed. The only operating costs incurred will be for workers' wages.

Partly mechanised sorting will require more substantial investments in equipment and installations. Depending on technical specifications, these can quickly add up to some tens of thousands of USD. Such investments will only be justified when large amounts of refuse are to be processed, and sufficient recyclable material can be extracted.

Main Features
Extraction of recyclable material and separation of hazardous waste from household or commercial refuse; preferably at source (households or enterprises); sorting after collection requires space and protection measures

Application
Well-suited for self-help approaches, as marketable products can be extracted, residual refuse reduced and hazardous waste separately treated and disposed of

Costs
No additional costs for sorting at source; main costs of manual sorting are for staff wages; sorting larger amounts of refuse can mean significant investment costs

Operations
Well-suited for self-help initiatives or small-scale enterprises, in particular when sorting is done by individual households or at collection places

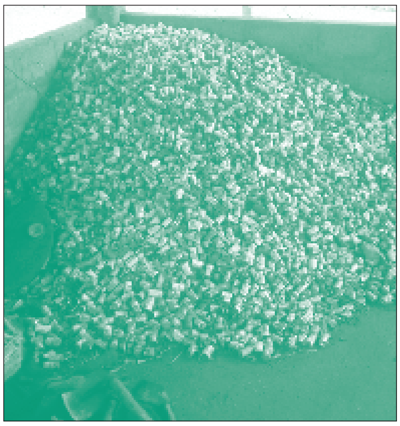
Interfaces
Larger volumes of residual waste accumulated after sorting have to be handed-over and transported for final disposal

Advantages
Costs of sorting can be partly or completely financed by marketing recyclable components

Disadvantages
Requires awareness, skills and acceptance of users; markets and marketing possibilities are required

To be Considered
The better sorted and cleaner the extracted fractions, the higher the possible revenue from from their sale.

Batteries separated from household refuse in Cotonou, Benin /41/



Refuse sorting in Cotonou, Benin /42/

Handling of Refuse and its Further Treatment

COMPOSTING

Application

In developing countries, more than 50% of total household refuse typically consists of organic material. Composting of organic components can therefore contribute significantly to reducing the amount of waste to be transported and disposed of. Usually, the more rural the location, or the poorer the inhabitants, the higher the amount of organic waste components.

Composting not only reduces the amounts of refuse to be disposed of, but it also produces valuable fertiliser that can be used for gardening or agriculture, or for public open spaces in and outside settlements.

However, composting is still new and relatively untested in solid waste management projects in urban poor settlements, where, in many countries, residents have grown up in urban environments, and thus usually have little knowledge of a procedure derived from horticulture and agriculture.

Introducing composting schemes will therefore normally need intensive advisory assistance, training and testing.

Composting can be done both individually at household level, and/or in central community or municipal level facilities.

The advantage of composting at household level is that organic waste components can be separated at source, thus avoiding the contamination of other waste components that could be further sorted and recycled.

Central composting allows for more professional operations, with regular control of humidity, temperature, the level of bacteriological sterilisation and the overall quality of the compost. Treatment of larger amounts of material usually requires appropriate equipment or machines, such as motorised shovels, drum sieves or shredders.

Compost rots in Cotonou, Benin /43/

Processing Features

In contrast to anaerobic fermentation, which produces biogas, composting is an aerobic process, which involves the intake of oxygen. To enable sufficient oxygen to enter the composting material, or “rot”, organic waste with low fibre content and few carbon/ nitrogen (C/N)components (e.g. kitchen waste, faeces etc.) is mixed with waste with a higher fibre and C/N content, which is also known as “structural material” (e.g. garden waste, twigs and chippings, etc.). Turning the compost over regularly improves the oxygen supply. In the composting process, the temperature in the rot increases and kills pathogenic germs. A correctly applied composting technique can even process faeces into hygienic and germ-free compost.

A second important factor is humidity, which is needed so that composting bacteria become active. In hot dry climates, regular control of the moisture content inside the rot will be very important. In cold regions, a sufficiently high temperature will have to be maintained (e.g. by using suitably large compost pits).

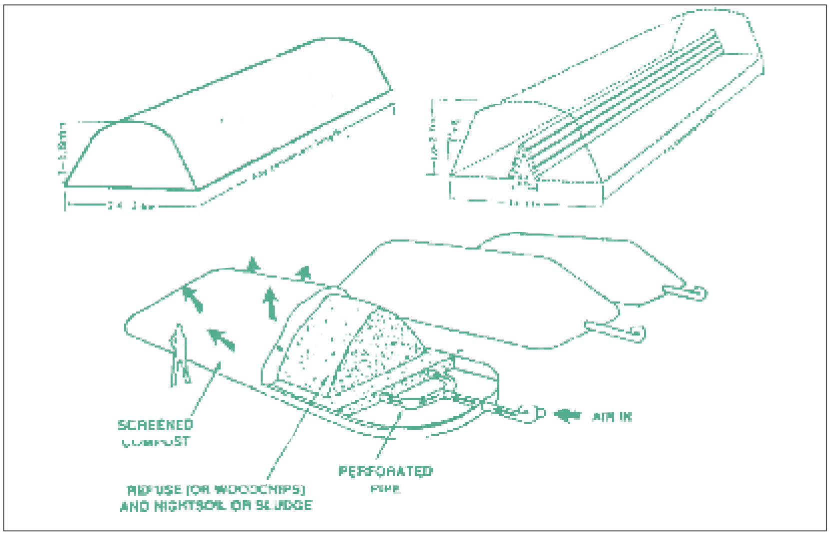
Individual composting can be done, for instance, in special “compost bins” which have a sufficient number of openings or holes to allow air, and hence oxygen to enter. Central composting is usually done in form of conical or frectangular heaps erected on levelled surfaces, sometimes made of concrete.

In more specialised processes, the compost is additionally ventilated or rotated in drums to speed-up the composting process.

Handling of Refuse and its Further Treatment

Design

The illustration below shows three kinds of simple conical rots; one without an oxygen supply channel, one with passive ventilation and a third with forced ventilation.



Different conical compost rots /44/

Limitations and Restrictions

Simple composting processes can be done with little equipment or machinery, but require a basic knowledge of and experience with the underlying biological processes. Both individual composting and more complex central composting will need a phase of testing and experimentation. Possible operators should therefore have motivation and constancy, as well as the courage to experiment.

In many countries, compost is not yet common as a marketable product, so selling it can be difficult. It may therefore be helpful to initially use compost for personal requirements, or, for example, for fertilising public gardens, to demonstrate its usage and provide a basis for later marketing.

Operations and Maintenance

As a rule, the percentage of water inside the rot should be 40-60% in order to ensure a sufficient level of humidity. At the peak of fermentation, the temperature can rise to up to 65°C. A drop in temperature indicates the transition from the aerobic to the anaerobic process, and the need to turn the rot over again. The period of time between two turnings over mainly depends on climatic conditions and cannot be generally determined. Followed fast decomposition in the initial phases (1-2 months, called the "main rot") the process slows down. The so-called "follow-up rot" can take an additional 2-4 months or more.

At the end of the process, the compost has an earthy, humus-like smell, and can be used or marketed as fertiliser or soil improver. Before marketing, another sieving process may be necessary to separate out remaining solid parts (plastic, glass, stones etc.) or incompletely decomposed components from the compost. These can be re-used as "structural material" for new rots.

Sieving composted components from household refuse in old informal dumping sites in Mogadishu, Mocambique /45/

2.4 Solid Waste Management

Handling of Refuse and its Further Treatment

COMPOSTING

Suitability for Self-help

Composting, with its low level of technical requirements, is well-suited for self-help approaches, which can significantly reduce waste generation and, at the same time, produce inexpensive fertiliser for gardening and agriculture. Even with very limited space, plastic bags filled with compost can be used to grow vegetables.

In many countries, composting initiatives can build on the local knowledge of traditionally rural societies. Additional skills and knowledge on how to produce and use compost can be disseminated by neighbourhood committees and self-help groups.

Bamako, Mali

Composting by a private initiative

The private initiative G.I.E. BESEYA separates and further processes organic waste components at a waste transfer station. The organic material is then composted in covered pits.

The compost produced is manually sieved and then sold. G.I.E. BESEYA has also established a tree nursery, and compost is used to fertilise fruit trees; the harvest is sold.

G.I.E. BESEYA employs a number of young men and women who had problems finding alternative employment.

Nairobi, Kenya

Composting by a self-help group

In Nairobi, some hundred families live at the municipal dumping site of Dandora. They make a living by searching the waste for recyclable materials, which are then sold. One of the self-help initiatives, the Mboela Group, uses organic waste components for small-scale composting. The group, supported by a neighbouring church, has learned to set up compost rots with the necessary mix of structural and fine material. The composting process is controlled by checking the temperatures inside the rot regularly, using a wooden stick which is inserted into the rot (see photo). After a certain time, the stick is withdrawn and the temperature checked by hand. If a sinking temperature indicates an insufficient air supply, the rot is turned over. This is repeated until the composting process stops (i.e. when there is no further increase of temperature). The compost is then sieved, filled into bags and sold, or used in the group's own adjacent garden.

Plastic planting bag filled with compost for growing vegetables in Kisumu, Kenya
/46/

Checking the temperature of compost at the Dandora dumping site in Nairobi, Kenya
/47/

Handling of Refuse and its Further Treatment

Assessment of Costs

The investment needed for composting will largely depend on the scale and scope of an initiative or project. It can range from almost no costs for individual composting at household level, to the purchase of motorised shovels, shredders, sieving and ventilation equipment, up to investment in completely mechanised composting plants.

Community self-help initiatives will require comparatively small investments. If composting cannot be done completely manually, simple drum sieves, small shredders and motorised shovels can be useful.

Main Features
Aerobic fermentation of organic substances by bacteria and compost worms

Application
Individually at household level or at central composting facilities

Costs
Low costs for individual composting; investment and operating costs of machines and other equipment for larger volumes of material

Operations
Individual and small-scale central composting facilities are well-suited for self-help initiatives; larger facilities are usually operated by municipalities or other institutions

Interfaces
Depends on the amount of organic waste to be composted

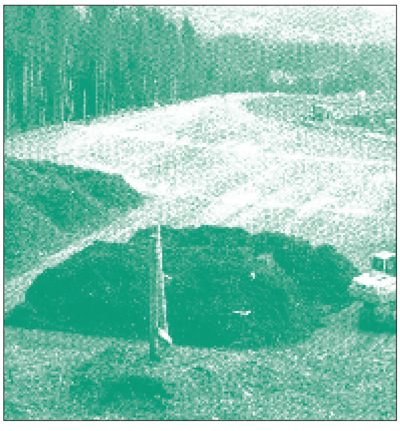
Advantages
Reduction of residual waste to be transported and deposited on landfill sites; production of valuable fertiliser; low investment needs; local knowledge of rural societies can be built on

Disadvantages
Requires separation of organic waste components; marketing and the acceptance of composting by the population can be difficult; requires basic understanding of underlying biological processes.

To be Considered
Depending on climatic conditions, special control of humidity levels and temperatures is necessary

Compost heaps

/48/



Manually operated drum sieve for sifting compost

/49/

Handling of Refuse and its Further Treatment

SORTING AND RECYCLING OF PAPER

Application

Paper is generally the most common waste fraction in urban poor settlements after organic components. With their long fibre content, cardboard packaging is usually the most valuable material for recycling. Separation at source (e.g. by using containers for paper) will facilitate recycling. Recyclable and marketable paper material can also be extracted from mixed refuse. Cleaner paper components can be extracted and recycled as paper, while extremely soiled paper material can possibly be used for composting.

The production of recycled paper goods requires rather complex technical installations and equipment. In most cases, even in developing countries, paper is therefore recycled industrially in large paper factories. Small-scale suppliers and enterprises are mainly limited to sorting different paper qualities and pressing transportable bales.

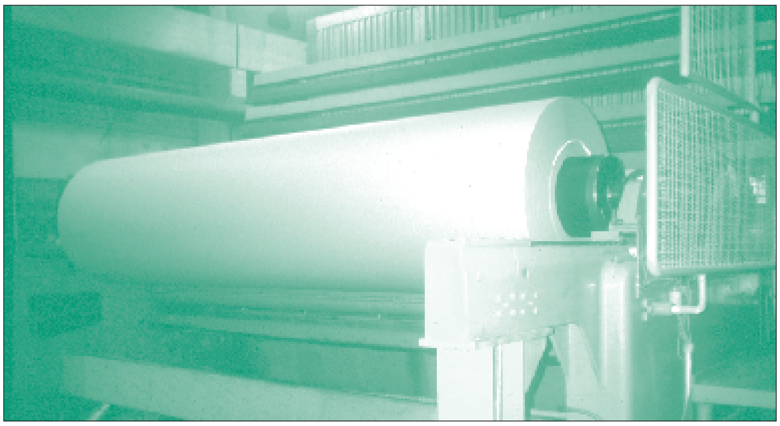
Small-scale industrial recycling processes can include the production of handmade paper, egg and fruit packaging and pressed paper briquettes for domestic or industrial heating. In industrialised countries, paper shavings are treated with fire-resisting chemicals and used as insulation for buildings. Paper shavings can also be used as animal litter.

Paper separated in urban poor settlements can supply both large-scale industrial recycling plants and small-scale settlement level recycling enterprises.

Collecting, sorting and pressing scrap paper are common activities, practiced globally by large numbers of formal and informal collectors and traders.

The production of handmade paper is also quite common. A more recent and innovative recycling process is the production of paper briquettes for fuel. The manufacturing of egg and fruit packaging requires machinery and technical equipment, and hence only large-scale production will be economically feasible.

Large-scale industrial paper recycling at "Zülpich Paper Mill" in Germany /50/



Technical Solutions

Three basic technical solutions can be applied for paper recycling activities at settlement level:

- sorting and compacting by baling presses to supply material for further processing at a larger scale;
- processing on the spot, using so-called "pulpers" to produce egg and fruit packaging;
- the production of paper briquettes as fuel for heating and cooking.

Sorting and Compacting

The most important piece of equipment for paper collectors and suppliers to larger industries is a baling press. It is used to compact paper into bales that can be transported at feasible costs.

Baling presses are available in different forms and sizes, e.g. with worm drive shafts for manual operations or with hydraulic drives. Higher pressure hydraulic presses generally produce more compact bales and hence a reduction of the volumes to be transported. Bale sizes should be chosen so that available equipment can move, load and transport them.

For sorting purposes, different paper qualities (e.g. cardboard packaging, office paper, magazines and newspapers, laminates, coated paper, etc.) will have to be considered. To market sorted paper, information on the expected quality and composition of the sorted paper should be obtained from potential wholesale buyers or end-product manufacturers (paper mills). As a rule, sorted

Handling of Refuse and its Further Treatment

Paper press in Manshiet Nasser in Cairo, Egypt /51/

cardboard packaging, the most important fraction, is usually allowed to contain 20-30% of other paper types. A certain amount of soiled paper or other material, such as adhesive tapes, cords, wires or plastic binding is usually tolerable.

Pressing involves putting cardboard into the press in layers, and then compacted it. The resulting bales are then tied with cords, wires or plastic strips.

Processing for Producing Egg and Fruit Packaging

To produce egg or fruit packaging, scrap paper (preferably from newspapers) is turned into paper pulp in a so-called "pulper". A vacuum generated by the machine sucks the pulp into a mould and excess water is drained off. The remaining still wet product is taken from the mould, and dried in the air or in a heated drying cabinet.

Egg and fruit package production can be done at different scales. Depending on the amount to be produced, packaging can be manufactured intermittently with simple small machines or, continuously, by completely automated production lines. Egg and fruit packaging can be made from relatively low-quality paper, and can contain a certain amount of soiled paper and other material.

Production of Handmade Paper

The production of handmade paper basically involves the same steps and processes that are used in large-scale industrial paper recycling. These involve:

- shredding sorted scrap paper;
- soaking;
- producing paper fibre pulp in a pulper and/or a beater;
- removing the usable paper components from the pulp using a sieve;
- laying the wet sheets of paper on a cloth;
- pressing the paper sheets to drain of the excess of water;
- drying;
- possibly dying and further processing.

Production of handmade paper in Manshiet Nasser in Cairo, Egypt /52/

Handling of Refuse and its Further Treatment

SORTING AND RECYCLING OF PAPER

Production of Paper Briquettes

To produce paper briquettes, shredded paper is hydraulically compacted to paper bars that are stable in form and storable (in dry environments). Briquette presses can be operated both continuously or discontinuously, e.g. only for a few hours at a time. The smallest production equipment currently available on the market can process about 50 kg of briquettes per hour.

It is possible to press fuel briquettes from almost all paper types, and also from extremely soiled sorts of paper that are otherwise difficult to market. With mechanised pressing, the proportion of sand in the paper to be pressed will have to be limited, since sand can cause considerable wear and tear in the machines. Before pressing, the paper has to be shredded and, depending on the type of press, made slightly wet. In industrialised countries, dry pressing procedures are used to dispose of files and paper records. These kinds of presses are less common in developing countries, where wet pressing techniques, as described by the Kenyan case study on this page, will generally be more applicable.

Limitations and Restrictions

The possibilities of recycling waste paper in an economically feasible way are primarily determined by quality standards and the capacities of local or national markets.

Due to the low specific gravity of paper and cardboard, and relatively low revenue from sales, long transport distances will usually have a negative effect on the economic feasibility of recycling.

Paper briquettes have not yet become common as an alternative fuel, and will normally need special marketing efforts and campaigns. Moreover, they are highly sensitive to moisture. When wet, they begin to swell and to lose their solidity and stability. Paper briquettes should therefore be stored in dry places, and, if necessary, packed in water-proof material (e.g. plastic bags).

Manual production of fuel briquettes from 30% scrap paper and 70% charcoal dust in Nairobi, Kenya /53/

Nairobi, Kenya

Paper recycling in slum settlements

The local NGO, Undungu Society, promotes and supports paper recycling and the production of paper briquettes as alternative fuel in various slums of Nairobi.

For this purpose, 80 previous scavengers at the Dandora dumping site, called the Jumuiya Group, were trained to operate two presses.

Scrap paper is processed into briquettes with a simple manual press. Although theoretically 100% paper could be used, only 30% paper is used together with 70% of other organic materials (charcoal dust, sawdust, bark mulch, carpentry chippings, etc.) to avoid generating too much smoke from burning paper only. The paper and other components are first soaked for 24 hours and then thoroughly mixed. The mixture is then slightly compacted in one of the hand presses; its final stability is achieved only after air drying. The briquettes are mainly held together by paper fibres which bind to the other components in the same way as in the original paper.

The briquettes are 15 cm long with a diameter of 10 cm. They are sold for 1 KSH (about 0.02 USD) a piece.

Improvement of briquette quality and wider sales are planned.

Handling of Refuse and its Further Treatment

Suitability for Self-help

Due to the low investment required for collecting, sorting and pressing scrap paper in urban poor settlements, these activities are typically taken up by small, mainly informal enterprises.

Although the production of egg and fruit packaging does require some basic investment, it can still be done at the level of small industries and enterprises.

The manufacturing of paper briquettes can be useful in situations where fuel scarcities can create a demand that self-help initiatives could cater for.

Assessment of Costs

The costs of recycling waste paper largely depend on the scale of production and on the type and origin of machines and other equipment (e.g. paper recycling machines are generally much cheaper in India than in Europe). For collection, sorting and marketing, additional costs for transport and staff wages have to be included.

A simple baling press can be purchased in Egypt for 5-6,000 USD; manually operated paper briquette presses can be produced locally for roughly 500 USD. In contrast, mechanical briquette presses or production equipment for egg and fruit packaging can easily cost up to 50,000 EUR.

Main Features
Collection, sorting and processing of scrap paper into intermediate (e.g. paper bales) or final products (e.g. handmade paper, egg or fruit packaging, fuel briquettes, etc.)

Application
When a market for recycled paper exists and appropriate small-scale technology is accessible

Costs
Manageable investment costs for collection, sorting and bale pressing; for further processing, costs usually increase with volumes and the quality of goods to be produced

Operations
At small-scale industrial level, suitable for self-help initiatives and small enterprises

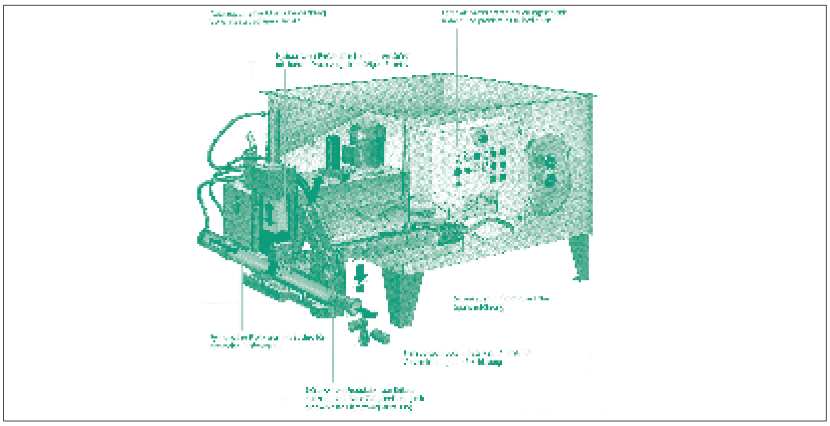
Interface
Marketing to wholesale buyers and further processing outside the settlement

Advantages
Marketable goods from waste with relatively low need for equipment and machinery; creates income and jobs at small-scale industrial level; environmentally friendly

Disadvantages
Due to the low weight and large volume of paper involved, transport is an important cost factor

To be Considered
Separation of paper at source is recommended to avoid contamination from other possibly soiled waste components

Hydraulic briquette press /54/



Handling of Refuse and its Further Treatment

SORTING AND RECYCLING OF PLASTICS

Application

Plastics are the third important component of household waste. In urban poor settlements, its amount, as a percentage of the total waste produced, usually increases with the growing wealth of residents over time. In older, more consolidated settlements, where residents have developed relatively stable sources of income, significant volumes of plastic waste can be generated. Its processing at small-scale industrial level can create new income sources and contribute to the reduction of residual waste to be disposed of.

Various processes for the recycling of plastics have existed for a number of years at small-scale industrial level, but they have not yet been applied or tested at a larger scale in urban poor settlements.

As with other waste components, recycling of plastic waste will only make sense when there is a real market for recycled products, and when the necessary technical equipment is available or accessible. Nevertheless, practical experience in many countries, e.g. Egypt, India, Brazil and some African countries, has shown that recycling plastics can create jobs and income in the informal sector.

Technical Solutions

Of the large number of modern synthetic materials, PE, PP, PET, PVC and PS are the most commonly found in household waste. Plastic foils, e.g. shopping bags made from polyethylene (PE), are especially appropriate for small-scale industrial recycling, as are containers and moulded objects made from polypropylene (PP), as well as tubes and other moulded items, such as the soles of shoes etc., made from polyvinyl chloride (PVC).

In small-scale industrial processing, plastic waste components are manually separated and sorted, if possible, directly at their source in households, shops or commercial enterprises. In most cases, foil material and moulded items and containers are collected separately. When plastics have to be separated from mixed refuse, it will usually have to be cleaned.

Small-scale industrial recycling usually consists of collection, sorting, cleaning, shredding, agglomeration and granulation. In some cases, it may also involve the manufacturing of new products.

The descriptions in this section refer only to the production of the following main intermediate products of plastics recycling:

- plastic chippings;
- foil agglomerates;
- granulate.

These are the results of the first stages of plastic waste processing, and can be produced at small-scale industrial level with relatively little investment and basic technical skills. All three intermediate products can be used as raw material to make a number of new plastic goods.

Production of Plastics Chippings

Hard plastic material and parts can be transformed into marketable intermediate products with shredding or grinding mills. This can be done either as a dry or wet process. The wet process simultaneously cleans the material.

Thick plastic chippings (in contrast to thin foils) are further processed either directly, or following an intermediate granulation stage, in screw extruders (see “Production of Granulate” below). These melt the material and process it for use in the making of injection or blow-moulded products.

Depending on size and capacity, prices for shredder mills generally start at USD 3,000. Their operation is rather simple and does not require special technical skills.

The wearing parts of shredder mills are their knives, which have to be regularly re-sharpened, and after a given operating time, will need to be replaced.

Locally manufactured mill for grinding hard plastic in Cairo, Egypt /55/

Handling of Refuse and its Further Treatment

Production of Foil Agglomerate

Foil agglomerate is produced in so called "pot agglomerators", which work in a similar way to kitchen mixers. Knives at the bottom of the machines rotate at high speed and shred the inserted foils. The heat generated in the process melts the plastic chippings and agglomerates them into irregular particles, which are transported to further processing machines (extruders) through a simple funnel.

Agglomerators have a high energy consumption. Their economic feasibility therefore largely depends on local energy prices. Their operation requires a certain amount of practical experience in order to decide when the agglomerate has reached the correct consistency to be removed.

Simple agglomerators, e.g. of Indian origin, can be purchased at prices starting at USD 5,000. They are also produced in many other countries.

Agglomerator for foil waste 56/

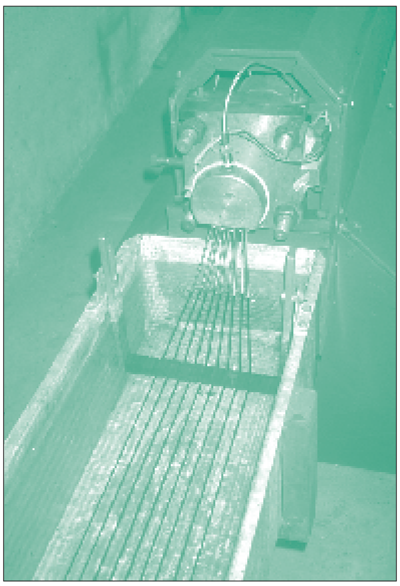
Production of Granulate

To produce granulate, intermediate recycled plastic products, e.g. cleaned plastic foils or shredded hard plastic chippings, are melted in a screw extruder and then continuously extruded as plastic strings, so-called "spaghettis". After cooling and hardening, the spaghettis are chopped into small granular pieces.

Granulation has the advantage that, through melting and mixing in the extruder, it results in a homogeneous product that is well-suited for further processing. Particular qualities of plastic can be achieved by introducing appropriate additives (colour, stabilisers, other primary plastic granulate etc.). Operating a granulator presupposes some basic technical skills, which can be acquired relatively easily. Prices for complete granulation equipment start at USD 15,000.

.

Granulation equipment manufactured in India /57/



Sizing and Processes

Plastic goods typically have low weights and large volumes. To extract sufficient plastic material in terms of weight, significant amounts of plastic bags and other plastic items need to be separated from other waste. For small-scale industrial recycling, the processing capacity of machines should therefore correspond to the volume of plastic that can realistically be collected. Machines made in industrialising countries (e.g. India, Brazil, China) are usually suitable for use in developing countries with low collection and processing capacities. The smallest machines available in the market can process about 20 - 30 kg of plastic waste per hour.

As a precondition for recycling, different types of plastics have to be separated since they generally cannot be processed jointly. The only exceptions are PE and PP plastics in specific applications. Separation of PE, PP and PVC is not an easy task because they look very similar. The so-called "swim-sink-separation technique" makes the separation of PE and PP from PVC easier. To do this, plastic chippings are put into water. Because they have different densities, the PE and PP fractions float upwards, while the PVC sinks to the bottom.

Due to their large surfaces and small volume, swim-sink-separation cannot be applied to plastic foils. They can only be sorted and separated according to their appearance and material characteristics.

The use of wet grinding mills will be useful in the recycling plastic containers and moulded items, as the material gets rinsed and cleaned in the grinding process; but an additional drying stage will then be

HANDLING OF REFUSE AND ITS FURTHER TREATMENT

SORTING AND RECYCLING OF PLASTICS

needed. Often foil waste must be washed manually, and locally made washing drums can facilitate this task.

Limitations and Restrictions

The possibilities of recycling plastic materials from household refuse are mainly determined by the degree to which they are soiled.

In most cases, it will not be useful to process extremely soiled plastic foils or containers since cleaning them would be too demanding (consumpt-ion of water and detergents) and the quality of the end product would be inferior.

Suitability for Self-help

The technical challenges of plastic recycling generally call for an initial phase of learning and training. Self-help groups or initiatives can play an important role in facilitating and promoting plastic recycling by informing residents on its potential benefits and the possibilities of contributing at household level (sorting, cleaning, etc.)

Kisumu, Kenya

Profitable plastic recycling

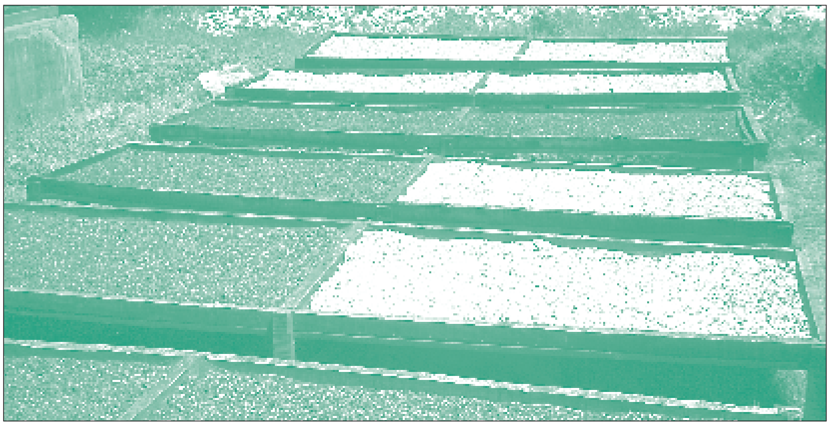
The Nyalenda Plastic Recycling Project in Kisumu, Kenya was established some years ago and was based on the initiative of a local Catholic Church and a German development worker. Its objective was to work against the increasing environmental pollution caused by plastic waste and to create new jobs in the Nyalenda neighbourhood.

The project buys hard plastic material from individuals, waste collection groups and intermediate traders. The plastic waste is sorted at the project's own compound by colour and material (LDPE, HDPE, PP) and by type of production (injection or blow moulding). The sorted material is shredded in a mill, and then rinsed a couple of times. It is then dried in the sun, filled into bags and sold to enterprises in Nairobi for further processing.

Depending on the type of plastic, the difference between the buying price for raw materials and the selling price for the plastic chippings produced is 300-500% (i.e. EUR 0.075 per kg of material becomes ca. EUR 0.35's worth of product). Although precise cost calculation remains a managerial problem, the project can survive well with this profit margin. Difficulties are mainly caused by fluctuating prices for the products, which are sometimes changed at will by the predominantly Indian wholesale buyers and enterprises that further process the material.

As a next step, the project plans to purchase an agglomerator in order to process foil waste as well.

Sun drying of plastic chippings in Kisumu, Kenya /58/



Handling of Refuse and its Further Treatment

Assessment of Costs

Simple plastic recycling equipment and machines produced in many industrialising countries (such as India, China, Brazil, etc.) are considerable less expensive as those made in the industrialised countries of Europe, North America or the Far East. Their comparatively lower processing capacities and simple operations make them potentially well-suited for use in urban poor settlements.

As a rough guide, shredder mills are available at prices starting from USD 3,000, pot agglomerators from USD 5,000, and granulation equipment from USD 15,000.

Sorting of plastic waste in Kisumu, Kenya
/59/

Main Features
Recycling of plastic components from household waste to produce marketable intermediate products (hard plastic chippings, foil agglomerate, granulate) with appropriate technology

Application
When a market for recycled plastics exists and appropriate small-scale technology is accessible

Costs
For small-scale industrial operations: shredder mills, available at prices starting from USD 3,000, pot agglomerators from USD 5,000, and granulation equipment from USD 15,000.

Operations
Small-scale industrial level operations, suitable for self-help initiatives and small enterprises

Interfaces
Possible marketing for further processing in the formal sector outside the settlement

Advantages
Production of marketable goods from waste with relatively low equipment and machinery requirements; creates income and jobs at small-scale industrial level; environmentally friendly

Disadvantages
Requires a lot of cleaning to achieve acceptable product quality; basic knowledge of materials and machines needed for sorting and processing; production of agglomerate is energy-intensive

To be Considered
Processing capacities of machines should correspond to amounts of material that can be collected for recycling

Handling of Refuse and its Further Treatment

SORTING AND RECYCLING OF METAL

Application

In urban poor settlements, many potentially recyclable metal items (e.g. non-ferrous metals, cast iron parts, or bulky steel objects) are rarely disposed of in household waste. The recycling of metal is therefore generally of less relevance here than the recycling of paper or plastics. Metals that are thrown away mainly consist of beverage or food cans, defunct small appliances with metal components, or cooking utensils. In most cases, these are thin pieces of iron, steel or tinplate, of low quality and little value.

In general, the only items that promise worthwhile recycling revenues are aluminium drink cans. However, globally only 50% of drink cans are made from aluminium, while the other 50% is made from tinplate of significantly less value. Moreover, due to their high material value, aluminium cans are specially sought out by all kinds of waste collectors and recyclers, and rarely end up in household waste.

Against this background, only two technical solutions are relevant for metal recycling at settlement level, and these are presented in more detail in this section. They are:

- the sorting and compacting of scrap metal as a basis for further processing;
- the recycling of aluminium drink cans.

Technical Solutions

Sorting and compacting of metal: Metal can be separated manually from household waste relatively simply. The use of magnets can be an option to separate iron parts from larger volumes of waste. If, for marketing purposes, scrap metal has to transported over large distances, compacting with baling presses can be useful.

Recycling of aluminium: As aluminium cannot be extracted with magnets, it is more effective to separate it out at source (households, restaurants, hotels, etc.). Due to their low weight (13g) and bulk (1 ton = 77,000 cans), aluminium drink cans must be collected in large numbers and compacted by baling presses. Scrap from aluminium drink cans is well-suited for processing into basic consumer items in small local foundries.

In many countries, collected cans are also used directly to produce various goods (e.g. oil lamps, containers, roof tiles, toys, etc.). Cans are cut up, and the pieces assembled and soldered or riveted to make the intended item.

Oil lamps manufactured from cans in Cotonou, Benin /60/

Dimensioning and Operations

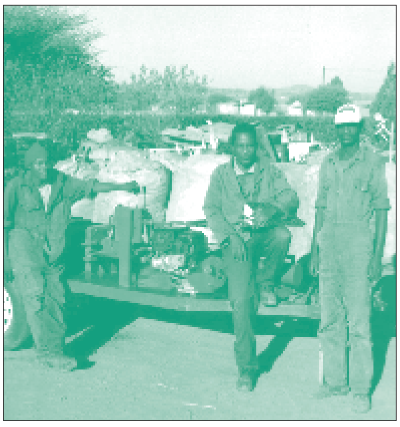
Baling presses should be selected so that they have enough pressure to produce stable and solid bales. For small-scale processing on the spot (see figure 61), bale sizes should be movable and transportable without lifting gear.

Metal separation from household waste presents no major technical challenges or requirements. However, to achieve a good price, it will be important not to mix non-ferrous metals, e.g. copper, brass or tin, with scrap iron.

Limitations and Restrictions

Scrap metals commonly found in urban poor settlements are hardly ever recyclable in a profitable and efficient way. Moreover, to do so can require further processing in electrical steel mills, which do not exist in all developing countries. In addition, large transport distances that may be involved are usually not economically feasible.

Mobile press for scrap drink cans /61/



Handling of Refuse and its Further Treatment

Molepolele, Botswana

Collection of drink cans

A GTZ project to promote local refuse management and recycling supported a local small entrepreneur in the purchase of a mobile baling press intended to improve the collection of tinplate drink cans. The entrepreneur was not able to provide any capital or collateral, but it was possible to obtain a loan from a governmental fund for the promotion of small-scale industries. It was, however, necessary to convince the lending institution that recycling was a productive activity that could be financed within the fund's guidelines.

The entrepreneur collects and buys drink cans, presses them into bales and sells them to intermediate traders. The scrap produced is then bought by a private sector agency (Collect-A-Can) that is financed by the South African steel and beverage canning industry, and is melted and further processed in South African steel mills.

Using the equipment as collateral, he is now able to get further loans.

Collection of drink cans

/62/

Suitability for Self-help

The collection of scrap iron, although not necessarily from household waste, is traditionally a preferred activity of informal, small-scale industrial recycling enterprises, and basically well-suited for self-help initiatives. Due to the small volume of metal in household waste and its low value, it will usually be of little interest or relevance in urban poor settlements.

Assessment of Costs

To collect and market large amounts of drink cans, a small baling press that can be purchased for about USD 10,000 will be needed.

Costs for larger presses that can process large heavy items, can range from USD 100.000 to 1 million, and can therefore not be financed by small enterprises or self-help initiatives. However, compact iron and steel scrap can possibly be marketed in bulk.

Main Features

Separation, sorting and possibly further processing of metal components of household waste, mainly of non-ferrous metals (e.g. aluminium drink cans); production of goods and consumer items (e.g. oil lamps) from tin cans

Application

Where a market for scrap metal exists and appropriate small-scale technology is accessible

Costs

Small baling presses for lightweight scrap can be purchased at prices starting from USD 10,000.

Operations

possible at small-scale industrial level, suitable for self-help initiatives and small enterprises

Interfaces

Possible marketing for further processing in the formal sector outside the settlement

Advantages

Production of marketable goods from waste with relatively low equipment and machinery requirements; creates income and jobs at small-scale industrial level; environmentally friendly

Disadvantages

Only aluminium drink cans are of substantial value; long transport distances for marketing scrap metal are not economically feasible; large-scale processing capacities (electrical steel mills) required

To be Considered

Separation of iron and non-ferrous scrap components is important for marketing.

Handling of Refuse and its Further Treatment

SORTING AND RECYCLING OF GLASS

Application

Glass recycling is of limited importance in urban poor settlements because reusable intact glass bottles and containers are generally sold rather than thrown away as waste.

Usually only broken glass will be found in household waste in poor residential areas, and this is difficult to commercialise.

There will therefore be only two main options for glass recycling at settlement level:

- sorting and conditioning of scrap glass with the intention of selling it to glassworks outside the settlement;
- processing in small local manufactories, where hand-blown glass goods are produced.

Technical Solutions

Sorting and conditioning: Larger glass pieces and shards are manually separated from waste; smaller pieces are discarded.

Broken glass or deliberately broken glass bottles or containers are sorted by colour and packaged for transport to glassworks.

Processing in local manufactories: In this form of recycling, scrap glass is processed in small local glassworks into consumer or craft items.

Dimensioning and Operations

Sorting and conditioning: The collection and conditioning of glass is usually a small-scale industrial activity in which glass is sorted according to colours and possibly broken into pieces of similar size. It does not require any investments in machines, but only needs protective clothing, like gloves, shoes and safety goggles, and some basic tools, like hammers for breaking glass into smaller pieces, or shovels for loading. Sorting should be done on a concrete or asphalted surface, and appropriate transport containers should be made available.

When sorting and breaking glass, protective clothes should be used to avoid injuries to hands, feet and eyes. The sorting area should be walled or fenced to prevent the entry of unauthorised persons, especially children.

Careful separation by colours will be important for later marketing. Even small amounts of mixed coloured glass can seriously hamper marketing chances; white glass in particular, should be free of other coloured glass pieces. The presence of certain amounts of paper residuals, plastic or metal lids or tops is uncritical, as they will be separated mechanically at the glassworks or be burnt in glass furnaces. On the other hand, it is important that stones and gravel, and in particular earthenware shards, are not mixed with the glass.

Processing in local manufactories: This requires a melting furnace that can be heated up to temperatures of 1,200 - 1,400°C. Depending on the kind of processing, other equipment, such as hand-blowing forms, and cutting and grinding tools, will be needed. Moreover, a reheating furnace may be necessary to heat treat the glass in a final processing step. The broad use of this technology in urban poor settlements will, however, be difficult because of the investment, knowledge and technical skills required.

Limitations and Restrictions

The use of broken glass as raw material for the production of new glass items is a well-established and traditional technology. However, due to economies of scale, most glass recycling is done nowadays through large-scale industrial processes.

The availability of glassworks not too far away from a settlement will thus be the most relevant factor for possible glass recycling activities. In most cases, it will not be economically feasible to transport broken glass scrap over large distances, e.g. to neighbouring countries.

Production of hand-blown glass from melted glass scrap in La Paz, Bolivia /63/

Handling of Refuse and its Further Treatment

Nairobi, Kenya

Glass recycling at settlement level

The Imani Glass Recycling Project is an initiative in one of the oldest slum areas of Nairobi, close to the Mathare Valley. In the context of a Church supported development project, a small workshop was established for the processing of scrap glass. The majority of workers are women, who manufacture beads, which are used to make craft objects, from broken coloured glass scrap. A gas-operated melting furnace was purchased, in which broken glass is melted in different ceramic moulds for different colours. Beads are made individually and by hand: a small amount of melted glass is put on the end of an iron stick, and then formed into a bead by turning the stick while applying some other small supplementary tools. When it has cooled down, the iron stick separates from the glass and leaves a hole in the bead. Beads are produced in different colours and sizes, and are sold to craft workers for further processing.

The experience gained from installing and setting up the melting furnace enabled the project workers to construct a second furnace themselves. The production of hand-blown glass items is planned as the next step. Sometimes there are problems because of the high costs of gas bottles for operating the furnaces. The group is therefore looking for options to replace expensive gas by other cheaper fuel.

Suitability for Self-help

Glass, in particular intact bottles and containers, has always been separated from refuse and recycled. Extending this to the collection of broken glass is therefore a logical next step. Glass recycling would be further facilitated if glass waste was picked-up and sorted by recyclers directly at the places where it is mainly generated, e.g. bars, restaurants, hotels, etc. Environmental groups and self-help initiatives can possibly support such an approach through appropriate information and awareness campaigns.

Assessment of Costs

Sorting and conditioning scrap glass for selling to glassworks requires little investment. Basically, all the work can be done manually, so recurring costs will mainly consist of wages. If glass waste is to be picked-up from where it is generated, suitable vehicles will be needed, which can entail associated additional operational costs.

Production of beads from glass waste in Nairobi, Kenya /64/

Main Features
Separation, sorting by colour and possibly further processing of glass components of household waste

Application
Where a market for recycled products exists and appropriate small-scale technology is accessible

Costs
Apart from some containers and protective clothing, no other investments are needed, so long as recycling activities are limited to sorting and conditioning

Operations
Possible at small-scale industrial level; suitable for self-help initiatives and small enterprises

Interfaces
When marketing and further processing takes place in the formal sector outside the settlement

Advantages
Production of marketable goods from waste with relatively low equipment and machinery requirements; creates income and jobs at small-scale industrial level; environmentally friendly

Disadvantages
Due to the relatively high specific weight of glass, transport costs for collection and marketing are high; further processing usually requires large-scale industrial capacities

To be Considered
Careful separation of glass by colour is necessary to improve marketing chances

Refuse Disposal and Depositing

SMALL-SCALE LANDFILLS

Application

In most urban poor settlements, the final disposal of refuse will only be possible outside their boundaries. This will generally require connecting refuse collection at settlement level to city-wide refuse disposal systems with a central landfill .

Where connection or access to a central landfill site is not possible or feasible, e.g. in isolated settlements far outside the main built-up urban area, or in an urban quarter that is difficult to access, an alternative can be to establish the settlement's or part of the settlement's own small refuse dumping site.

To save costs and reduce the effort of site development, operation and follow-up care, such small dumping sites should only be used for residual waste, i.e. waste from which valuable and recyclable material has been extracted. This, however, presupposes that there is a functioning solid waste management and recycling system at local level, which can be a major challenge in most urban poor settlements.

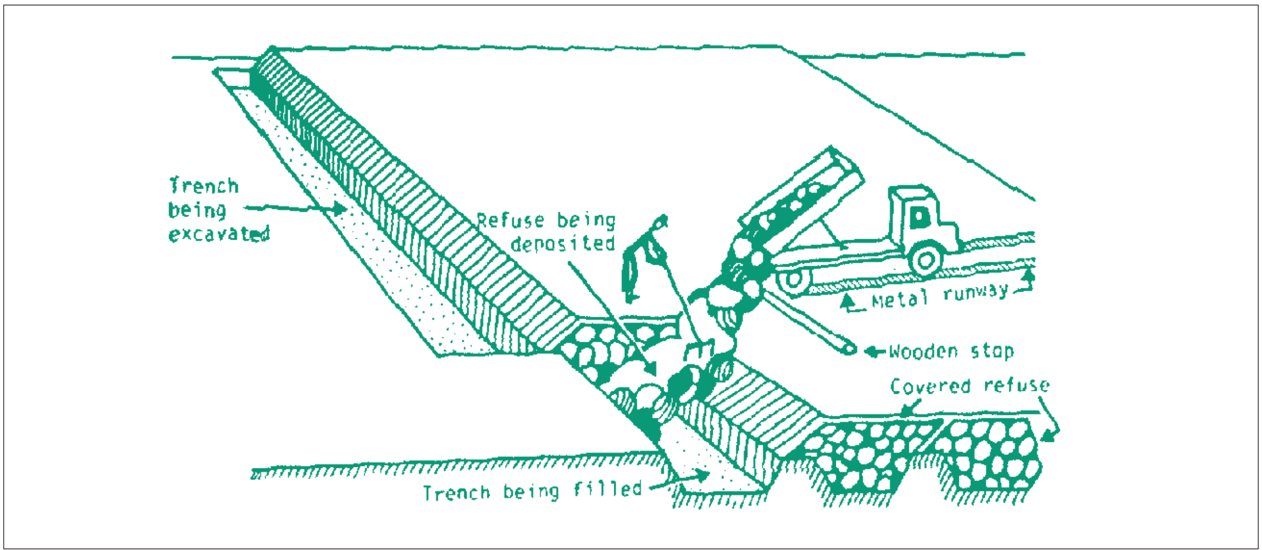
Dimensioning

The most appropriate kind of small refuse dump at settlement level is a trench landfill. For this, trenches with a width of 2-3 m and a depth of 2m need to be dug. They should be built with a slope to one side to drain rainwater. Ideally they should be built on a site that has a natural slope. In these cases, trenches should be dug from below to above to avoid water accumulating in the trench during excavation. The excavated earth should be piled alongside the trench, to be used later to cover the refuse. The sidewalls should be slanted, instead of vertical, to prevent collapsing.

The follow exclusion criteria should be applied in the selection of possible sites for small local landfills:

- at least 1 km distance from airports;
- not below the highest flood levels of the previous 50 years;
- not closer than 50m to surface waters (lakes, rivers etc.);
- not in geologically unstable regions;
- not in ecologically sensitive or historically important areas;
- not near settlement water catchment areas or wells;
- not in regions with high ground water levels or springs;
- not in regions with permeable soil;
- not in rocky regions with insufficient soil cover;
- not closer than 500m meters to inhabited areas;
- not in the main wind directions of settlements;
- not in areas crossed by infrastructure mains (water, gas und electricity).

Schematic sketch of a simple trench landfill /65/



Refuse Disposal and Depositing

Operations

Depositing of refuse should start at the higher end of the trench to ensure that the landfill is not filled with water. In order to work systematically, refuse should be tipped in one place at a time. Deposited refuse should be covered with previously excavated earth every day or, if that is not possible, at least once a week. In that way, a layer of earth can be gradually built up covering the trench. Because the landfill will sink, possibly unevenly, over time, this avoids the development of gullies, which may accumulate water, or cracks that may go through to the buried refuse.

It will be useful to fence the landfill site to prevent paper or plastic waste blowing away, and to restrict the access of unauthorised people. In addition, this enables control on the type of refuse to be deposited by entering vehicles.

Limitations and Restrictions

The simple construction of a trench landfill does little to prevent the seepage of pollutants into the soil and groundwater. It will therefore be important that only household refuse, and no industrial or hazardous waste is deposited. Sites should be carefully selected to especially avoid negative impacts on groundwater resources. Waste should be sorted to reduce its organic content in order to avoid bio-chemical processes, which can generate seeping water and gas.

Suitability for Self-help

Due to their simple set-up and low operational requirements, trench landfills can be operated by self-help groups at community level. Operational costs can be covered by a combination of user charges for local refuse collection and possible revenues from the sorting and recycling of valuable waste components.

Assessment of Costs

The costs of trench landfills will involve initial investments (possibly for purchasing the necessary land, and then for fencing, buying a front loader, etc.), and operating expenses (fuel, maintenance, wages).

In most cases, costs will have to be covered by residents when no support is available from public or governmental institutions.

Simple trench landfill in Aqaba, Jordan
/66/

Main Features
Disposal of residual waste after separating out and recycling valuable fractions; depositing of waste in earth trenches subsequently covered with earth

Application
Outside built-up areas on sites where groundwater resources will not be affected

Costs
Investment and operating costs are mainly defined by the size of the landfill

Operations
Can be operated by self-help initiatives at community level

Interfaces
With increasing landfill size and waste volume deposited, higher costs, higher operational requirements and more need for control and supervision becomes necessary. This may call for operations to be taken over by municipal services.

Advantages
Simple and inexpensive waste disposal that can be done by self-help initiatives when disposal at a central landfill site is not possible

Disadvantages
No protection against seepage of pollutants into soil and groundwater; no provision for disposal of industrial and hazardous waste

To be Considered
Control over refuse before it is deposited .

Refuse Disposal and Depositing

DISPOSAL OF HAZARDOUS WASTE

Application

Hazardous waste can often be found in household or commercial waste in urban poor settlements. The most common types of hazardous material are batteries, as many households are only connected to unreliable or informal (i.e. illegal) electricity supplies, if at all, and thus largely depend on batteries for all kinds of appliances.

In quarters with larger numbers of commercial enterprises, other hazardous forms of waste, such as scrap tyres, used oil, solvents, paint residuals, acids or lye (strong chemical washing solutions), may be found. Small restaurants or food stalls may throw used cooking fats away. Health stations and doctors' practices are sources of medical waste infected with bacteria.

Moreover, informal recycling workshops and activities can produce significant amounts of highly polluted wastewater, ashes and cinder, and metal or non-metallic residuals.

There are no standardised procedures for disposing of these highly dangerous materials. Different kinds of substances will therefore need specialised treatment, according to their characteristics and pollutant content.

Returning problematic material to its producer, or handing it over to specialised enterprises for treatment, as practiced in most industrialised countries, is uncommon in most developing countries, and is seldom a realistic option, particularly in urban poor settlements. At settlement level, it will thus generally only be possible to try and reduce the hazards resulting from such waste components, and to look for ways of disposal that minimise risks to the natural environment and human health. The following basic options are possible:

- separate collection and disposal of hazardous materials;
- depending on the particular risks of different materials, measures to transform pollutants into less hazardous waste, or to seal them to avoid or limit their dissipation into the environment;
- if there are no possibilities of transport to safe disposal sites or facilities outside the settlement, the construction of specially protected waste pits for temporary or permanent disposal.

Technical Solutions

When no other, more environment-friendly options are possible, different minimum solutions that can possibly be applied for most common hazardous waste components, are as follows:

- Waste oil, non-halogenated solvents, fats and medical refuse can be incinerated in special furnaces when no other means of safe disposal are available. It will be important to ensure that there are high enough temperatures and adequate conditions for oxidation inside the furnace. Moreover, furnaces should have sufficiently high smokestacks, with the main wind direction leading away from the settlement. Operating staff should be provided with protective clothing.
- Used batteries, capacitors, soluble salts with heavy metal components, soluble cinder, injection needles and used glass phials can be put into plastic or metal containers and then sealed with concrete or asphalt. Final disposal at a normal landfill site or in a secure refuse pit is then possible.
- Paint residuals and small amounts of solvent can be dried by normal evaporation, and then disposed of with other solid waste, or deposited in a secure refuse pit inside the settlement.
- Acids and lye can possibly be neutralised with appropriate chemical additives. If they do not contain any heavy metals, they can then be diluted with other wastewater and discharged into the sewage system (if there is one).
- Heavy metal salts in solvents can be concentrated by evaporation or vaporisation. The residual salt can be sealed with concrete or asphalt as described above, and then disposed of.

Dimensioning and Operations

Pits for hazardous waste, in particular for infectious medical waste, should be designed so that they can take in sufficient amounts of waste over suitably long periods of time, and, if necessary, allow for the possibility of later final sustainable disposal.

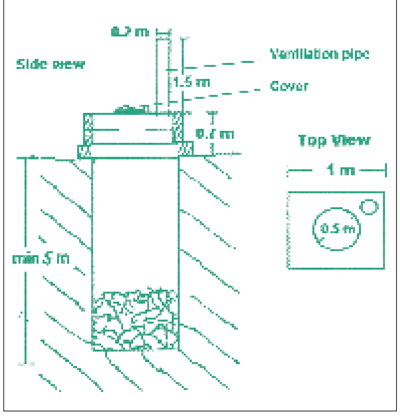
Refuse Disposal and Depositing

The pit chamber will need to be covered by a lid, a removable plate or top section, with a ventilation pipe. The lid should be lockable to prevent unauthorised opening, particularly by children. The ventilation pipe will not be necessary in all cases. In hot climates, where organic waste components decompose quickly, it will be sensible to consider ways of avoiding smells when opening the lid for waste disposal e.g. by wrapping likely material before depositing it.

Sites for the digging of secure refuse pits should be selected according to the same criteria as for pit latrines*. Soluble waste components that do not organically decompose easily or at all (such as heavy metal salts, solvents, mineral oil, etc.), should not be deposited unsealed in such refuse pits.

▶ *for criteria for the construction of latrines, see chapter 3

Schematic sketch for the construction of a secure refuse pit /67/



Limitations and Restrictions

It will not be possible to dispose of all hazardous waste residuals in an environment-friendly way at settlement level. For each particular material, appropriate solutions will have to be found. This presupposes special technical knowledge, which is often not available in urban poor settlements. Moreover, the risks resulting from hazardous waste are often unknown to the residents.

Suitability for Self-help

If individual community members have the necessary technical knowledge and skills to distinguish and treat hazardous waste, most of the settlement internal solutions described above can be applied in self-help initiatives with relatively little effort and at reasonable costs. However, such initiatives will have to be complemented by information campaigns to raise residents' awareness of the risks of hazardous waste and its handling.

Self-help initiatives can also establish and operate special collection points for hazardous waste to be transported for disposal outside the settlement.

Assessment of Costs

All the measures and solutions described above can be implemented with limited financial resources. The main effort will have to focus on the establishment of appropriate settlement-wide logistics for collection and disposal.

Main Features

Identification and separate collection and disposal of hazardous waste, such as used batteries, oil and fat, solvents and paint residuals, acids and lye, small-scale industrial refuse and medical waste

Application

Urban poor settlements with few other alternatives for the collection and treatment of hazardous waste

Costs

Low: measures use simple technical solutions

Operations

Can be operated by self-help initiatives at community level

Interfaces

If possible, hazardous waste components should be handed-over to municipal or authorised private sector waste enterprises for specialised treatment and disposal

Advantages

Better organised disposal and health hazard awareness campaigns help protect local residents from health risks

Disadvantages

Lack of specialised know-how and information; insufficient waste management structures

To be Considered

Hazardous waste should not be mixed with other waste, but separated and treated individually according to characteristics of specific materials

3 WASTEWATER

3.1 Wastewater
Problems and Challenges

Problems

Most urban poor settlements have developed in an unplanned way without following formal urban layout standards. High densities and often extremely narrow internal streets make it difficult to establish a sewerage system. Municipal infrastructure, eg. for wastewater treatment plants, is usually completely lacking.

Without functioning municipal sanitation systems, problems of discharging wastewater from kitchens, bathrooms and toilets have to be solved individually. Where there is sufficient space, it may be possible to construct a simple filtration pit for greywater and a latrine.

However, in densely built metropolitan areas, e.g. at the fringes of Indian megacities, there often is no space. The few public open spaces that may exist (e.g. railway tracks) are thus used for defecation, and greywater from kitchens and bathrooms is simply discharged onto streets.

In industrialised countries with ample water supplies, the usual sanitation method is water-borne sewerage (so-called flush-and-discharge-systems). Large amounts of fresh water flush relatively small volumes of wastewater and faeces through piped systems to central treatment plants.

This conventional form of sewerage used in industrialised countries, and which is also often applied in wealthier urban neighbourhoods in developing countries, is, however, hardly appropriate for urban poor settlements.

Globally, about 80 countries, with about 40% of the world's total population, are affected by regular periods of water shortages. 95% of all wastewater generated in Third World countries is discharged completely untreated into surface waters. Many cities do not have any wastewater treatment system, and even in cities that do have sewage systems, only a few households are actually connected to it.

Where there is a lack of treatment capacities, the mixture of different types of wastewater can seriously aggravate hygiene problems, as small amounts of hazardous wastewater (e.g. faeces) can pollute large volumes of less problematic wastewater (i.e. rainwater, surface water and grey water from kitchens and bathrooms).

Factors impeding efficient sanitation in urban poor settlements:

- **The usually unplanned pattern of settlement development renders it difficult to construct efficient sewage systems.**
- **High densities and limited space hamper ex-post improvements of sanitation infrastructure.**
- **Municipalities that do not support the connection of poor areas to existing sewage systems.**
- **Sanitation is often left to the individual initiative of residents.**
- **Functioning self-help sanitation systems require joint communal efforts with some degree of participation and a sense of ownership.**

Discharging of wastewater and refuse in canals in Thailand /68/

Discharging wastewater in a flooded seashore area /69/

Problems and Challenges

Potentials

Suitable sanitation options for urban poor settlements are simple water-saving on-site and off-site systems. Such systems are characterised by:

- low investment requirements;
- low water consumption with low (regular) pipe flushing requirements;
- adequate environmental health and hygiene standards;
- possibilities for self-help construction and operation;
- feasibility of connection to citywide municipal sewage systems.

Community-operated wastewater systems call for high levels of participation and resident self-help, but this cannot always be mobilised.

Availability of water as a decisive factor for waste-water systems

The availability of water, or rather its scarcity, is a decisive factor in selecting a sanitation technology.

Water supply is often not sufficient, therefore solutions at household level or decentralised dry or semi-dry (on-site) systems will be needed. Instead of systems providing continuous flushing of wastewater and faeces through interconnected pipe work, as in conventional sewerage, discontinuous sanitation options at settlement level will usually be preferable.

Approaches

The basic principle for the design and selection of sanitation options for urban poor settlements should therefore be:

Limiting and avoiding the mixing of wastewater and faeces (don't mix!)

As far as possible, mixing the following wastewater components should be avoided:

- urine and faeces;
- faeces and water;
- greywater and sewage
- wastewater and rainwater;
- household and industrial wastewater.

Separating urine and faeces can reduce or even eliminate problems such as bad smells or the breeding of flies, and storage, treatment and transport can be facilitated. Separating faeces from toilet flush-water also greatly reduces the treatment needed for relatively small volumes of urine and faeces.

Storage systems and local treatment technologies needed for such separation will have to comply with the following requirements:

- secure storage that protects both the environment and the inhabitants;
- the facilitation of aerobic or anaerobic decomposition processes;
- the conditioning of wastewater, e.g. the separation of solid and liquid components, of grease etc.;
- easy access for transport and discharge.

Where the construction of piped systems (off-site systems) is possible, "unconventional" systems, known as settled sewage, simplified sewage or condominial sewage, might offer the most appropriate solutions. They can either be connected to decentralised small treatment plants or to the city-wide sewage network.

Sanitation systems in urban poor areas will usually require a high level of participation and self-help.

Shallowly laid sewage pipes with small diameters in Karachi, Pakistan

/70/

/71/

3.1 Wastewater
Problems and Challenges

Since more developed sanitation systems are communal installations that cannot be constructed or operated individually, they will usually require a communal approach. For this purpose, functioning community organisations will be necessary to take on the construction and operation of wastewater systems.

In most cases, it will be difficult to generate direct operating revenue for such approaches. Financial contributions from individual households will thus have to be organised and monitored.

Many sanitation services at settlement level can be privatised

Many services necessary to construct and operate communal sanitation systems at settlement level can be contracted to small private enterprises, either for individual works or services, or as more comprehensive packages. These may consist of the following:

- construction and maintenance of piped sewage systems;
- emptying of septic tanks and latrines;
- operation of small decentralised wastewater treatment plants;
- composting of sludge derived from organic waste generated by refuse separation;
- operation of biogas installations.

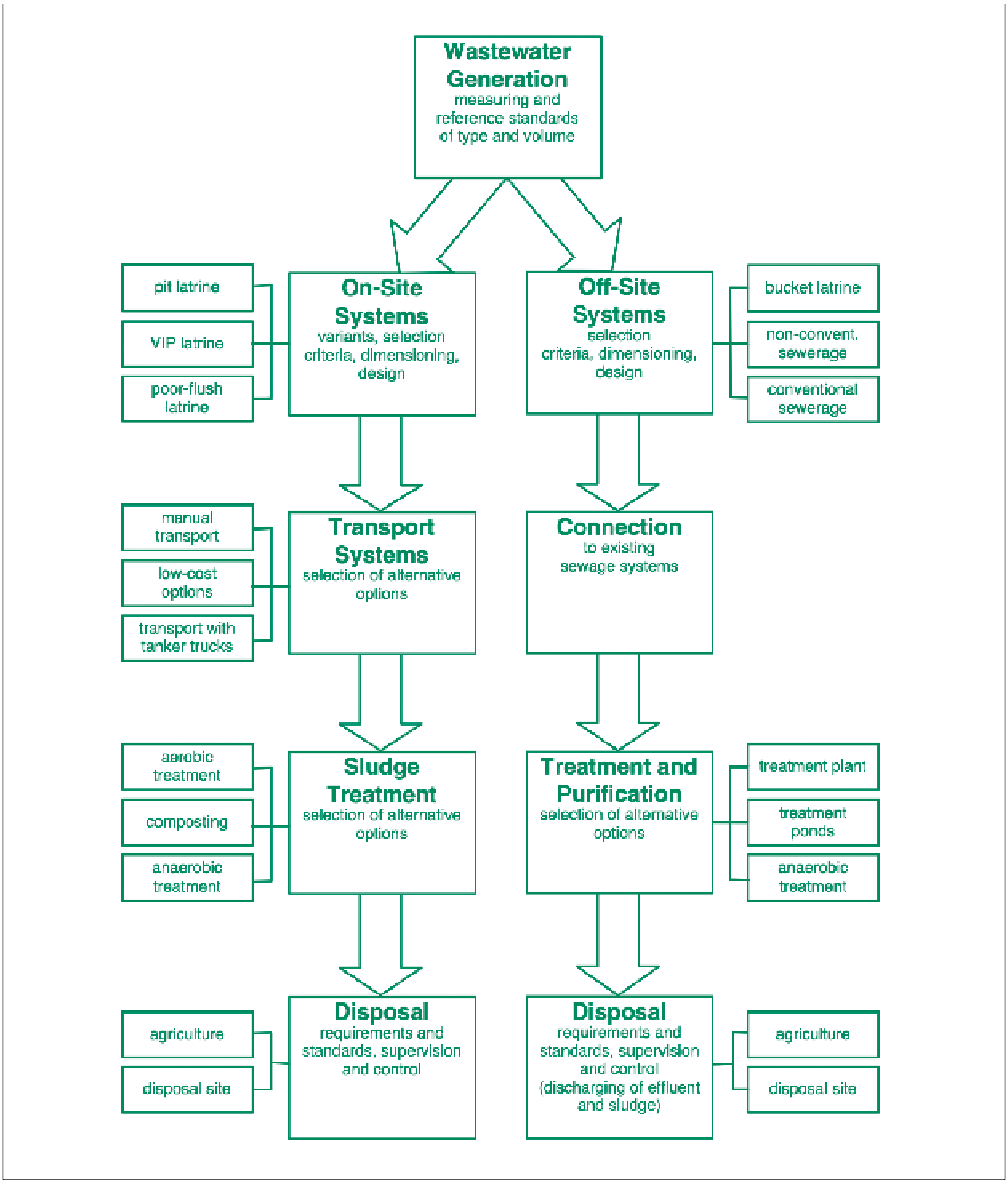
Such services will have to be paid for directly by individual users either according to their utilisation of the particular service, or, in the case of communal installations, by paying a fixed share of the service's costs. Composting and biogas installations can possibly cover part of their costs through the marketing of the compost, biogas or energy produced. The opportunities for jobs and income that this might offer may improve residents' acceptance of such solutions.

Self-help laying sewage pipes in Aswan, Egypt /72/

Emptying of septic tanks by private small-scale enterprises /73/

PROBLEMS AND CHALLENGES

The diagram below is an overview of sanitation options and processes. This publication mainly focuses on sanitation options at settlement level with a view to the specific problems and conditions in urban poor settlements: city-wide systems and options are only dealt with so far as they are relevant to interfaces with local solutions. /74/



3.2 Wastewater

Wastewater Generation

Basic Concepts

The generation of wastewater is directly related to the water supply provided. Usually, the larger the water supply, the more the wastewater generated. However, in most urban poor areas, water supply is scarce. Large parts of the population have only limited access to potable piped water. They get their water either from public faucets or wells, or buy it from private water vendors. Few households have their own private tap or water connection on their plot. Even for those, water is often rationed or not permanently available.

Wastewater can be classified according to its components and concentrations:

- surface water: rainwater discharged into wastewater systems;
- greywater: wastewater from kitchens and bathrooms;
- sewage or black water: wastewater from toilets;
- industrial wastewater: hazardous effluent from commerce and industry.

Depending on its components, the needs for cleaning and treating the different types of wastewater can vary considerably. Treatment costs can be reduced significantly when less polluted wastewater can be reused for other purposes (e.g. use of rainwater or surface water for toilet flushing).

Procedures and Approaches

It is generally difficult to reliably establish the amounts of wastewater generated. In most cases, wastewater is not metered.

A rough indication of wastewater volumes may be derived from water consumption, which is largely determined by the economic conditions and life styles of a country or a region.

Furthermore, it has to be borne in mind that in some countries rainwater is discharged into sewerage systems. Wastewater generation may thus also depend on the volume and seasonal distribution of rainfall.

Economic situation /conditions	water consumption at household level
High to medium income (Europe/USA, warm climate: connected to public water supply)	200 l/capita and day
High to medium income (Europe: connected to public water supply)	165 l/capita and day
Low income (Europe: connected to public water supply)	
• small appartment with shower	100 l/capita and day
Low income (low income: public faucet)	
• urban	70 l/capita and day
• rural (incl. laundry)	65 l/capita and day
• rural (only drinking water and personal hygiene)	25 l/capita and day

Insufficient water supply results in the generation of only small amounts of wastewater: Discharging household wastewater at a central collection point in Cairo /75/

Wastewater Generation

Factors Determining Volume and Type of Wastewater

Users/use	water consumption
individuals	15 to 20 l per capita and day
schools	15 to 30 l per student and day
hospitals (with laundry)	220 to 300 l per bed and day
decentralised health posts	ambulant patient: 5 l per capita and day stationary patient: 40 to 60 l per capita and day
mosques	25 to 40 l per capita and day
pour-flush latrines	1 to 2 l/flush 20 to 30 l/latrine and day
dry latrines	2 l/latrine and day (for cleaning)

Determining factors

- type of water supply provision
- sanitation facilities at household level
- wastewater system
- public infrastructure (community facilities, schools, hospitals, mosques, commercial enterprises, etc.)
- life style and nutrition pattern
- cultural and religious specifics
- financial resources

In addition to the absolute volume of wastewater generated, its hazardous components (e.g.. BOD_5 and COD levels*, sediments, etc.) will have to be considered. Of particular importance in this context is that human faeces in developing countries have a greater mass because of their higher fibre content, and hence more solid components will be discharged into wastewater. This will have to be considered in determining the needs for flushing water and in dimensioning on-site sanitation facilities, such as latrines, compost toilets, septic tanks and biogas installations.

An analysis of specific indicator bacteria can be used to assess the hygienic qualities of wastewater and sludge, and its further treatment or possible use, above all for agricultural purposes. Among the bacteria found in faeces, Escherischia Coli, measured by number per 100 ml, is an important indicator, as is the number of Helminth eggs per litre of wastewater or sludge.

* BOD_5 - biochemical (or biological) oxygen demand over 5 days; COD - chemical oxygen demand. Comparative tables on fibre content, BOD5 levels and bacteria occurring in stools can be found in the annex, together with quality guidelines.

A common problem: Mixing of wastewater and refuse /76/

Open sewage canal /77/

WASTEWATER DISCHARGING AND TREATMENT

SOLUTIONS AT SETTLEMENT LEVEL (ON-SITE-SYSTEMS): LATRINES

Application

Latrines are one of the oldest and best-proven technical solutions for dealing with human excrement. Due to their excellent ability to manage human faeces without the need for a water connection, they are the simplest way to dispose of faeces in many urban poor settlements, and can be installed either as individual toilets or communal toilets. They are especially useful in areas without functioning water supplies or other sanitation options.

A large variety of solutions and latrine types have been developed for different location-specific conditions and climates. Three of the most common and appropriate forms of latrines are:

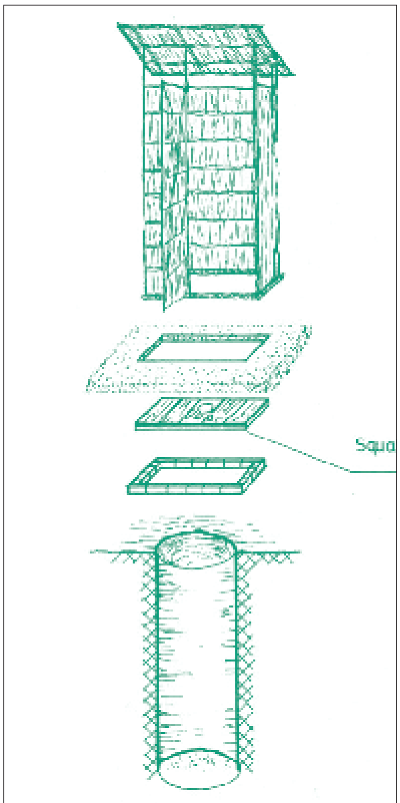
Pit-Latrines: This basic type of latrine is one of the simplest and most cost-efficient methods of discharging faeces. When a pit latrine is well designed and constructed, and is properly positioned, it can significantly prevent infections caused by faeces. They can be operated without any water.

VIP-latrines: The Ventilated Improved Pit latrine is a further development of the pit latrine.

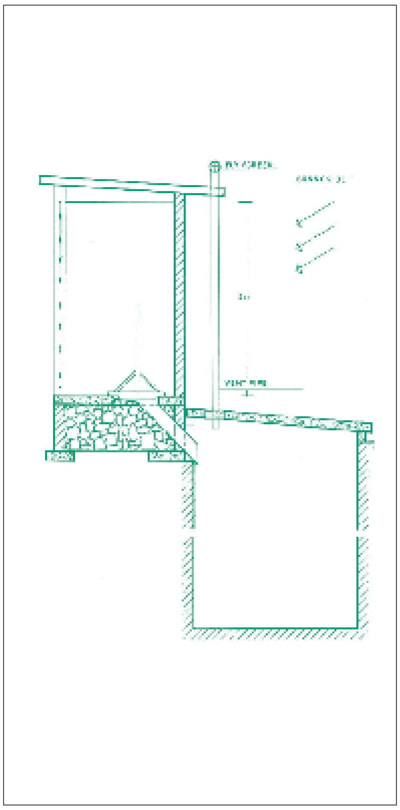
Inclusion of a simple ventilation pipe significantly reduces bad smells and nuisance from flies, and thus considerably improves this simple form of toilet's hygienic conditions.

Pour-Flush-Latrines: The pour-flush-latrine requires small amounts of water (2-3litres per flush) to discharge faeces and to clean the toilet. A residual water seal reduces smell nuisances.

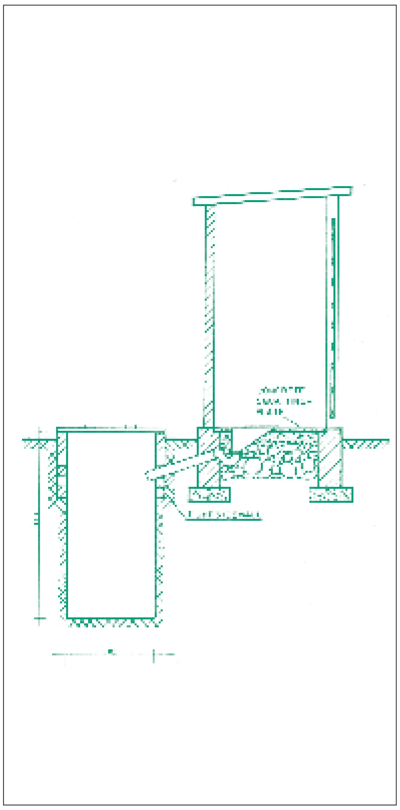
Schematic sketch: pit latrine /78/



Schematic sketch: VIP-latrine /79/



Schematic sketch: pour-flush-latrine /80/



WASTEWATER DISCHARGING AND TREATMENT

Construction

The design and construction of latrines will have to take into consideration the following aspects:

- The latrine should be placed downhill from, and at least 30 m below wells or other water sources. The flow direction of groundwater streams should be taken into consideration. For convenience of use, the latrine should be located not closer than 5 m and not farther than 50 m from the building or dwelling.
- When a concrete platform is used, it should extend at least 15 cm beyond each side of the pit.
- Platform construction and anchoring over the pit: Where soil conditions are unstable (e.g. sand), foundations will have to be constructed to stabilise the pit walls before the platform is laid.
- Building materials, such as stone, wood or mud can be used to construct the latrine hut. Where possible, locally available materials should be used. The latrine hut should have a door or a permanently screened off entrance.
- The roof should be sloped towards the back of the latrine.

Some special considerations will be needed in the construction of VIP-Latrines:

- The ventilation pipe of a VIP latrine should be placed so that it has maximum exposure to the sun and it should be painted black (by warming the pipe, the air within it will be heated and rise; the pressure of the air in the pit will drop, and it will be sucked into the pipe, resulting in better ventilation of the latrine). To allow for adequate ventilation, the pipe should have a diameter of at least 15 cm and should project at least 50 cm over the latrine roof.
- The pipe's opening should be covered by corrosion proof fly net (mesh size smaller than 1,3 mm) to prevent insects entering.
- To ensure continuous ventilation, the lid over the defecation hole should not be airtight.
- The latrine's interior should be darkened to reduce the number of flies and insects attracted to the pit by light.

Dimensioning

To determine the pit size required and to calculate the latrine's possible life span, the following formula can be used:

$$V = n * s * L$$

V = aeffective pit volume [m^3]
n = number of users
s = solid feces volume [m^3]
L = life span [years]

The volume of solid faeces generated per year is calculated at 0.04 m^3 per person. For a user group of 25 (recommended maximum number of users per latrine), a pit with a volume of at least 0.04 x 25 = 1m^3 per year will therefore be needed. To calculate the effective pit volume correctly, an air space of at least 0.3 m will have to be added. When the pit volume is known or estimated, the equation can be reformulated to calculate the latrine's life span, L (i.e. L= V/ n*s).

Simple pit latrine /81/

Minimum distance of latrines to different installations

Type of installation	distance [m]
Residential dwellings	6
Hospitals, food stores, etc.	10
Wells or other sources of water supply	15-30

For latrines on sandy soil with high filtration capacity, the minimum distances to sources of water supply will have to be applied.

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Latrines

Operations and Maintenance

The following rules should be taken into consideration in operating and maintaining latrines:

- The pits of pit latrines should be covered to avoid smell nuisances and insects inside latrine huts and in their direct surroundings.
- The pit's squatting platform and its surroundings should be cleaned on a daily basis.
- Latrines should be provided with some form of lighting for night use. Facilities for washing hands after use should also be provided.
- To avoid contamination and health hazards, the latrine should be closed, when the pit is filled up to 0,5 m below the platform.
- So that small children can use latrines safely, i.e. so that they cannot fall into the pit, defecation openings should not be larger than 18 cm in diameter.

Limitations and Restrictions

Latrines should not be built in flat areas or depressions affected by seasonally high groundwater levels or flooding. Otherwise, pits could fill with water and become ideal breeding areas for mosquitoes and other insects. An overflowing pit containing excrement would contaminate the environment and cause health hazards and infections.

Constructing latrines will be difficult in areas with rocky soil or high groundwater levels. Necessary design adjustments, e.g. to turn it into an aqua privy, are costly and will have to be considered in an early planning stage.

The construction of latrines is not in itself enough to reduce the risk of infections from excrement. To do this effectively, they must be regularly cleaned and maintained. As a rule, private latrines are normally kept cleaner and are better maintained than public facilities.

If the excrement sludge is to be used without any further treatment as fertiliser in agriculture or horticulture, it will have to be stored for at least one year after the latrine has been closed in order to reduce its pathogenic effects on humans to a minimum.

Latrines are not a viable sanitation options in areas with residential densities above 300 persons/ha, as the necessary minimum distances to buildings or wells cannot be assured.

Suitability for Self-help

Digging a hole, e.g. for a well or for mining, is a common skill in most societies. Normally therefore, it will not be difficult to find workers for this in urban poor settlements.

Locally available materials and common and/or traditional techniques (wood construction, thatched or stone walls, etc.) can be used to build latrine huts. Such techniques will probably be similar to those used to construct the (often self-built) houses in the area, so latrines can usually be built through self-help initiatives. Some assistance may be needed to select appropriate locations for latrines. In many cases, this may be provided by local environmentally involved NGOs.

Assessment of Costs

Apart from manual labour, the construction of a latrine will require the following tools and materials:

- spades and pickaxes;
- a squatting platform made out of concrete (or similar material);
- a lid for the defecation opening (wood, metal or cement);
- locally available materials for the latrine hut and the door.

Most of these tools and materials will usually be available locally at low costs.

Wastewater discharging and treatment

Jalalabad, Afghanistan

Latrine construction in a refugee camp

The Sar-Shahi Refugee Camp near the Afghani city of Jalalabad was established in 1994/95 in the wake of the Afghan war. It housed up to hundred thousand refugees in intolerable hygienic conditions in a very confined area. The prefabricated communal toilet blocks in the camp were totally overloaded by fast growing streams of refugees. Moreover, the refugees did not feel responsible for cleaning or maintaining them.

As a result of this experience, a different approach was used when a second camp was established in New Hadda. Here, support was given to individual family groups in the self-help construction of improved pit latrines. Within six months, basic sanitary facilities for about 90,000 people were built. The latrines were:

- adapted to local conditions with the use of local building materials and techniques (wood and clay construction);
- inexpensive due to the high level of self-help;
- sufficient, in terms of numbers, to serve the refugee population;
- adequately maintained, as the family groups involved in their construction developed a sense of ownership.

Where possible, only private sanitary facilities were built, which was more in line with the social and cultural codes of the Islamic community there.

Main Features
Inexpensive and simple on-site sanitation option without the need for a water supply; discharge and storage of faeces in a covered pit

Application
In settlements with insufficient or irregular water supply provisions and with suitable soil conditions

Costs
Low, as most materials needed for construction are usually cheaply available locally

Operations
Self-help construction, operations and maintenance is possible

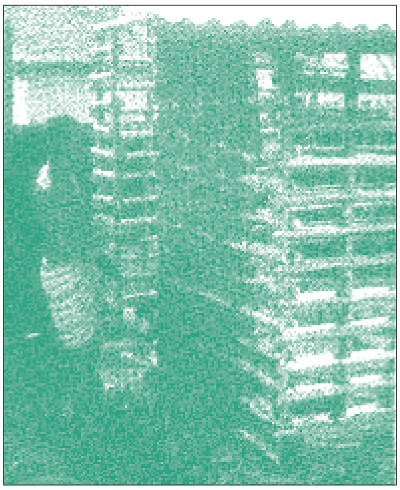
Interfaces
As or when required, emptying of latrines and discharging of sludge carried out by city-wide service providers (e.g. municipalities, private sanitation enterprises)

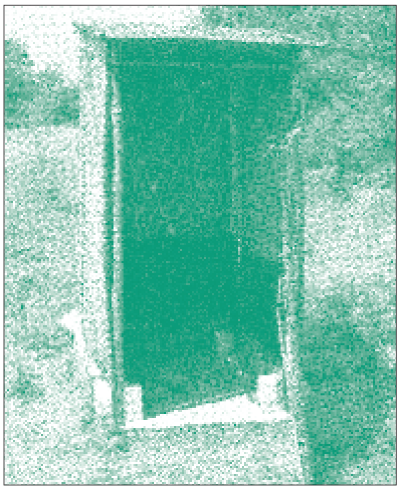
Advantages
Simple and cost-efficient system; can be constructed with local building materials; low need for technical skills and know-how

Disadvantages
Risk of flooding (including seasonal flooding) and environmental contamination when located in low-lying land and/or depressions; inappropriate for areas with rocky subsoil or high groundwater levels

To be Considered
Successful prevention of health hazards will largely depend on social and cultural traditions, and on regular cleaning and maintenance.

Latrine huts built with locally available materials /82/ /83/





WASTEWATER DISCHARGING AND TREATMENT

SOLUTIONS AT SETTLEMENT LEVEL (ON-SITE SYSTEMS): DRY AND COMPOST TOILETS – SEPARATION OF URINE

Dry Toilets - Possible Applications

Dry toilets and compost toilets that provide for the separation of urine and stools are an alternative solution to simple latrines, which can be inappropriate in areas with high residential densities, risks to potable water supplies or groundwater resources, or with difficult ground conditions (e.g. rocky subsoil). They can also be a viable alternative to technically and financially more complex sanitation solutions (e.g. septic tanks or conventional sewage systems).

Although the separation of urine and faeces is a traditional solution in some parts of the world (e.g. in Yemeni cities), in most regions, and in particular in densely built-up urban areas, it is an innovative approach, and there is only limited practical experience with it to date.

Dry toilets avoid potential groundwater contamination and can generate fertiliser for agriculture. Where gardens or agricultural fields are close to urban settlements, their use enables almost all the faeces, along with the other organic waste generated at household level, to be used as fertiliser in an environmentally friendly way.

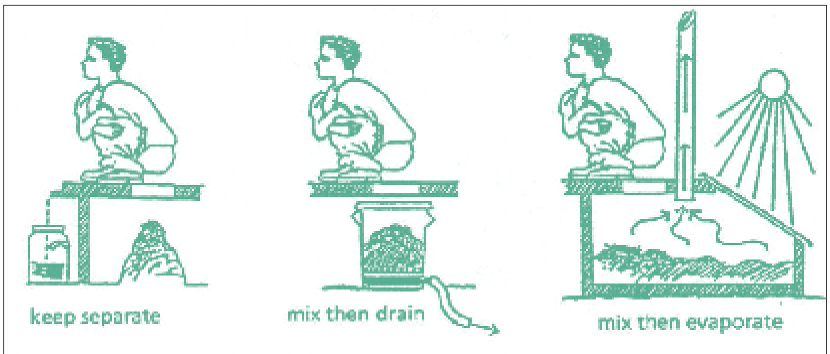
Construction

In dry toilets, faeces are separated from urine, and their undesirable constituents are neutralised by drying. In compost toilets, this is done through controlled aerobic decomposition processes.

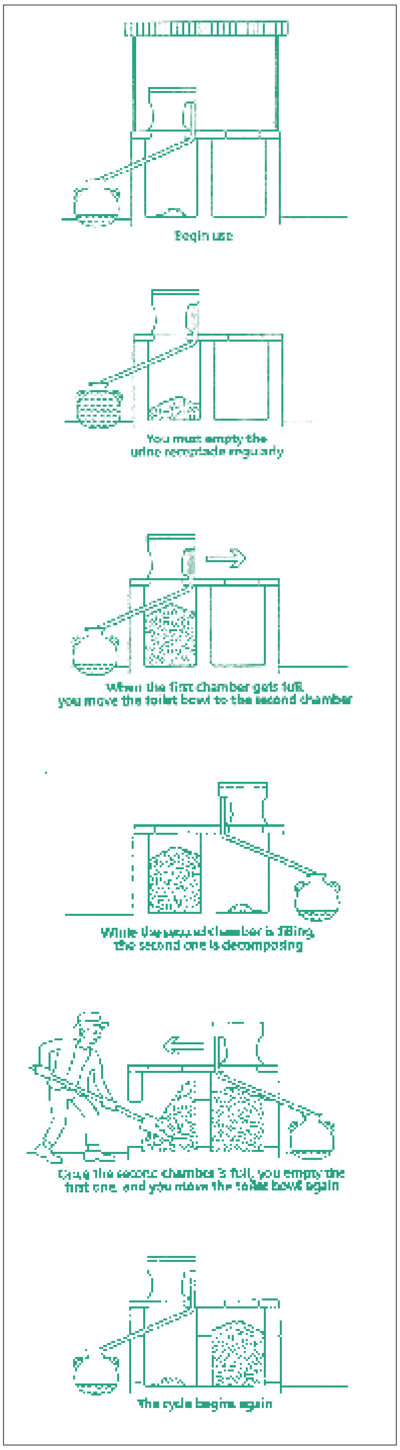
Urine and stool can be separated in different ways: usually, separation "at source", i.e. before any mixing takes place, will be the preferred solution.

Separating urine and stools can significantly reduce or even totally eliminate problems such as smell nuisances or breeding flies, and can also facilitate the storage, treatment and transportation of faeces. Urine itself is comparatively germ free and can be directly applied, untreated or in solution, as fertiliser. The solid components of excrement can be easily composted, and compost toilets take advantage of this. Some types of compost toilets are constructed so that other organic waste (e.g. from kitchens) can also be disposed of there, which further facilitates the composting process.

Schematic sketch: options for separating faeces and urine /84/



Double chamber dry or compost toilet
/85/



Wastewater discharging and treatment

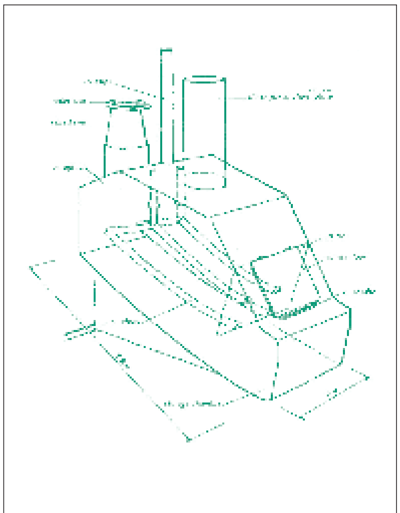
Dimensioning

Dry and compost toilets will have to be designed according to the number of users and according to the volume of stools and organic waste to be processed. It has to be ensured that the material remains in the composting chamber long enough for the full composting process to occur. In double chamber systems, the solid components in the unused chamber should be allowed to dry and decompose completely.

In a continuous composting toilet, material is regularly added and taken out: material that has already composted is removed, making space for new material. Again, sufficient processing time should be guaranteed so that the material can completely decompose.

Continuously operating compost toilet

/86/



Operations and Maintenance

Operating compost toilets requires a high level of user awareness and care. Determining factors will be: humidity levels, the amount of organic material added, which increases the nitro-carbon content, and the processing times. As a rule, discontinuous compost toilets are easier to operate than continuous systems, which cannot completely rule out the risk of contaminating already composted material with raw waste or excrement.

With discontinuously operated dry toilets, it is important to ensure that urine is properly separated from faeces, and that the amount of additionally needed water, e.g. for cleaning, is kept as low as possible. In order to minimise smell nuisances, ashes or lime should be added after each use. As a chamber fills up, the faeces material dries out; this occurs especially during the storage phase of the other full and unused chamber. In cooler or more humid climates, using solar heat can support this process. After a drying period of at least six months, most patho-genic germs are likely to have died, and the dry material can be removed and used, e.g. as fertiliser.

In case of composting, it will be important to carefully control humidity levels (optimum is 40-60%).

Liquid content usually consists of urine, cleaning water, the natural fluid content of faeces and other material, e.g. organic kitchen waste. The storage chambers will thus need drainage or other possibilities of filtering off excess moisture.

For compost toilets, structural material like organic garden waste (grass, foliage/leaves, etc.), sawdust or soil will have to be added regularly to achieve appropriate nitro-carbon levels. Again, it is recommended that ashes, lime or soil be added after each use to avoid smell nui-sances.

When a chamber is 3/4 full, usage will have to be switched to the second chamber. The material will then decompose aerobically over a period of about one year, after which the resultant compost can be removed and used as fertiliser.

Toilet bowl for separating urine and faeces developed in South Africa

/87/

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Dry and Compost Toilets – Separation of Urine

Limitations and Restrictions

Using dry toilets, and in particular compost toilets, requires significant care and discipline. As specific processes (drying, composting) will have to take place in the toilet itself, all users have to be aware of the consequences or their behaviour and usage patterns. To support these processes, some necessary additives (ashes, soil, lime) will have to be available and used in an appropriate way. A good amount of knowledge, sensitivity, discipline and acceptance is required of all users.

As this cannot always be guaranteed, the resultant dried material and/or compost should always be handled with care. It should not be simply deposited on the surface of the ground, but instead worked into the soil. In this way, possibly incomplete decomposing processes can continue without major health risks.

Suitability for Self-help

The technical skills needed to build a dry or compost toilet are similar to those needed for the construction of standard pit latrines. However, their use and operations requires intensive advisory assistance and training. In this context, community based organisations, environmental groups or other self-help initiatives can and should have an important role.

Assessment of Costs

Similarly, the construction costs of dry and compost toilets differ little from those of pit latrines, although it may be necessary to employ more skilled labour with higher wages, resulting in slightly higher costs.

On the other hand, cost savings are possible in locations with solid soil conditions, as compost and dry toilets can be built with comparatively smaller pits.

Compost toilet with plastic storage tank /88/

Locally produced toilet bowl for urine separation in Kisumu, Kenya /89/

WASTEWATER DISCHARGING AND TREATMENT

Soweto, South Africa
Compost latrines in an informal settlement

In the informal settlement Elias Mofswaledi in Soweto, the Greater Johannesburg Transitional Metropolitan Council (GJTMC) and the Water Research Commission built 300 compost latrines. Maintenance was taken on by the GJTMC.

A later evaluation of this project showed that compost latrines can be a viable and affordable sanitation option. In spite of high requirements for user care and discipline, which called for user awareness campaigns, this solution can be recommended, in particular for dry (arid or semi-arid) climates.

Compost toilet in South Africa /90/

Main Features
Cost-efficient inexpensive on-site-sanitation option; based on a direct separation of urine and feces; separate treatment and processing (drying, composting) and use (fertiliser)

Application
Where pit or VIP latrines cannot be used because of difficult soil conditions, high groundwater levels or scarcity of space (particularly in dry climates)

Costs
Low, as most material needed is cheaply available locally

Operations
Self-help initiative possible both for construction and operations

Interfaces
Emptying of toilet storage chambers and disposal of processed material can be done by city-wide service providers (municipalities, private sanitation firms), but in most cases, is not necessary

Advantages
Simple and inexpensive technical solution; use of local material possible; no sewage permeation, i.e. no soil contamination; production of fertiliser; low requirements for technical skills for construction

Disadvantages
Requires high level of user care and discipline, and a basic understanding of composting processes

To be Considered
Hygiene aspects of using processed materials in order to avoid infections and other health hazards

3.3 Wastewater

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Aqua Privies / Septic Tanks

Application

In urban areas without the possibility of connecting to sewage systems, septic tanks are another viable and environmentally friendly sanitation option. Applied for decades in many different parts of the world, septic tanks are a well-proven and established technical solution for the discharge of household sewage.

Septic tanks are usually rectangular waterproof containers installed below ground, and receive wastewater from toilets, kitchens and bathrooms. They can serve just one household or building or, when connected with a small network (or settled sewer), a group of buildings or households. They can be designed as a one chamber or a multi-chamber system.

Septic tanks are based on the principle of separating solid components (sludge) and liquid components. After separation, the liquid components leave the septic tank and are filtered through soakage pits or drainage fields and discharged to the soil or a sewer system (e.g. a small bore sewer); the solid components remain in the septic tank. Anaerobic decomposing and fermentation processes reduce the sludge volume. The residual sludge has to be removed at regular intervals (e.g. every 2-3 years, depending on the size of the tank).*

**In septic tanks for household wastewater, a layer of scum builds up over time close to the inlet. It consists of floating material, such as grease, oil, hair, small pieces of wood etc., and of sludge particles that are carried upwards by fermentation gases. New scum material rises and pushes the old scum upwards above the water level where they dry and loose weight, and thus the scum layer continues to grow. Although this does not affect the treatment process, it reduces the tank's capacity. The scum layer has therefore to be removed from time to time.*

Technical Solutions

The following basic technical solutions can be applied:

- Aqua privies are one-chamber-systems, into which faeces and wastewater are discharged below the surface level of the tank. This reduces smell nuisances in the toilet to a minimum.
- A standard septic tank consists of two chambers. Solid components settle in the first chamber, while the second chamber is used to treat the liquid components. Wastewater arriving in the second chamber produces no turbulence; consequently, small lightweight particles may be suspended within it.
- Because the purity of the wastewater improves the longer it remains inside the septic tank, three-chamber-systems are used in some countries. All the wastewater generated by household toilets, bathrooms and kitchens are discharged into the first chamber. All three chambers are then used for the sedimentation of solid components and their decomposition. In the third chamber, a partially anaerobic process further cleans the wastewater, which is already largely free from sediments. In some cases, the last chamber directly serves as a soakage pit. To do this, it is fitted with a water permeable base. As a rule, the outlets for treated liquids should be below the scum layers that build up in each chamber.

The advantages of septic tanks are their low maintenance requirements, the avoidance or limitation of smell nuisances and the possibility of later connecting to a sewer system.

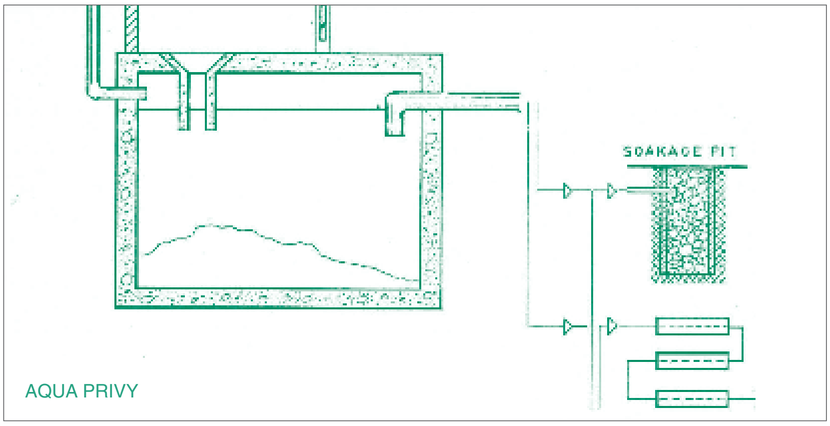
Disadvantages are their relatively high initial investment costs, the operating costs of regular emptying and the need to use sufficient amounts of water from toilets, bathrooms and kitchens for flushing. Septic tanks can usually therefore only be applied when households are connected to water.

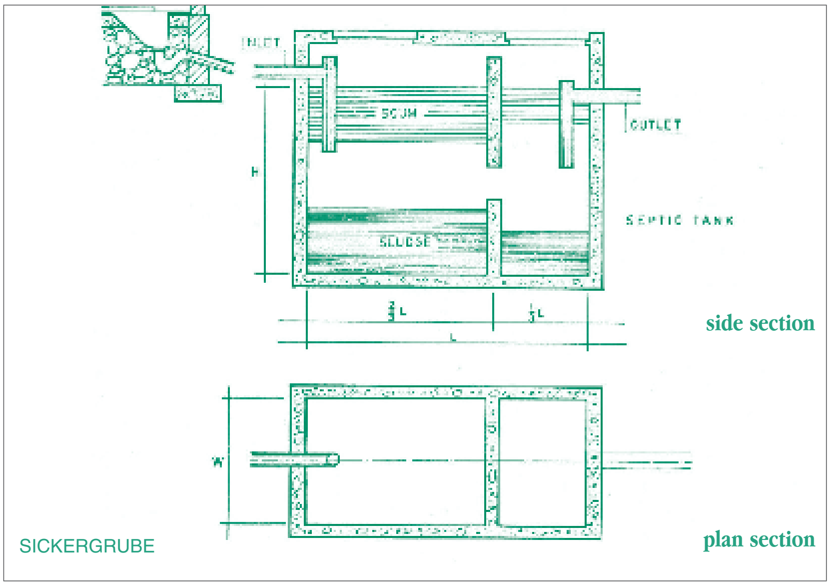
Construction of a septic tank /91/

Wastewater discharging and treatment

Construction

/92/93/





Dimensioning

The volume of a septic tank has to be determined in relation to the amount of wastewater to be discharged. A two chamber septic tank should be designed to allow the liquid components to remain in the system for 1 to 3 days; with 3 chamber systems, the processing and treatment time could be up to 10 days.

In two chamber systems, the first tank is generally twice as large as the second. For operations, the accumulation of 0.03 - 0.04 m^3 of solid material per person per year has to be al-lowed for. The layer of sludge built up over time should not exceed 1/3 of the tank's total height. The number of users and the planned emptying cycle thus determines the necessary tank volume.

Operations

As wastewater treated in septic tanks goes into the soil, certain minimum distances to other buildings, infrastructure or topographic features will have to be considered. The figures presented by the table below are valid for soils with normal filtration capacity.

Minimum distances of septic tanks and soakage pits to buildings, infrastructure and natural features

Type of installation	septic tank (m)	soakage pit (m)
buildings	1.5	3.0
plot boundaries	1.5	1.5
wells	10.0	10.0
rivers and creeks	7.5	30.0
slopes and valleys	7.5	30.0
water supply pipes	3.0	3.0
streets and roads	1.5	1.5
large trees	3.0	3.0

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Aqua Privies / Septic Tanks

Operating a septic tank requires the regular discharge of water and other liquids into them. The tank should be regularly inspected in order to ensure that solid components from the first chamber are not entering the second chamber. Moreover, built-up scum should be removed regularly. To allow and support bacterial decomposition processes, the discharge of any chemicals (particularly cleaning detergents containing chlorine) into the septic tank should be prevented.

Septic tanks should never be emptied completely. As a rule, about 1/3 of the sludge volume should be left in the tank. This volume of bio mass (and bacteria) will be needed to ensure appropriate anaerobic decomposition.

Limitations and Restrictions

Septic tanks and soakage pits need sufficient space and permeable soil conditions. In densely built-up urban areas, the space needed is often not available. Moreover, soil absorption capacities can already be exhausted by large numbers of pit latrines, septic tanks and soakage pits.

Since they need water for flushing, septic tanks are usually not a viable sanitation option for settlements without water supply provisions.

In addition, septic tanks can only be installed in places where road and street condition allow for the regular emptying and disposal of sludge.

Bengkulu, Indonesia

Improved septic tanks at settlement level

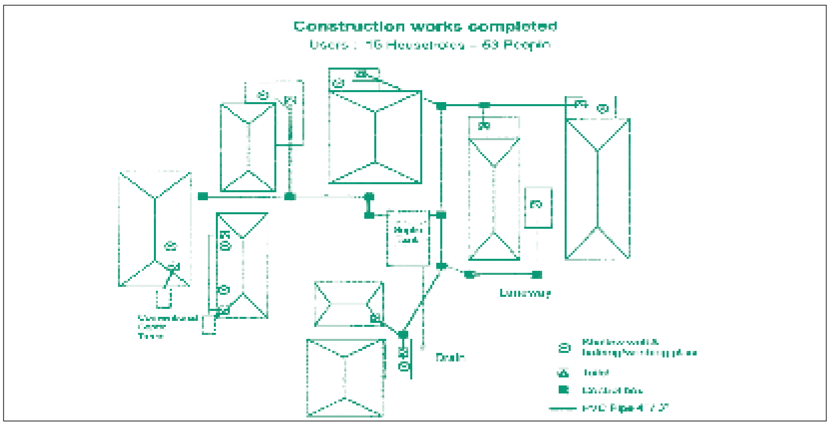
In the context of a GTZ demonstration project, improved septic tanks were designed, built and tested in two neighbourhoods of the Indonesian city of Bengkulu on the island of Sumatra. The project's objective was to increase the efficiency of the treatment of effluents from septic tanks from BOD_5 reductions of only 20%, to 60%. In addition to the construction of improved (multi-chamber system) septic tanks, other communal sanitary installations, such as toilets and laundry facilities, were rehabilitated.

To complement those measures, approaches to increase resident's participation in decentralised sanitation projects and appropriate financing instruments were developed.

The main conclusions of the model project were that:

- Unclear tenure, unfavourable soil conditions and high groundwater levels hampered the selection of appropriate locations for septic tank construction.
- Due to high groundwater levels, the tanks had to be watertight, which called for high requirements with regard to the technical skills of the firms and labourers commissioned with the construction works.
- The participation of residents and local institutions presented problems. Hence, accompanying awareness campaigns and training in matters of sanitation and hygiene were indispensable.
- Most residents had difficulties with the high construction costs. Complementary credit programmes were thus necessary.
- The municipal administration was not sufficiently capable of managing the participatory approach for decentralised sanitation and needed substantial advisory assistance.
- It was possible to achieve the intended reduction of wastewater BOD_5 content in all the tested septic tank installations.

Schematic sketch of a communal septic tank for a number of households in Bengkulu/Indonesia /94/



WASTEWATER DISCHARGING AND TREATMENT

Suitability for Self-help

The technology of septic tanks is well known in most countries. Septic tanks are constructed both individually in self-help and by small enterprises. However, the provision of advise on suitable locations, operations and maintenance, and the final disposal of liquid and solid products may be necessary.

Septic tanks can be constructed with the mutual help of neighbours and can be financed by local small-scale credit programmes. The emptying of sludge can also be organised at neighbourhood or community level, or can be commissioned to small local enterprises.

In any case, the installation of septic tanks is a viable option for improving hygienic conditions at settlement level and can be implemented and operated through self-help.

Assesssment of Costs

Compared to other simpler sanitation options, septic tanks are relatively cost intensive. The construction and operating costs per household are 3-5 times higher than those for simple pit or VIP latrines. Households therefore require a certain minimum income level. Costs can be reduced when a group of households jointly operates a larger septic tank.

Main Features
Environment-friendly solution for the disposal of household wastewater in settlements that are not connected to sewer systems; joint use by a group of neighbouring users is possible

Application
Takes wastewater from toilets, kitchens and bathrooms in tanks with separation of liquid and solid components

Costs
Costs per household 3-5 times higher than for simple latrines

Operations
Construction and operations by individuals, small-scale enterprises or by mutual help at neighbourhood level; financing through local small credit programmes

Interfaces
If necessary, emptying of tanks and disposal of sludge by providers from outside the settlement (municipalities, private operators)

Advantages
Technology and construction methods well known in many countries; low maintenance requirements; partial decomposing of faeces to less hazardous products; connection to sewerage possible at later stages of development

Disadvantage
Initial investment costs relatively high; regular emptying against fee payment necessary; re-quires a certain amount of wastewater from toilets, bathrooms and kitchens for flushing

To be Considered
Chemical contents of wastewater, in particular disinfectants with chlorine contents, can impede the bacterial decomposing of sludge

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systeme): Biogas Plants

Application

Small biogas plants or "biodigesters"* provide a special form of decentralised wastewater treatment. Since their construction requires high initial investments, their application in urban poor settlements will generally be limited.

On the other hand, biogas plants can be a viable option for treating wastewater from households, agriculture and some commercial activities, especially because of their environmental benefits. In order that the sanitation options presented in the context of this publication are as comprehensive as possible, they are described here as a possible alternative in specific situations:

- for wastewater management in urban settlements with low densities, where sufficient space is available and where biomass is also generated by agriculture or horticulture.
- for the treatment of wastewater from larger facilities like schools, hospitals or markets, even in innercity locations. Such solutions will focus more on treating wastewater (e.g. infectious wastewater from hospitals) than on biogas production. However, the biogas produced can be used as energy source, and can thus subsidise the costs of wastewater treatment.

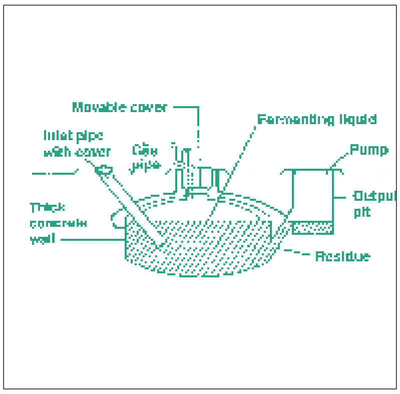
*Larger-scale municipal plants that are used more for wastewater treatment than biogas production.

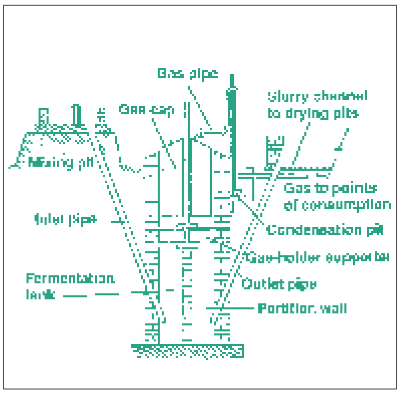
Construction

Biogas plants can be operated both at neighbourhood level and as larger communal installations. Depending on construction type and technology, they can have a processing capacity ranging from just a few cubic meters of wastewater and biomass to some hundreds of cubic meters.

Generally, a distinction is made between two different types of biogas plants: those with a fixed top or vault (Chinese type) and those with a movable top or cap (Indian type).

Biogas plants: Chinese (above) and Indian (below) type /95 a/b/





Technical Procedures

Biogas plants can process both solid and liquid organic waste. They can thus be a comprehensive solution for the disposal of human and animal excrement, waste from agriculture and horticulture, and organic residuals from food processing (e.g. slaughterhouse waste).

On one hand, a biogas plant neutralises wastewater and other organic waste. On the other, it produces valuable fertiliser and biogas as a source of energy.

Biogas plants are particularly efficient when solid and liquid waste components with low carbon and nitrogen content (faeces) can be mixed with components with high carbon and nitrogen content (straw, garden waste), and when temperatures are sufficiently high (30-35°C). The material is fermented by an anaerobic process. Bacterial decomposition produces mainly methane gas (and some carbon dioxide), which can be used as energy source. The solid residues built up over time inside the plant are a valuable fertiliser and has to be removed at certain time intervals.

Toilet connected to a Chinese type biogas plant /96/

WASTEWATER DISCHARGING AND TREATMENT

Dimensioning

Urban households do usually not produce sufficient animal and agricultural waste to operate a biogas plant efficiently. In most cases, biogas plants will therefore only be useful for large numbers of households or as large-scale installations.

The necessary size of a biogas plant depends on the amounts of wastewater and solid organic waste components to be processed. Experience from China shows that the solid and liquid waste generated by one family, complemented by the waste produced by 1-2 pigs, can be sufficient to operate a small biogas plant. As a general rule, the production of 2 m^3 of biogas requires organic waste (manure) from 2-4 cattle or 2-3 pigs.

If biogas production as an energy source is the main purpose of a biogas plant, its dimensioning will have to relate to the amount of gas to be produced rather than the necessity of disposing of wastewater and other organic material.

The basis for the dimensioning of biogas plants for large facilities (school complexes with kitchens, boarding establishments, hospitals etc.) is the volume of wastewater and organic waste generated per time unit (day, week or month). The plant should be large enough to guarantee that the wastewater within it has sufficient space and hence time to process, in order that anaerobic decomposition can be complete, and all pathogenic germs are killed.

Gas demands for different uses

Use	type of consumption equivalent to	gas demand (cbm/h)
cooking	2 fire places	0.33
	4 fire places	0.47
	6 fire places	0.65
	2-4 fire places	0.20-0.45
	per capita and day	0.35-0.45
lighting	electric lamp with 100 W	0.13
	single mantle lamp	0.07-0.08
machines	modified to gas motors per kWh	0.61-0.68
cooling	for 100 litres	0.10

Operations

Biogas plants are generally operated continuously, i.e. solid material mixed with water or wastewater feed into to the plant at regular intervals. A minimum amount of water (about 10 litres per day per person, when human excrement is being treated) will have to be added to this mixture in order to keep it sufficiently liquid and pumpable.

An anaerobic process that kills all pathogenic germs occurs inside the biogas container. The necessary processing time inside the plant is determined by the container size and the volume of material to be processed. Generally, a processing time of 40-50 days will be needed. The solid residues produced are rich in nutrients, and can be used, dried or composted or as liquid fertiliser, for agricultural purposes.

The simple Chinese type of construction, with a fixed top built of bricks, is vulnerable to gas leakages and losses when, as a result of discontinuous operations or the removal of solid residues, changing gas pressures cause cracks in the brickwork.

In contrast, the “floating” cap of the Indian type guarantees a constant gas pressure. However, the cap, usually built from sheet steel, is often subject to corrosion problems. The Indian type is technically more sophisticated and more expensive.

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Biogas Plants

Limitations and Restrictions

To guarantee the efficiency of a biogas plant, all necessary operations (e.g. the introduction of new material) have to be done regularly and with a high level of discipline. Furthermore, to produce gas constantly, the material to be processed will have to be available regularly and in similar volumes and compositions. If this is not possible, continuity will have to have to be ensured by using stored, thinned down or acquired additional waste material.

The construction of biogas plants also requires building workers to have special technical skills.

The dealing with human and animal excrement intensively, as occurs with biogas plants, is not acceptable in all cultures, and is sometimes only permitted to certain social groups. Moreover, the perception of using products from human or animal excrement (i.e. biogas) for cooking purposes may be difficult to accept in some cultural contexts.

To facilitate the use of faeces, wastewater and other organic waste, biogas plants should be located close to residences or animal stables. In addition, gas pipes should be as short as possible to avoid or limit leakages. Sufficient space to construct the plant should therefore be available in the direct vicinity of toilets, bathrooms and kitchens, and also be close to the rooms where the biogas will be used.

Practical application of biogas plants

Small-scale biogas plants are most commonly found in Asia. In China alone, it is estimated that there are 7 million biogas plants at household level, which are operated with excrement from household members and 1-2 cows or pigs, and organic household and agricultural waste. They produce sufficient gas for household cooking and lighting. Biogas plants are also common in India, where at least 750,000 small biogas plants are estimated to be used at household level.

In Nepal, the first biogas plants were set up on an experimental basis in 1955: by July 1995, their number had increased to 24,000. Current estimates based on the total volume of biomass (manure) generated and the average size of households using biogas (5.5 persons and 4.7 live-stock), put the possible total number of biogas plants in Nepal at 1.3 million.

Within the framework of the “Community Mobilisation Process” of the “Rural Energy Programme”, 15 biogas plants were established in the village of Khalte in the District of Tanahun. All the plants have a tank volume of 6 m3 and are generally operated for 4 hours daily - two hours in the morning and two hours in the evening. They produce sufficient gas to run a stove for four hours. Each household uses about 36 kg of biomass (manure) per day, mainly from the household's livestock (buffalos, cows, pigs and goats), and roughly the same amount of water.

Modern biogas use in Europe and the USA mainly involves the collection and processing of gas from sanitary landfills and the operation of so called “bio-digesters”. These are large-scale installations with relatively sophisticated technology (tube extruders, heating, electronic control instruments, etc.), and are principally used to process wastewater and other organic waste. The gas is produced by anaerobic processes similar to those in conventional biogas plants, and is mainly used as an energy source for the plant itself (for heating, generating electricity etc.). The treated wastewater and sludge produced is valuable as fertiliser..

Construction of a Chinese type of biogas plant /97/

Wastewater discharging and treatment

Main Features

Neutralisation of solid and liquid organic waste and wastewater; production of valuable fertiliser and of biogas as an energy source

Application

Disposal of wastewater from households, agriculture and some commercial activities

Costs

High, will have to be supported by appropriate financing instruments

Operations

Can be operated by individual households, NGOs, public institutions or private enterprises

Interfaces

If necessary, emptying and disposal of residues by service providers from outside the settlement (municipalities, private operators)

Advantages

Biogas plants can be operated both at individual household level and as communal facilities; they are a comprehensive and environment friendly solution for the disposal of organic waste and human and animal excrement, whilst simultaneously producing fertiliser and biogas

Disadvantages

Construction and operations of biogas plants need special technical skills and know-how; they must be operated with great regularity and discipline

To be Considered

Dealing with human and animal excrement intensively, as is involved, is not socially acceptable in all cultural contexts

Suitability for Self-help

Due to demanding building techniques and the technical skills needed for operations, the introduction of biogas plants has to be accompanied by technical and organisational support and advice. This can be provided by community organisation and/or NGOs that have the necessary experience and expertise.

With adequate support, biogas plants can be constructed and operated by residents' self-help groups, or by initiatives by local schools, hospitals or other public institutions.

Because the construction of biogas plants calls for substantial financial resources, such initiatives will also have to be supported financially, e.g. by small loan funds, saving programmes or the acquisition of donations.

Assessment of Costs

In most cases, the construction costs of biogas plants will be difficult for individual households to afford. Communal solutions, or joint initiatives by a group of people, families or institutions, will usually be less expensive than individual plants.

In larger scale biogas installation (e.g. for hospitals), the gas produced can be used to meet energy demands and thus subsidise the costs of wastewater treatment.

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Grease Traps

Application

In urban poor settlements, as in other residential areas, the oil or grease contents of wastewater can cause serious environmental pollution when effluents are discharged in ground or surface waters.

Wastewater from kitchens (particularly from the large kitchens of schools, factory canteens, restaurants, and hospitals), as well as cleaning and surface water from workshops, garages, petrol stations and transport companies, can contain significant amounts of grease, oil and other lubricants.

Grease separators are especially useful and necessary for environmental reasons when wastewater can directly infiltrate the soil or is discharged without treatment into creeks, rivers and other surface waters.

Technically simple forms of grease traps or grease separators can be used for small-scale enterprises or similar activities in urban poor settlements that generate wastewater with high grease or oil contents.

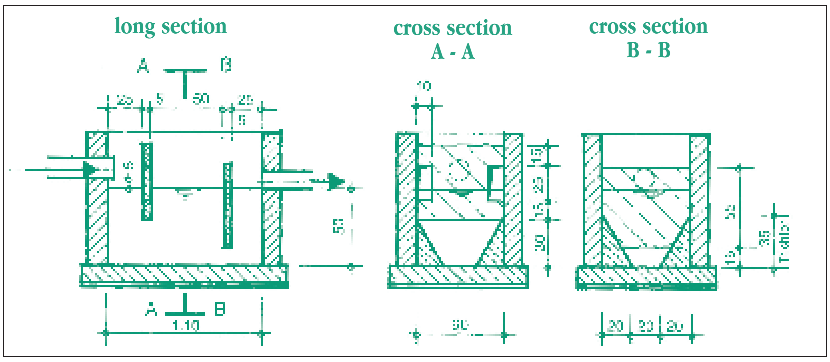
Groundwater pollution from a vehicle depot /98/

Technical Solutions and Dimensioning

Grease traps are devices that separate grease, oil and other lubricants from grease-water mixtures.

Simple grease traps can be produced locally without the need for special machinery or equipment. They should consist of a simple waterproof tank fitted with parts welded from metal (preferably high-grade steel) or made from PVC sheets, or cast from glass fibre reinforced synthetic resin.

Schematic sketch of a grease trap made from metal or plastic parts inside a concrete and/or brickwork tank /99/



Operations and Maintenance

Grease traps or separators are installed in wastewater outlets and operate continuously without specific maintenance requirements. Oil and grease is separated on the principle that the density of oil or grease is different to that of water (hence oil or grease floats on water).

Following a rough pre-filtration (which separates out solid items such as food residues, sand or stones), the mixture of water and grease/oil enters into the trap's main chamber. The mixture remains long enough inside this chamber to allow the oil and grease components to rise and settle at the surface. The oil and grease free water is then discharged from the main chamber via an outlet below its surface level.

The only maintenance required is regular cleaning of the pre-filtration sieve and the removal of the oil and grease. Depending on the volume of wastewater and the amount of oil and grease, this will have to done once a day or every few days. Regular cleaning is important in order to maintain the trap's efficiency and to avoid smell nuisances from decomposing processes.

When the separated grease consists mainly of cooking fats, it can be fed to pigs. Mineral oil or other grease residues have to be incinerated in special furnaces or deposited in a proper manner at landfills.

WASTEWATER DISCHARGING AND TREATMENT

Limitations and Restrictions

Large amounts of detergent in wastewater can dissolve its grease content so that it cannot be separated. In order that the maximum amount of grease fractions can be separated, the detergent content of kitchen wastewater should be kept as low as possible.

Appropriate disposal of grease residues can be another problem when access to landfills or incineration facilities is difficult.

Suitability for Self-help

Grease traps are small, simple and inexpensive devices. Their deployment depends less on investment costs or operations requirements than on potential users being convinced about their benefits. This may have to be supported by awareness campaigns, which can be undertaken by local environmental initiatives or community associations. Where local businesses or other users are convinced and willing to use them, simple grease traps can be produced and installed locally through self-help.

Assessment of Costs

Technically simple grease traps can be manufactured at reasonable costs and can be installed without the need for large investment.

Their operation involves little or no costs; some time needs to be dedicated to cleaning and the removal of oil and grease deposits.

Main Features
Separation of oil and grease from wastewater of canteen kitchens and workshops based on the difference in density between water and oil / grease

Application
Where large amounts of oil or grease are discharged into wastewater; grease traps are installed in wastewater outlets, close to the wastewater source

Costs
Can be manufactured at low costs; operations involve little or no costs

Operations
Can be produced and installed locally through self-help

Interfaces
Large amounts of oil and/or grease residues will have to be disposed of outside the settlement (landfills, incineration, recycling)

Advantages
Small, simple and inexpensive; continuous mode of operation without specific maintenance requirements; where residues consist only of cooking fats, they can be fed to pigs

Disadvantages
Grease dissolved by detergents cannot be separated; proper disposal of oil and/or grease residues can be problematic

To be Considered
Regular cleaning necessary to maintain efficiency and to avoid decomposition and associated smell nuisances

Wastewater discharging and treatment

Solutions at Settlement level (On-Site Systems): Soakage Pits • Drainage Fields

Application

In urban poor settlements, a soakage pit or drainage field can be an alternative to a connection to a sewer system under the following conditions:

- When the solid components of toilet effluent are separated from the liquids (e.g. in septic tanks, aqua privies or dry toilets), the remaining wastewater is largely free of hazardous components and can be discharged together with grey water from kitchens and bathrooms.
- Where space is available and the soil is permeable enough to absorb discharged wastewater.
- Where there is no risk of nearby water sources (e.g. wells) being contaminated by infiltrating wastewater.

Soakage pits and drainage fields are classical approaches to wastewater disposal, and can be found in many countries and regions.

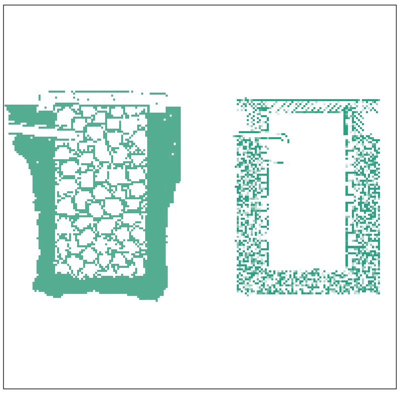
Technical Solutions

Infiltrating wastewater into the soil is a well-proven method of disposing of less hazardous wastewater and grey water. It is based on the filtering and cleaning capacity of soils and vegetation. Two basic solutions are possible:

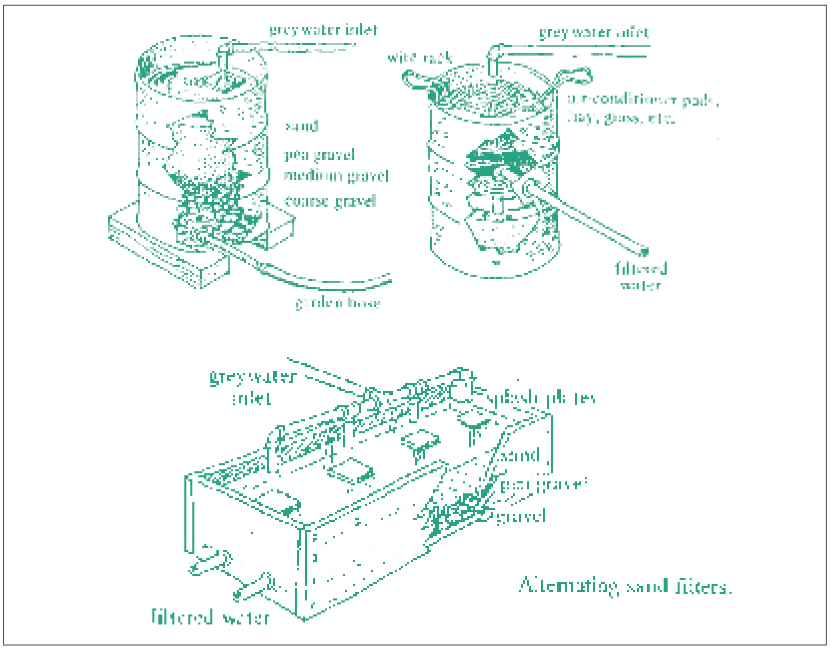
- Where sufficient space is available, wastewater can be infiltrated into drainage fields.
- Where space is scarce, soakage pits built of brickwork or filled with coarse gravel and stones can be used.

Schematic sketch of a drainage field /100/

Schematic sketch of soakage pits /101/



Small sand filters can be used to treat grey water on its own for irrigation purposes. /102/



WASTEWATER DISCHARGING AND TREATMENT

Dimensioning

The size of soakage pits and the necessary lengths of drainage pipes depends on the volume of wastewater to be filtered and on the filtration capacity and permeability of the soil. As soil conditions can differ considerably even in small areas, general recommendations are difficult to be made. In most cases, an analysis of soil conditions and/or practical tests will be necessary.

The same applies to the dimensioning of grey water filters, which is also best tested in practice. It depends on the volume of water and the type of filter to be used (surface, thickness of layers, gravel and sand grain sizes etc.). As a rule, 10-20 m of drainage pipe will be needed per inhabitant connected to the filter.

Soakage pits or drainage fields should not be located where they might have a negative affect on potable water installations, water intakes, surface waters or other infrastructure facilities. Necessary minimum distances to such installations are similar to those for septic tanks (see section on septic tanks).

Operations and Maintenance

Wastewater should be discharged continuously to soakage pits and drainage fields; sudden large intakes of wastewater should be avoided. Flooding of filtration installations by heavy rainfalls should be prevented, as the resulting possible dispersion of pathogenic germs risks exposing the population to infections.

The filtration capacity of drainage fields normally decreases over time. Depending on the salinity of the wastewater and the amount of material suspended in it, a film of algae builds up and the filtration pores become clogged. When this happens, the drainage field has to be relocated or closed for a certain time to allow the algae film to dry and degrade.

Limitations and Restrictions

The possible usage of soakage pits and drainage fields is largely determined by the space available and the soil's filtration capacity. Negative impacts on drinking water sources and installations have to be avoided. In densely built-up urban settlements, infiltration and soakage are thus often not viable sanitation options.

Suitability for Self-help

The technology is simple and can be used by private households and local craftsmen. Assistance may be required in selecting appropriate locations and soils. Design and construction can be coordinated and carried out through self-help.

Assessment of Costs

The main costs of constructing soakage pits or drainage fields will be labour costs. It may be necessary to purchase or at least transport appropriate filtration gravel. In drainage fields, drainage pipes will be a major investment item. Generally, costs will be reasonable and locally affordable.

Main Features
Filtration of sewage and greywater free of solid components, based on the filtration and cleaning capacity of soil and vegetation

Application
For low-density settlements without possibilities of connecting to a sewer system

Costs
Mainly labour costs; limited investment costs (drainage pipes) that can generally be financed locally

Operations
Construction and operations in self-help possible

Interfaces
None

Advantages
Traditional approach to wastewater disposal; well-known in many countries; simple technology, can be applied by individual private households and local craftsmen; inexpensive

Disadvantages
Application limited in densely built-up areas and by filtration capacity of soils

To be Considered
Locations should be selected in ways that do not negatively affect drinking water resources or surface waters.

Wastewater Disposal

Off-Site-Systems: Transport Containers • Vehicles

Application

Almost all on-site sanitation options (different types of latrine, compost toilets, septic tanks and aqua privies, biogas plants etc.) need to be emptied regularly and sludge and other residues have to be disposed of.

For this purpose, various methods using containers and vehicles can be applied.

In urban poor settlements, most of these methods are well-known and proven solutions. They can be tailored to meet the specific conditions and situations of the different types of settlement that need off-site disposal of sludge and other wastewater residuals.

Technical Solutions

Depending on the type of on-site sanitation installation, two basic solutions for disposing of wastewater residues are possible:

- The decomposed paste-like residues (sludge) of pit, VIP and pour-flush latrines, of septic tanks and, in particular, of biogas plants are liquified by adding water, pumped out and removed by tanker trucks.
- The more solid residues produced by compost and dry toilets, or the dried-up material in latrines, septic tanks and biogas plants, are shovelled out and loaded onto carts or trucks for transport.

The selection and dimensioning of containers and vehicles depends on the type of sanitation option, the consistency of the residues and, in particular, the possibilities of access (street conditions and width).

It will be important to leave part of the residue in the sanitation pit as a “bacterial start-up” to facilitate a new decomposition cycle.

Operations and Maintenance

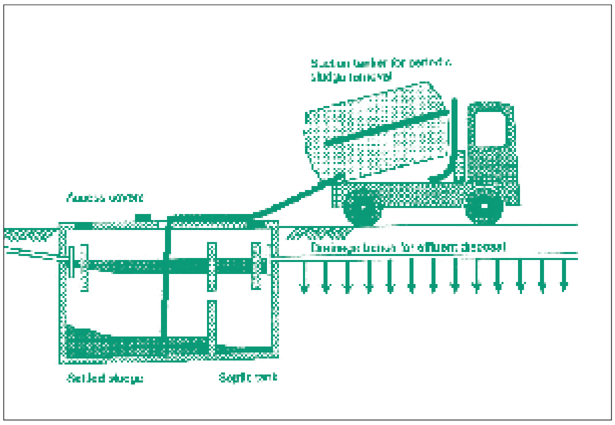
There may still be pathogenic germs in the solid, paste-like or liquid residues that are being emptied and transported. Basic precaution will therefore need to be taken in the handling of tools and equipment (workers should avoid contact with residues), in transport (leakages are to be avoided) and in final disposal (groundwater pollution and contamination of agricultural fields is to be avoided). Moreover, cleanliness and hygiene should be observed (protective clothing should be worn, personnel should wash and avoid eating at work).

The selection of further processing and final disposal methods should take environmental aspects into account and protect the population from health hazards.

Limitations and Restrictions

Due to the usually large volumes of material to be removed and disposed of, the option of transporting manually in buckets, tubs or barrels will generally be limited.

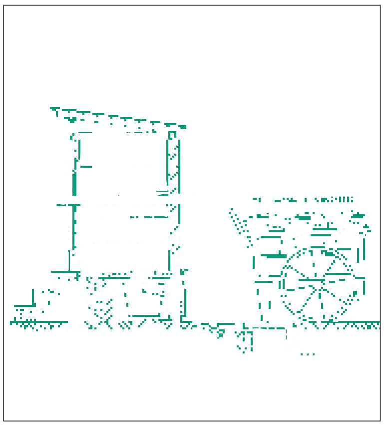
Emptying a septic tank with a small suction tanker /103/



Bucket latrines /104/

Bucket latrines are a special type of sanitation installation that is still found in some parts of Asia and Africa. Excrement is collected in buckets and removed daily.

Their acceptance, however, is rapidly decreasing, even in urban poor settlements.



WASTEWATER DISPOSAL

Dar es Salaam, Tanzania

Manual Emptying of Latrines

The "Manual Pit Latrine Emptying Technology (MAPET)" is a method that combines traditional and modern approaches. The Dar es Salaam Sewerage and Sanitation Department (DSSD) uses it in settlements that cannot be accessed by large suction trucks. Emptying is done using a simple pump and a drum system, which is transported on specially developed push carts with bicycle tires.

The simple pumping and storage technology has replaced unhygienic manual emptying with buckets. The equipment is inexpensive and can be locally manufactured by small workshops.

Barrel cart for emptying latrines in Asia /105/

Suitable end processing and disposal facilities are needed to prevent local sanitation and hygiene problems being simply exported outside the settlement. Furthermore, households have to be willing and able to pay appropriate fees for emptying and transportation services.

In addition to the technical and financial aspects, cultural or religious reservations may have also to be taken into consideration in some countries.

Suitability for Self-help

The emptying of latrines and septic tanks can be carried out through self-help. If this is organised as mutual help at community level, labour costs can be reduced and individual households would just have to pay for the tanker truck's fuel and possibly its rental.

The service can also be provided by local small-scale enterprises. In this case, service fees will have to be paid.

Assessment of Costs

The main cost item will usually be the service fees to be paid to local small-scale private enterprises. When emptying is undertaken with self-help, a financial share of the purchase (or rent) and operational costs of vehicles will have to be paid in addition to the in-kind contribution of labour.

The initial investment costs of large, communally operated tanker trucks will be a major item. In addition, operational (diesel fuel, lubricants) and maintenance costs (spare parts, regular servicing) will have to be covered.

Main Features
Emptying of on-site systems (e.g. latrines, septic tanks, etc.) and transportation of residues

Application
Manual or mechanical emptying and transportation, depending on (vehicle) access and the composition of the residues; selection of types of container and modes of transport depends on the consistencies and types of residue

Costs
Labour costs, and investment and operating costs of equipment

Operations
Can be carried out in self-help or mutual help, or as service of local small-scale operators

Interfaces
Where necessary or possible, emptying of pits and disposal of residues by outside service providers (municipalities, private enterprises)

Advantages
Regular emptying ensures on-site sanitary facilities are continuously available for use; possible job and income creation; self-help possible

Disadvantages
Transportion by vehicles often restricted due to difficult access; manual transport in buckets, barrels, etc. only possible for smaller volumes

To be Considered
Hygiene, technical and economic aspects; cultural or religious reservations in some countries

Wastewater Disposal

Off-Site-Systems: Conventional And Unconventional Sewer Systems

Application

In most cities, especially in more densely built-up areas, waterborne sewerage is the most common and widespread form of dealing with non-industrial effluents. Wastewater is collected in pipe systems and subsequently discharged at treatment plants, or in watercourses (rivers, canals, etc.) or the sea.

Piped sewerage will also often be the most appropriate and efficient solution for improving sanitary and hygiene conditions in many urban poor settlements, most of which have very high residential densities.

However, conventional sewerage systems may not be feasible because of the high costs of initial investments in installations and construction, and of operations and maintenance. Alternative low-cost solutions with reduced technical standards will therefore be the preferred option.

Technical Solutions

There are several distinctions between conventional and unconventional piped sewerage systems, but as there are smooth transitions between both types, only their major differences and characteristic features are described in the following:

Conventional sewer systems, functioning on the principle of waterborne and regularly flushed piped networks, are characterised by large collector mains, which are usually laid with relatively large gradients in the middle of streets. Each building or plot connects to the mains through smaller connection pipes. To allow for inspection and maintenance, the mains have manholes at regular distances. In addition to sewage, the mains are often also sized to receive rainwater and other surface water. Flow through the pipe network is usually achieved through gravity. The collected wastewater is carried through the pipe system to a central treatment plant, or to watercourses or the sea, where it is discharged.

Uncontional sewer systems do without collector mains in streets. The wastewater generated in a neighbourhood or settlement is collected and transported in smaller and more shallowly laid pipes to small decentralised treatment plants or to larger sewer mains outside the area.

The most important types of unconventional sewer systems are:

Condominial sewer systems: In condominial systems, wastewater pipes with small diameters (100-150 mm) are laid with small gradients relatively close to the surface. In contrast to conventional systems, there are no collector mains. Instead, sewage pipes are laid house to house (across the private plots). Connection distances are kept as short as possible because a large number of households discharge into the same pipe. For maintenance, small inspection chambers are installed instead of large manholes.

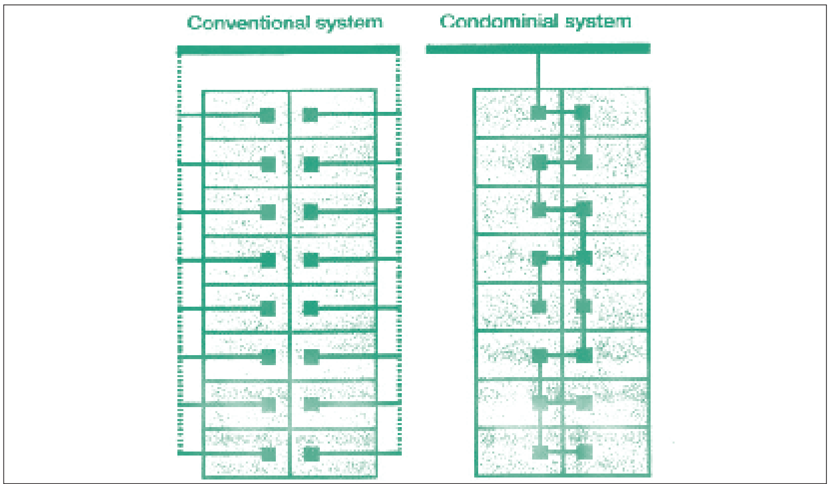
Simplified sewer systems operate on the principle of conventional waterborne sewerage, but for smaller volumes of wastewater and with pipes of small diameter laid close to the surface. They are designed in a way that all household wastewater is conducted to larger mains directly, i.e. without any intermediate interceptor tanks for separating out solid components.

Settled sewer systems are based on separating solid components from wastewater. They are particularly appropriate where septic tanks have already been established, but where the amount of wastewater exceeds the absorption capacity of the soil. Sewage from one or more households is first collected in an interceptor tank (a one-chamber pit), where solid components are separated out through sedimentation. The wastewater is then discharged from the pit into small diameter pipes (so-called small bore sewers).

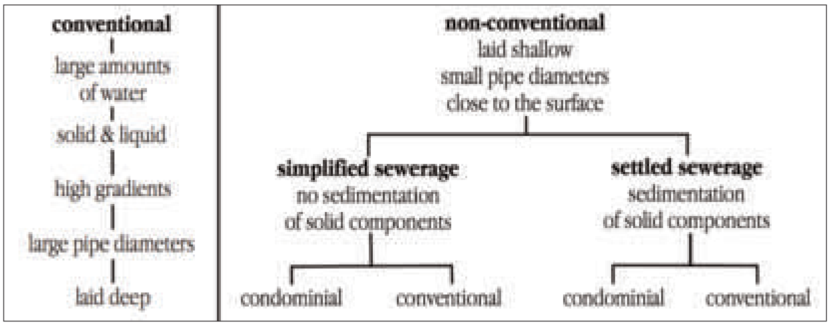
Wastewater Disposal

Sewers can either be laid as a condominial system inside housing blocks, or outside of them, beneath the sidewalks or streets.

/106/



Type	water consumption	pipe diameters	solid components	gradient
conventional systems	high	large	exist	high
unconventional systems				
• simplified sewer systems	low	small	exist	high
• settled sewer systems	low	small	separated	not necessary
• small-bore sewer systems	low	small	separated	low
• condominial sewer systems	moderate	small	possible	low



Dimensioning

Conventional, simplified and settled sewer systems all need a certain amount of water to move the wastewater through the pipes. Therefore a water connection and a flush toilet is usually required. To ensure the proper transport of faeces and sufficient self-cleaning, pipes will require a gradient of about 1:120, and a flow velocity of at least 0.5 m/s.

In settled sewer systems, wastewater free of solid components can move with a lower flow velocity (ca. 0.3 m/s, equivalent to a gradient of 1:220). Since only liquids are being conducted, pipes can, in certain cases, even be laid uphill (i.e. with negative gradients), so long as the final discharge outlet is lower than the lowest inlet (on the principle that flowing water in an interconnected system will fall to the lowest point). Settled sewer systems consist of the following components:

- A house connection to the inlet of the interceptor tank, from which all household wastewater (excluding rainwater) is discharged into the sewage system.
- An interceptor tank, an underground waterproof tank with an inlet and outlet, which should have the capacity to contain the effluent generated over 12 to 24 hours to allow for the sedimentation of its solid components. Generally, such tanks are designed as one-chamber pits
- Small sewer pipes made of plastics or ceramics, laid underground.

In extremely flat areas, it may also be necessary to install pumping stations.

Wastewater Disposal

Off-Site-Systems: Conventional And Unconventional Sewer Systems

The required pipe diameters (as a general rule, 100 mm or 150 mm are needed for simplified and settled sewer systems) are determined by the wastewater volume, which in turn depends on the number of household inlets and on the connected households' living standards. For house connections, pipes with diameters of 75 mm would be sufficient in most cases. The necessary underground pipe depth and earth cover is defined by the pipe material used and by the expected weight loading (e.g. the weight of vehicles when pipes are laid in streets or roads). For small bore pipes normally used in simplified and settled sewer systems, a cover of 50 cm will in most cases be sufficient.

Operations

In spite of small diameters and low gradients, simplified sewer systems can conduct large volumes of wastewater. System blockages occur only rarely. Even in the upper parts of a network, where discharges usually tend to bunch together, wastewater (including solid components) flows will be sufficient, as the sequence of flow-sedimentation-flow is more efficient in small pipes.

Wastewater from simplified sewer systems need subsequent anaerobic treatment. This also applies to settled sewer systems, although partial anaerobic cleaning already takes place in the interceptor tanks.

The collection of wastewater free of solid components in settled sewer systems has four major advantages:

- **Reduced water consumption:** In contrast to conventional systems, sewer pipes need not be dimensioned to carry large amounts of solid material, and therefore need less water for flushing. Settled sewer systems are thus particularly appropriate for discharging small amounts of household wastewater (as is the case in many urban poor settlements).
- **Lower pipe laying costs:** Due to the prior separation and sedimentation of solids, pipes can be laid with low gradients and can better follow the ground contours and topography of a settlement.
- **Lower material costs:** Variations in discharge flows are easier to handle: interceptor tanks even-out temporary high discharge volumes, so pipes can have lower technical standards and are cheaper than those in other systems.
- **Reduced need for treatment:** Some treatment stages, such as screening, removal of sludge or fermentation in an anaerobic basin, are not necessary as these processes already take place inside interceptor tanks.

Consideration should be given to incorporating inspection chambers in settled sewer systems to facilitate maintenance and cleaning.

Limitations and Restrictions

In condominial sewer systems, large parts of the network run through private property. Municipal or other operators will therefore have to agree to take on the responsibility for operating and maintaining sewers on private land in housing areas, in particular for repair works and the removal of possible blockages.

If the operator is not willing to assume this function, self-help and the participation of users will be necessary to maintain the system. As wastewater is discharged to sewers in sequence, a lack of maintenance in just one household (resulting, for example, in a blockage) can affect a whole block of buildings or the entire settlement network.

The main disadvantage of settled sewer systems is the need to regularly empty and dispose of the sludge in the interceptor tanks.

Suitability for Self-help

A high level of user participation will be necessary, at least during construction, but also, where possible, in subsequent operations and maintenance. As most pipes in a condominial sewer systems go across private property, the support and participation of each individual household will be essential.

In general, the success and efficiency of these kinds of unconventional sewer systems largely depends on the collaborative efforts of operators (municipal or private), local community associations or political bodies, and individual households.

Wastewater Disposal

Karachi, Pakistan

Orangi Pilot Project

In Orangi, the largest informal settlement in the city of Karachi, sewage was discharged into open canals causing serious health hazards to the residents.

In a participatory approach, the NGO Orangi Pilot Project Research and Training Institute (OPP-RTI) planned a new sewage system for the whole settlement in close cooperation with residents, represented by lane managers, and the municipal administration. Between 1981 and 2000 approximately 90% of the ca. 104.000 households were connected to the new sewer system.

The settlement was connected to external sewer mains using settled sewers and simplified sewers laid shallowly in streets and lanes. The residents paid for house connections and pipes to the sewer mains, which were extended and refurbished with municipality financing.

Through mobilisation, training and advisory assistance, OPP-RTI enabled resident groups, each from about 30-40 households, to execute the necessary works in their neighbourhood (lane). The self-help approach reduced construction costs significantly. Users' financial contributions were facilitated by a previous savings plan combined with a small-scale loan programme.

▶ *More details on the Orangi Pilot Project can be found in Volume 1, “Basic Concepts”, of this publication series.*

The system will only function with the active support of all stakeholders. In this context, local self-help groups will play an important role in raising the awareness and motivation of residents, and in coordinating the cooperation of all those involved.

Assessment of Costs

Compared to conventional systems, condominial sewer systems will be considerably less expensive chiefly due to the use of small bore pipes and shallow pipe trenches. Using small inspection chambers instead of large manholes also saves costs. The construction costs of settled sewer systems largely depend on whether the households to be connected already have septic tanks.

As a rule, simplified sewer systems will be 60-80 % less expensive than conventional systems, while settled sewer systems will be 30-50 % cheaper. However, actual costs may vary considerably according to local conditions (topography, soil, etc.).

Main Features

According to the type of sewer system: shallow laying of pipes with low gradients; prior separation of solid components; small pipe diameters; pipes laid on private plots

Application

Cost efficient and water saving alternatives to conventional sewerage; appropriate for urban poor settlements

Costs

Because of the previous features, construction and operation costs can be significantly reduced (to about 30-80% of conventional systems)

Operations

Can be constructed and operated through community self-help

Interfaces

In most cases, wastewater discharges into municipal sewer systems or to small decentralised treatment plants

Advantages

Relatively low costs due to simple sewer pipe-work

Disadvantages

High level of organisation and participation of residents required when systems have to be operated and maintained through self-help

To be Considered

Regular emptying of interceptor tanks in settled sewer systems

3.5 Wastewater

Wastewater Treatment and Purification

Decentralised Wastewater Treatment Plants at Settlement Level

Application

Small decentralised wastewater treatment plants at settlement level can be a viable disposal option where no central treatment facilities exist, or where a connection to central treatment is too expensive and technically difficult.

Decentralised plants have been used for many years, mainly in the context of pilot projects, for the treatment of wastewater from smaller urban or rural settlements, predominantly in industrialised countries.

In developing countries, such plants are mainly used by commercial facilities, such as factories, slaughterhouses or paper mills. In some cases, the wastewater of large hospitals is also treated decentrally.

Small decentralised installations can also be appropriate in principle for urban areas in developing countries that have no connections to municipal sewage systems. For urban poor settlements, they can be a technically simple and cost efficient alternative for wastewater treatment when there is sufficient space near to the settlement.

Technical Solutions

In decentralised wastewater treatment plants in settlements, wastewater from one or more settlement is collected and treated in a number of stages. Treatment is usually done in various basins or ponds:

- anaerobic basins (separation of solid components, anaerobic fermentation);
- facultative basins (sedimentation of residual solids, aerobic decomposition);
- oxidation basins (aerobic decomposition, also often in the form of fish ponds);
- plant (i.e. vegetation) treatment basin (optional).

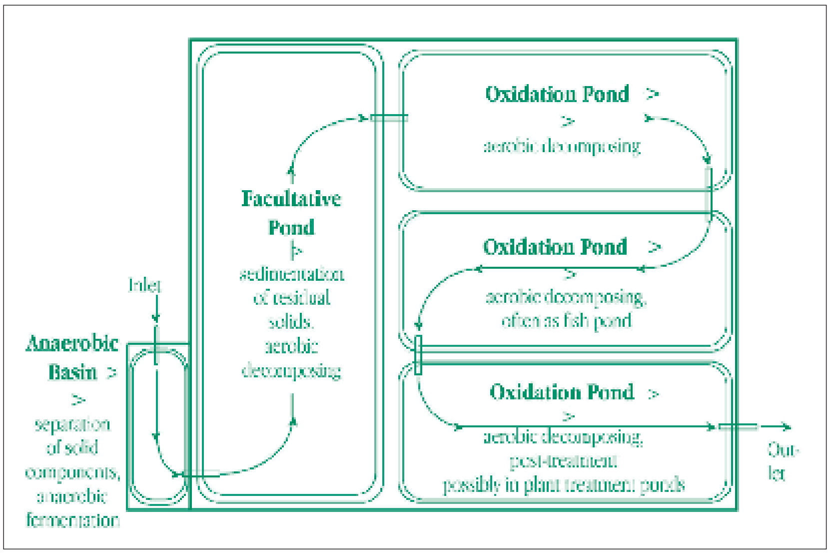
This type of wastewater treatment does not involve mechanical equipment. In larger plants, revolving plates, spirals or injectors are used to accelerate aerobic decomposition *.

For small decentralised plants, traditional treatment in three stages, using three basins, will usually be sufficient. If wastewater is collected in a settled sewer system, the anaerobic basin will not be necessary because separation of solid components and anaerobic fermentation has already taken place in septic tanks or interceptor tanks.

In settlements at the urban fringe or in peri-urban settlements with sufficient space, oxidation basins can be designed as fish ponds, or (instead of oxidation basins) as plant treatment lagoons, with or without infiltration.

* The most modern wastewater treatment techniques involve numerous other more complex and technically challenging procedures. As they would not be applicable or relevant in the context of urban poor settlements, they are therefore beyond the scope of this publication.

Schematic sketch of a decentralised treatment plant with different ponds and treatment stages /107/



Wastewater Treatment and Purification

Dimensioning

A decentralised treatment plant and its different basins will have to designed and dimensioned according to the following parameters:

- the volume of wastewater to be treated;
- the amount of solid components, BOD_5 and COD in the wastewater;
- the average ambient temperature;
- the oxygen supply (to anaerobic/aerobic basins).

As little data based on practical experience is available it will usually be necessary to use empirical approaches for the design and dimensioning of basins (e.g. the expected quality of wastewater after treatment).

Anaerobic basin: Due the anaerobic processes inside the basin, the volume of wastewater will be the major factor.

Facultative basin: The basin's surface area will be important for aerobic processes.

Oxidation basin: The main design criterion is usually to ensure the decomposition of faecal coliforms.

Treatment basins usually have a rectangular form with a length to width of 2 or 3:1. To avoid potential erosion from effluent washing up against the basins' rims, these should be slanted at an angle of about 30°.The bottom should be waterproof, which can be achieved by using a layer of natural clay or a suitable plastic foil. According to EU environmental directives, effluent from plant treatment ponds with a treatment capacity of >8m^3/d will have to comply with the following minimum standards:

BOD_5 <40 mg/l; COD<150mg/l

In most developing countries, such environmental standards do not exist. Even where they have been introduced, they are rarely controlled or monitored.

▶ *Further design details and parameters can be found in specialised technical literature.*

Operations and Maintenance

Organic substances (BOD_5) in anaerobic basins should not exceed 400 g/m^3 in order to avoid major smell nuisances. The pH-value should not be acidic and, if necessary, be regulated to a value of 7-8 by adding lime water. Sludge should be removed when it has reached half the total depth of the basin.

Sludge should be emptied from facultative basins when it has reached 2/3 of their total depth. In facultative basins fed from an anaerobic basin or a settled sewer system, sedimentation of solid components will normally be very limited.

Processing time is 5-10 days in oxidation ponds, which are usually arranged as 2-3 basins in a row. After treatment, the number of faecal coliforms should have been reduced to <30 pro 100 ml.

Results of a three-stage treatment

Sample	treatment time (days)	BOD_5 (mg/l)	suspended solid components (mg/l)	faecal coliforms (no)	intestinal nematode eggs (no/l)
Raw wastewater	-	240	305	4.6×10^7	804
Wastewater quality:					
• stabilisation basin	6.8	63	56	2.9×10^6	29
• facultative basin	5.5	45	74	3.2×10^5	1
• oxidation basin 1	5.5	25	61	2.4×10^4	0
• oxidation basin 2	5.5	19	43	450	0
• oxidation basin 3	5.8	17	45	30	0

Wastewater Treatment and Purification

Decentralised Wastewater Treatment Plants at Settlement Level

Limitations and Restrictions

The main limitation of decentralised treatment plants in urban poor settlements will usually be the scarcity of space, particularly when a large number of ponds or basins are necessary.

More compact, less space consuming alternatives, such as biodigesters or fermentation towers, are considerably more expensive. They cannot therefore be used in urban poor settlements without major financial subsidies.

To achieve sufficient treatment and purification effects, some basic operational parameters (wastewater volume, treatment time, ventilation and oxygen supply) will have to be carefully considered. This requires skilled personnel, and disciplined operations and maintenance. The operating staff will also have to consider seasonal climatic conditions (heat, drought, heavy rainfall, frost).

Suitability for Self-help

Decentralised wastewater treatment plants are complex installations that cannot be operated by individual households or small self-help groups.

If public sector or municipal institutions, or private enterprises are not willing or interested in taking on the operations of such plants, they could possibly be carried out by suitably stable community organisations that are sufficiently capable and willing to acquire the necessary skills. The financing of operating costs will, in any case, have to be secured by user fees and other contributions from the community.

Obregon, Mexico

Combined Wastewater Treatment: Sunwater Wastewater Treatment Project

The private enterprise Sunwater Systems Inc. of San Diego, California, has embarked on a joint venture with other San Diego firms and a Mexican partner to construct and operate a wastewater treatment plant, based on the “Sunwater System”, for 300.000 inhabitants in the city of Obregon, Mexico.

Wastewater is treated as a “living stream” in a sequence of ponds, lagoons and canals, in which sunlight and fast growing organisms are used as catalysts. The system is designed to specific local conditions and comprises a series of “aquacells”. Each cell contains various living organisms that ferment and biologically decompose wastewater in different stages.

Wastewater flows through the “Sunwater System” by gravity, and various types and combinations of bacteriae, algae and water plants raise its level of purity at each stage. Wastewater can can be processed to different qualities and standards by altering the number of aquacells and adjusting the processing time, and can almost reach the quality of potable water, if required.

In more detail, the Sunwater System consists of the following components:

- covered anaerobic ponds or tanks;
- a two-stage ventilated facultative lagoon;
- a high-rate algae system;
- treatment by duckweed and the biomass of other water plants;
- a system of fish ponds using biomass from algae, duckweed and other plants as fish feed;
- a system to clean fish for marketing;
- cultivated marshland for the infiltration of treated wastewater.

Wastewater Treatment and Purification

Assessment of Costs

The necessary investment costs for setting up a non-mechanised treatment plant will include the purchase or long-term lease of land, the labour costs for constructing the ponds and the costs of materials (pipes, foils, etc.)

Operating costs are normally for regular maintenance and to the removal of sludge at regular intervals.

It will generally be useful to check whether several decentralised plants are more cost-efficient than just one larger installation.

A particularly cost-efficient option can be when a settled sewer system feeds into a biological treatment plant, which uses soil infiltration.

Main Features

Treatment and purification of urban wastewater before discharge into surface waters; phased treatment process consisting of separation of solid components, anaerobic fermentation and aerobic decomposition

Application

For whole settlements; depending on design and the availability of space, also applicable in urban poor settlements

Costs

High, due to substantial investment and operating costs

Operations

Generally by municipal or private operators; in exceptional cases, operations by stable community organisations

Interfaces

Discharging of pre-treated wastewater into a city-wide sewerage system possible

Advantages

Protection of surface waters

Disadvantages

High investment and operating cost; high level of organisation required; large space requirement

To be Considered

Regular control and monitoring of effluent quality facilitates efficient operations and protects against unforeseen discharges of under-purified effluents in surface waters

WASTEWATER TREATMENT AND PURIFICATION

BIOLOGICAL TREATMENT PLANTS

Application

Biological treatment plants can be applied for various purposes. They can be used to treat both household and commercial wastewater. Even industrial wastewater and effluent from landfill sites can be treated with this technology.

Biological treatment is used to purify wastewater from one-family houses, housing estates and even whole cities. In the past, biological treatment was mainly applied in industrialised countries. Currently, it is being increasingly used in countries of the South.

In urban poor settlements, biological wastewater treatment is still an exception. However, due to its flexibility and relatively modest operational and maintenance requirements, it can be a viable alternative to other forms of wastewater treatment.

The versatility of biological treatment allows its application even in extreme climates: it can be used in deserts, in tropical areas, and also in highlands or mountainous areas with extreme frost. In addition, it is suitable for the treatment of both lightly and highly contaminated wastewater, and is tolerant to the discharge of toxic substances and physical impacts or shocks (e.g. earth tremors).

The operations of biological treatment plants do not require highly skilled personnel, or machinery, equipment or energy.

A broad range of technical solutions is available for a wide variety of possible uses. The basic prerequisites are for appropriately selected filtering materials and plants adjusted to the specific climatic and other environmental conditions of their location. In addition, a sufficient supply of water and nutrients will be necessary, as will pre-treatment to separate and sediment solid wastewater components.

Biological treatment plant for a housing estate (200 PE*) in Berlin (International Building Exhibition Block 6); the effluent is used for flushing toilets /108/

WASTEWATER TREATMENT AND PURIFICATION

Technical Solutions

The most important form of biological treatment plants are installations through which wastewater flows in vertical and horizontal streams. The water flows through a 0.3 m - 1.0 m thick body of filtering substances that can consist of different materials planted with macrophytes (e.g. Phragmites Australis / reed).

The organic wastewater components are decomposed by both anaerobic and aerobic micro organisms, which are supplied with oxygen and other metabolic plant products through the plant roots. For pre-treatment in larger systems, a multichamber pit, such as an "Emscher Well" (or Imhoff tank) can be used. Treatment plants can be constructed with just one basin or a number of basins in a row.

The basins should be sealed with concrete, foil or clay. The inflowing wastewater should be distributed evenly at the inlet(s) in order to best use the filter volume and to avoid localised short-circuit currents.

The size of the plant determines the quality of treated water it produces. The technology is capable of purifying household wastewater to the standard of the EU directive for washing water, recycled irrigation water or toilet flushing water. In the body of the filtering material, all pathogenic germs (viruses, bacteria and worm eggs) are permanently eliminated - a level of efficiency that no conventional treatment technology, with the exception of membrane (or fine mesh) technology, can achieve.

Dimensioning

In moderate climates, minimum requirements for the discharge of household wastewater with a specific surface of 5 m2/PE* and a maximum hydraulic load of 40 l/m^2d can even be met in winter. In warmer climates, the maximum load can be significantly higher (in India, horizontally layered installations are designed on the basis of 1-2 m^2/PE).

In installations with horizontal flows, a water gradient of about 1 % should be considered.

Filter materials should have a permeability of k_f = 10-4 m/s. Filtering material and layering should be selected according to the type of wastewater to be treated.

* PE - population equivalent: a unit of measurement referring to a contaminated wastewater load of 60 mg/l BOD_5 per person per day

Biological treatment plant with a pre-treatment "Emscher well" and sludge separation for 60 PE in Grace, Auroville, Tamil Nadu in India; the effluent is used for irrigation purposes /109/

Wastewater Treatment and Purification

Biological Treatment Plants

Operations

Installations based on vertical flows have to be operated in a discontinuous way; if colmation* occurs, operations will have to be suspended for some time. Treatment ponds with horizontal flows can operate continuously and can be more efficient.

In temperate climates, plants have to be removed once a year, in spring after flowering. In tropical climates, this needs to be done twice a year, again after flowering. In addition to the regular maintenance of pre-treatment installations, all the wastewater inlets, and treated water outlets should be checked and cleaned, as necessary, from time to time.

Colmation occurs only when pre-treatment does not function properly, or when inappropriate filtering materials have been selected.

The ponds should not be built in shady locations and should always be supplied with sufficient water. Macrophytes have a high transpiration rate, a fact that will have to be considered, especially in hot and dry climates.

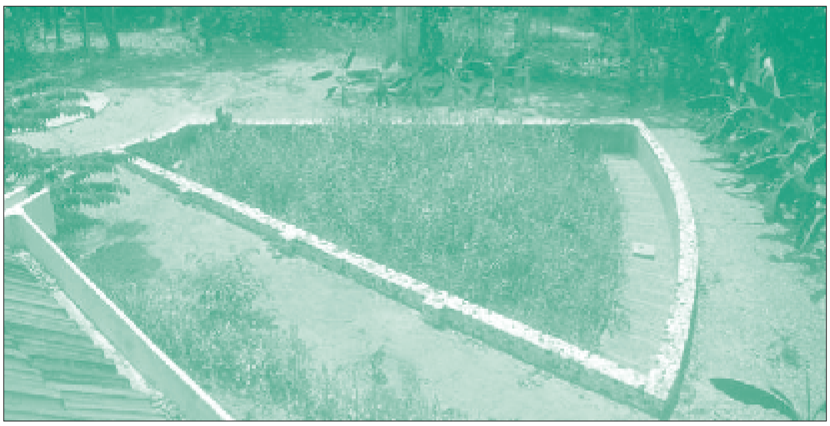
Limitations and Restrictions

Horizontally layered installations, in which wastewater is kept under the filter material's surface, operate free from insects and bad smells. They can therefore be established close to residential buildings. Their applicability basically depends on the availability of space and appropriate filter materials. In steeply sloping terrain, terracing may be necessary to provide the needed space. Construction costs will thus be higher and may limit their application in such cases.

When the amount of wastewater falls off seasonally, supplying the plants with water during downtime will be a determining factor in operations.

* Colmation - Clogging or blocking of the upper layers of filter material resulting in blockages and a slowdown of the purification processes and a reduction of its permeability.

Biological treatment plant in Grace, Auroville, Tamil Nadu, India: Filter basin /110/



Auroville / India

Wastewater Recycling

The city of Auroville is a new town, established 200 km South of Madras. In the first phase of development, reforestation and measures to prevent soil erosion were implemented. As urban infrastructure was still missing, the new settlements needed autonomous water supplies and sanitation. To overcome water shortages during dry seasons, wells were drilled, with depths of up to 100 m, which were soon threatened with salinisation. Protecting the main aquifer, rainwater harvesting and wastewater recycling thus became important priorities for securing sustainable water supply.

As early as 1994, a decentralised treatment plant for 85 PE, consisting of an “Emscher well” and a biological treatment system, was planned and constructed for the settlement of Grace. After fermentation, sludge is mixed and composted with organic horticultural waste and used for landscaping projects. The wastewater treated is largely free of toxic components, and is either used for irrigation directly, or is infiltrated into the soil through “French drains” (*rigoles*).

Based on the same principle, four smaller treatment plants were built later in Auroville. Pre-treatment is done in 3-chamber fermentation pits, followed by biological treatment in basins with a specific surface area of 2 m2/PE. They were designed to be extendable in line with future settlement growth, with, in the first phase, 12 - 35 PE.

Wastewater Treatment and Purification

Suitability for Self-help

Individuals and local craftsmen can use the simple technology. Technical assistance may be necessary in selecting appropriate locations and soils. Smaller plants can be designed, constructed, coordinated and operated through self-help. Local craftsmen, supported by substantial community self-help, can even construct larger installations.

Biological treatment plants for whole urban districts are communal facilities but cannot be operated by individuals or self-help groups.

If public sector or municipal institutions, or private enterprises are not willing or interested in taking on operations, they could possibly be done by suitably stable community organisations that are sufficiently capable and willing to acquire the necessary skills. The financing of operating costs will, in any case, have to be secured by user fees and other contributions from the community.

Assessment of Costs

In Germany, construction costs for biological treatment plants, depending on their size, range from EUR 35 to EUR 200 /m^2. In India, they cost USD 30-130 US/m^2. The main cost factors are the availability of appropriate filter material (e.g. sand or gravel); the costs of sealing material, plants and other construction items are less significant.

Operation costs are very low, as such installations need very little energy and limited maintenance.

Main Features

Environment-friendly and biological treatment of household, urban or industrial wastewater, with subsequent soil infiltration or discharge into surface waters. Multi-staged process comprising: pre-treatment to separate and ferment solid components; absorption and adsorption of non-depositable wastewater components in planted soil filters; almost complete elimination of pathogenic germs

Application

For individual housing areas, whole urban districts, urban poor settlement, commercial areas and factories

Operations

Construction and operations by individuals, small-scale contractors or community self-help possible; financing through small-scale loan programmes possible

Interfaces

Emptying and disposal of sludge residues from pre-treatment pits by community or private disposal companies

Advantages

Simple technology, low maintenance requirements, free from smell nuisances, elimination of pathogenic germs, high levels of purification, versatility and flexibility; few restrictions with regard to the type of wastewater to be treated

Disadvantages

Relatively high investment costs, large space requirements, minimum water supply necessary, high evaporation levels

To be Considered

Needs locations exposed to maximum sunshine, requires a high quality of pre-treatment and sealing of plants

4 RAINWATER

Problems and Challenges

Problems

Rainwater can pose problems when there is too much or too little of it. This is particularly true in urban poor settlements, which are often in climatically or topographically hazardous locations, e.g. on steep slopes threatened by landslides, on loamy soil, in marshland with high groundwater levels, or in arid or desert areas with inadequate water supply.

Too much rainwater

Rainwater can be a particular problem when it occurs seasonally in heavy downpours. If this is aggravated by adverse topographical conditions, such as steep slopes, low soil absorption capacities or high groundwater levels, it may have the following hazardous impacts:

- erosion of roads, public open spaces or cultivable land;
- undermining of roads, bank reinforcements, bridges or houses;
- landslides or mudslides;
- local or extensive area flooding;
- overflowing latrines, septic tanks and treatment ponds;
- increase of water-breeding insects;
- increase of infections caused by polluted water.

Too little rainwater

However, rainwater need not be a hazard: in dry and arid climates, it can be a highly valuable asset. In particular, in peri-urban areas, which often suffer from inadequate water supplies, rainwater can be used to partially cover household water demand. When rainwater is collected before it can be contaminated by contact with the ground, it can be reasonably clean. With some pre-treatment, it can be used for different purposes:

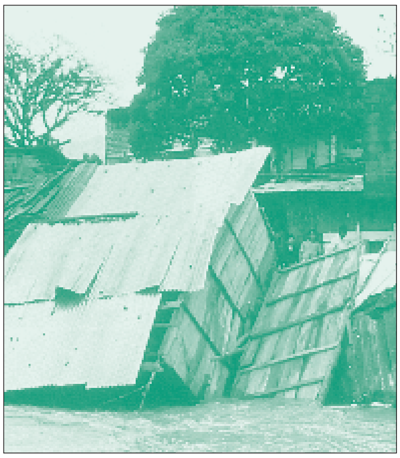
- as potable water (when boiled for sterilisation);
- for washing, cleaning, dishwashing and laundry;
- for irrigation in horticulture and agriculture.

Hazardous slopes and soil erosion

Due to hazardous locations of many urban poor settlements, problems are not only caused by too much or too little rainwater. Often, geological conditions can pose serious risks of landslides and erosion:

- steep or overhanging cliffs;
- rifts or cracks in the ground, particularly in earthquake-prone regions;
- loose rock or stone.

Danger of flooding /111/



Landslide at a site adjacent to a steep slope /112/

Vulnerable housing beneath overhanging cliffs /113/

4.1 Rainwater
Problems and Challenges

Potentials

The main considerations for avoiding hazards from too much rainwater are:

- controlled drainage of excess water;
- stabilisation of soil, buildings and slopes against undermining water.

Where rainwater is scarce, possible measures to conserve it can include:

- using rainwater from roofs and courtyard surfaces;
- provision of rainwater collection and storage containers.

Precautions can be taken to deal with the potential problems of both excesses and scarcities of rainwater at individual household level, or by community initiatives at neighbourhood level, involving participation and self-help.

Possible Approaches

In the case of excessive rainwater, controlled drainage reduces soil erosion and avoids the occurrence of stagnating water. Rainwater can be drained in open or covered culverts. In addition, streets and roads can be designed in a way that drains off water (e.g. in form of so-called trough roads. Measures, such as terracing, erosion protection trenches or ditches, slope stabilisation and planting trees and shrubs can also reduce erosion risks. Well-targeted residents' self-help initiatives can be promoted to implement rainwater risk reduction measures.

Rainwater harvesting involves the selection and introduction of suitable approaches to collecting, storing and cleaning rainwater, if possible in combination with greywater recycling. Traditionally, rainwater is harvested from roofs of buildings, but it can also be collected from impermeable ground surfaces (paved public spaces, rocky soil, arroyos or wadis, etc.). Collected rainwater can be stored above ground and underground. Depending on its intended use, suitable filters may be needed.

Many rainwater harvesting techniques are well suited for self-help application. When accompanied by awareness campaigns and training in water saving methods, rainwater harvesting can make a significant contribution to satisfying the water needs of residents of urban poor settlements.

Main elements of rainwater management:

- **controlled drainage of rainwater from buildings and other installations;**
- **construction and maintenance of drainage canals;**
- **road and street design enables temporary excess rainwater to drain off;**
- **connection of drains and culverts at settlement level to citywide or regional drainage systems**

Main elements of rainwater harvesting:

- **using available roofs and other suitable surfaces (e.g. paved courtyards) for rainwater collection ;**
- **construction of rainwater conduits or pipes (possibly with intermediate interceptor tanks for sedimentation of solids) to water storage tanks or containers;**
- **construction or installation of appropriate rainwater storage containers above or beneath the ground**

Threat from loose rocks

/114/

4.2 Rainwater

Drainage Systems

Open and Covered Culverts • Trough Roads • Rainwater Retention Ponds

Application

There is a broad range of well-proven solutions for rainwater and other surface water drainage in urban poor settlements.

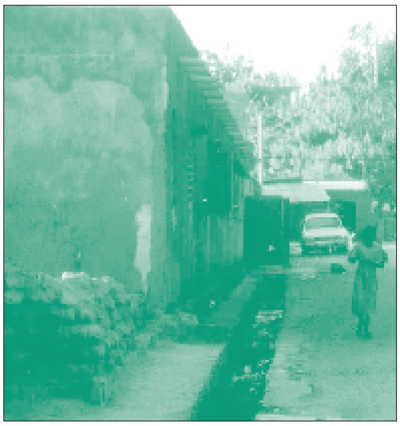
In simple, but effective ways, these solutions provide efficient drainage for rainwater from often sudden heavy tropical and sub-tropical downpours, and hence protect against potentially major damage.

Effective rainwater drainage is essential to avoid uncontrolled water discharges, flooding and erosion, particularly in urban settlements, where large parts of the ground surface are sealed by buildings, pavements or asphalting.

Functioning drainage will also be important in suburban and peri-urban areas with fewer sealed surfaces, for keeping streets and roads passable after heavy rainfalls, and for limiting hygiene problems.

Simple rainwater culvert in Mali

/115/



Technical Solutions

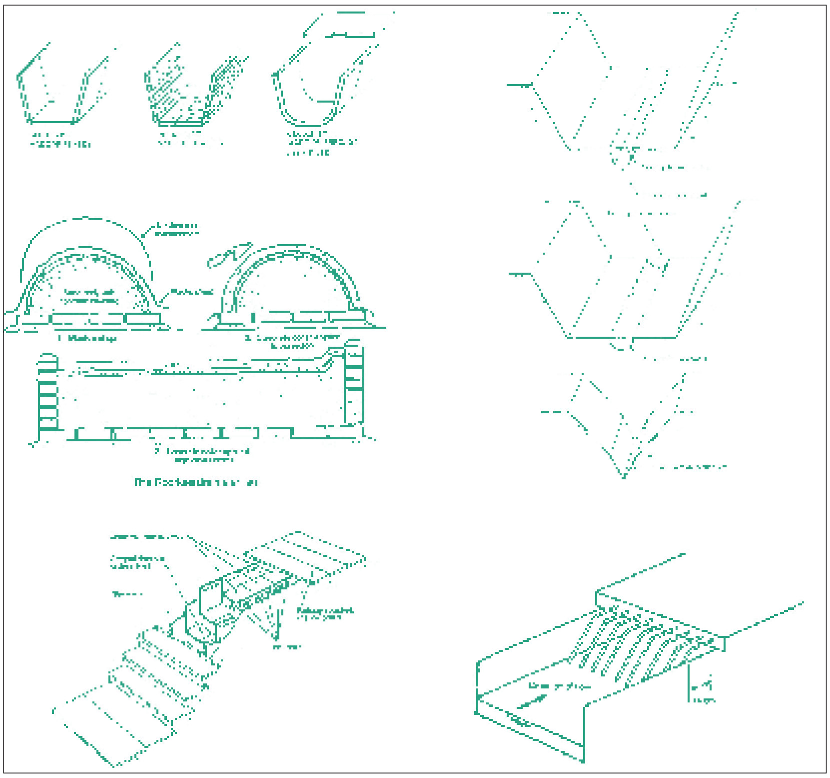
Depending on climatic conditions, amounts of rainwater and soil absorption capacities, different drainage solutions can be applied:

Drainage channels, gutters and culverts can be constructed parallel to streets, or along their middle, or by profiling the street itself. They can also be independent of roads and streets and run through open terrain. There are a large number of technical and engineering options for their design:

- Simple, open or covered channels with different profiles for smaller streets and pathways. These normally discharge into local sewer systems or large rainwater collector mains that carry rainwater from whole urban districts.
- "In channel channels", which enable drainage of different amounts of water according to seasonal variations of rainfall. During dry seasons, such channels can also be used to discharge household greywater.
- Underground pipes and culverts, similar to sewer systems.
- Covered culverts running underneath footpaths and stairways, which are particularly suitable where space is scarce. The cover can be designed to be walked on.

Different types of drainage channels

/116



The drains can be cast from concrete, constructed from bricks or natural stone, or assembled from ceramic (or sometimes plastic) half-pipes.

Trough roads are designed to serve as drainage canals for heavy rainfalls. Either the whole street (edged by high curbs) or parts of it (with built-in drainage profiles) can be used. With extremely heavy rainfall, high flow velocities can occur. To avoid erosion, trough roads will have to be made with solid surfaces of asphalt, concrete or stone.

Rainwater retention ponds are an alternative to the big drains that would otherwise be needed to take in large amounts of rainwater. To do this, ponds (sometimes in the form of infiltration basins with permeable bottoms) are built at appropriate locations. The rest of the rainwater drainage system can therefore be smaller (and less expensive), without the risk of flooding that small drains can entail. This solution can be especially appropriate for densely built-up settlements, where sufficient space to install such ponds is available in areas above the settlement.

Depending on their type and usage (i.e. with or without infiltration to the soil), retention ponds are constructed either with waterproof (concrete or brickwork) materials, or permeable (gravel) bottoms.

Dimensioning

The following factors will determine the design and dimensioning of rainwater and surface water drainage systems:

- the maximum amount of rainfall per time interval;
- the absorption capacity of soils;
- the type of drain channel, culvert or pipe (its material, bore smoothness, diameter, profile and form);
- the gradient and the resulting flow velocity.

As a general rule, rainwater drainage and retention systems should not be designed for the maximum amount of possible rainfall, since, in most cases, this would lead to over-dimensioning. For drain profiles and diameters in systems with retention ponds, 3-6 times the average water volume to be drained during dry seasons is generally used as a basis for dimensioning.

Often, sewage canals are also used for rainwater drainage. They are frequently designed for the maximum expected amount of rainwater, and so they tend to fall dry over large parts of the year. The average water and sewage volumes to be carried can be well below the capacities of the channels, and therefore insufficient flow velocities are generated. As a consequence, deposits and sediment will build up over time, and this is often aggravated by residents using the channels for refuse disposal. When rainfalls begin, the sediment and garbage are washed through, but can block lower parts of the system or treatment plants, or can pollute the rivers or lakes into which the rainwater discharges.

Improved types of channels have been developed especially to improve the functioning of these combined wastewater and rainwater systems. By incorporating smaller "in channel channels", sufficient flow velocities can be achieved, even for small amounts of water.

Staircase with culverts in Medellín, Colombia /117/

An over-sized drainage canal during the dry season /118/

4.2 Rainwater

Drainage Systems

Open and Covered Culverts • Trough Roads • Rainwater Retention Ponds

Operations

Requirements for operations and maintenance will differ according to the type and construction of the installtions:

Drainage channels, gutters and culverts: To avoid blockages caused by garbage or sand sediments, it will be useful to cover channels with, for example, concrete slabs. In densely built-up areas, covered channels can then also be used as footpaths. The covering slabs should be heavy enough to prevent children moving or lifting them. On the other hand, they should be light enough to be removed without machinery by adults for maintenance, repair or clearing blockages.

To avoid refuse or other debris being washed into the system, all inlets should be covered by a grille. This also facilitates the removal of such material with a rake. Both open and covered channels will have to be cleaned at least once a year. In order to make sure that the system functions properly when rainfalls begin, this should preferably be done before rainy seasons.

In tropical regions, drain trenches can fill up quickly with organic and other material. In settlements at urban fringes or in peri-urban areas, where roads and streets are often unpaved, they can also silt up much faster than in more consolidated inner urban areas. Cleaning intervals will thus have to be much shorter. For hygiene reasons and to limit water-breeding insects, accumulations of stagnating water should be avoided by providing channels with adequate gradients.

Trough roads are primarily for traffic and basically will have to be operated and maintained like other roads. To ensure their drainage capabilities, road surfaces should be kept intact. The disposal of refuse, gravel or soil on them should be avoided, as should the long-term parking of vehicles.

Rainwater retention ponds tend to silt up. Large amounts of sand, tree branches or garbage can accumulate inside the pond, particularly after heavy rainfalls. They will therefore have to be cleaned after every major downpour, in order to maintain their capacities.

Limitations and Restrictions

Because all rainwater drainage and retention installations should not be sized to take maximum amounts of possible rainwater, extremely heavy rainfalls may lead to short-term flooding.

In mixed sewage and rainwater systems, contaminated wastewater can flood adjacent areas during short phases of overload. But as this will usually occur during periods of abundant rainfall, i.e. water supply, the wastewater will be quickly diluted and cleaned by new water: such short-term adverse effects can be acceptable in many cases.

Bulawayo, Zimbabwe

Streets as rainwater drains

In semi-arid south-western Zimbabwe, rainfall occurs only during the rainy seasons, when it can be extremely heavy. In the city of Bulawayo, all streets going downhill are constructed with W shaped profiles. Their highest point is in the middle, and they slope down towards both sides with a large gradient. The street then tilts upwards to its edges.

In heavy downpours, the water flows outwards from the middle to both sides. Water from sidewalks and curbs discharges inwards. Both rainwater streams merge in the right and left low points and then flow downhill. Both the street and the sidewalks thus remain passable even during heavy torrential rains. A particular advantage of this solution is its low cost, since no additional rainwater drainage is needed.

The disadvantages are at inter-sections, where crossing traffic must sometimes go through up to 20 cm deep rainwater streams. The arrange-ment also requires substantial space.

DRAINAGE SYSTEMS

Suitability for Self-help

In most cases, all settlement residents will benefit from improved rainwater drainage, and their living conditions can improve considerably. The construction of such systems does not pose any major technological or financial challenges, and is therefore well suited for community initiatives. If it is well organised at settlement or neighbourhood level, most necessary works can be done through self-help. However, it may be necessary to contract specialised construction firms when there are difficult soil conditions, e.g. rocky subsoil.

Most maintenance and repair work can also be organised and executed through self-help at settlement or neighbourhood level.

Assessment of Costs

Construction costs will largely depend on the type of drainage system selected, and on the kind of material required.

Depending on soil and subsoil conditions, expected rainwater volumes and other local specifics, system components and construction can either be relatively simple or require more sophisticated (and costly) technical solutions.

If construction is done through self-help, the main costs will be for materials.

A small culvert running alongside a profiled street /119/

Main Features
Controlled drainage of surface water by culverts, larger channels or trough roads; possibly complemented by retention ponds

Application
Settlements with sealed ground surfaces and protection against erosion

Costs
Limited construction and material costs, if carried out through community self-help

Operations
By individual self-help on private property only; otherwise through community self-help at settlement or neighbourhood level

Interfaces
Discharge of collected rainwater into municipal systems

Advantages
Controlled drainage prevents major flooding and erosion damage

Disadvantages
Blocking of channels and retention ponds by refuse and sand; regular maintenance and cleaning is indispensable

To be Considered
Because systems should not be sized for the maximum amount of possible rainwater, heavy rainfalls may lead to short-term flooding.

Erosion Protection

Erosion Protection and Slope Stabilisation

Application

Urban poor settlements often develop in disadvantageous locations, such as steep mountainsides, slopes threatened by landslides or flood-prone areas, and so they are often seriously affected by erosion problems.

Preventing and repairing erosion damage is often a major challenge for waste management projects. In many cases, erosion prevention measures complements rainwater drainage, and are indispensable.

Technical Solutions

As a general rule, such measures protect against soil slippage or erosion caused by climatic effects (above all, from water and solar radiation), and help prevent damage to built works (houses, streets and roads, community facilities etc.) from landslides, subsidence, flooding or undermining. The following mainly preventive solutions can be applied in urban poor settlements:

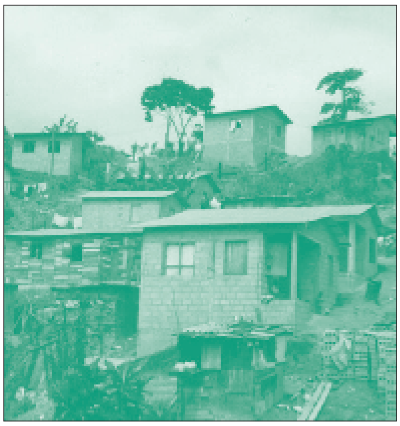
- **Building drainage:** Drainage can protect buildings from being undermined by water. Trenches filled with coarse gravel and with an outlet to the ground, are dug alongside the building's walls. Water spilling off roofs, or accumulating close to the building, is thus effectively carried away. It will be important to prevent drainage trenches becoming clogged with debris over time, reducing drainage efficiency. Inserting a horizontal barrier (e.g. a layer of tar paper) can prevent drainage trenches silting up.

  Often, it will be sufficient to simply pave the ground alongside the building (e.g. with stone or concrete slabs), sloping away from the walls. Water spilling from the roof will be diverted from the base of the walls and thus be prevented from undermining the building.

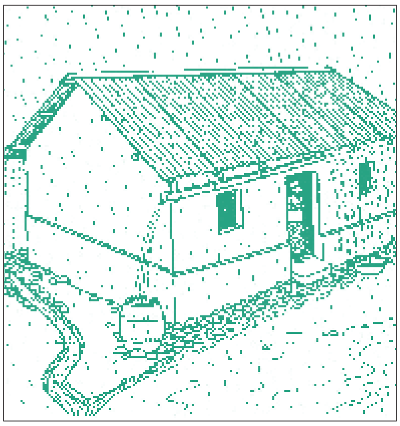
- **Terracing:** Terracing risk-prone slopes is one of the most effective ways to reduce the flow velocities of rainwater and other surface water. For this purpose, low walls are constructed along the contour lines of the terrain and back filled with earth. Where sufficient space is available, terraces can be planted with grass, shrubs and trees to prevent the earth washing away and to further reduce water velocities.

  During the initial stages, when terraces are not yet protected by vegetation, mesh-like wattle, made from twigs and branches, can prevent soil washing away. In densely built-up areas, it may be difficult to build the terracing surfaces flatly enough to prevent landslides.

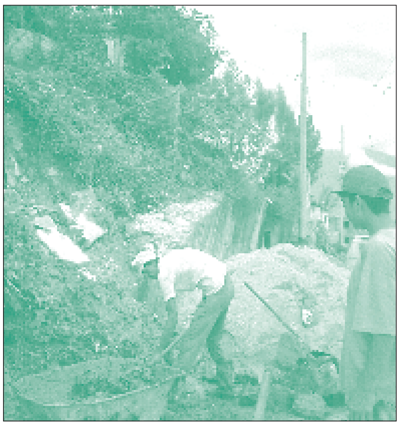
Slopes threatened by erosion in Honduras /120/



Building drainage /121/



Terracing in Medellín, Columbia /122/



Erosion Protection

- **Stabilizing erosion gullies:** Erosion gullies often form in eroding soils. Rainwater flows are confined within them, resulting in high flow velocities. Erosion gullies are thus extended and deepened. When they cannot be completely filled in, small barrages should be built across them to reduce flow velocities and to promote sedimentation. These can be made from wattle, earth or wire packages filled with stones.

- **Retaining walls:** The construction of retaining walls will often be the only viable, but usually very cost-intensive, option for protecting slopes against landslides, particularly in densely built-up areas in mountainous or hilly areas.

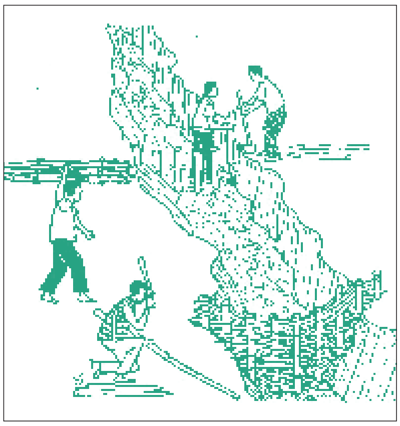
  It will be important to allow for sufficient openings in the walls for the discharge of built-up water and to avoid erosion and undermining.

  Retaining walls can either be made of concrete or bricks or stonework. Building materials, machinery and labour can make retaining walls expensive. However, they may be the only possibility for protection against landslides, particularly in densely populated settlements.

- **Bank reinforcement:** Many urban poor settlements are in flood-prone waterfront areas. They are therefore exposed to high risks from flooding and erosion, particularly during rainy seasons.

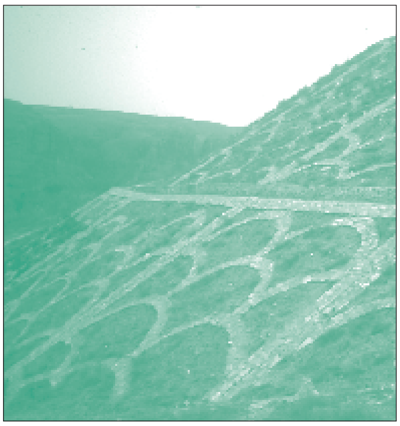
  Water banks can be protected by constructing jetty walls, river dams or weirs (to slow water flows) or by stabilizing or reinforcing the banks themselves. Bank reinforcements mainly prevent soil washing away or the bank being undermined. In many cases, this can be achieved by tree planting. Trees with deep roots that grow in water or marshland or mangroves are usually appropriate. Species should be selected according to region and climate.

Rehabilitation after erosion damage /123/



Retaining walls erected in the context of a slum upgrading project /124/

Slope stabilisation in Inner Mongolia, China /125/



Erosion Protection

Erosion Protection and Slope Stabilisation

Dimensioning

The type and scope of necessary erosion protection measures will depend on the volume and intensity of rainfall, soil conditions and on topographical and geological specifics (slope gradients, rock stratification etc.).

The design of technically more sophisticated solutions (such as slope stabilisation or bank reinforcement) requires special engineering know-how, and in cases, detailed investigations and calculations.

Less complicated small-scale solutions (e.g. building drainage or terracing) can often be based on experience gained from local "trial-and-error" undertakings.

Operations

Erosion protection is an ongoing process, requiring all year round attention. All installations will have to be regularly maintained and looked after. Potential dangers will have to be avoided and improvements should be made continually (e.g. planting of trees, repair works).

Limitations and Restrictions

The success of erosion protection measures in urban poor settlements largely depends on the motivation and initiative of residents and local administrations. Protection measures should not be beyond the technical, financial and spatial resources of both residents and local administrations.

But in settlements affected by erosion problems, the effort needed to implement protection measures will often be too high and, in addition, may not be financially feasible.

Operations and maintenance of erosion protection installations require a high level of organisation and community ownership, which cannot always be guaranteed in urban poor settlements.

Slope stabilisation in Medellın, Columbia
/126/

Medellin, Colombia

Erosion Protection Measures in the Context of an Urban Upgrading Programme (PRIMED)*

In Medellin, the second largest city of Colombia, about 250,000 people, or roughly 14% of the city's total population, live in about 104 informal settlements, so-called *barrios subnormales*, which have developed on the steep slopes of the mountains surrounding the city. Most of these slopes are highly threatened by erosion; heavy rainfalls usually cause landslides and avalanches of falling rocks, endangering the lives and property of residents.

Within the framework of an integrated urban upgrading programme, financially supported by German Financial Assistance (KfW) since the beginning of the 1990s, comprehensive measures were implemented to stabilise eroding slopes. These measures included the paving of streets (either with concrete or asphalt, depending on the load bearing capacities of the ground), the construction of footpaths and stairways (where street building was not possible without implementing expensive slope stabilisation measures), building retaining walls, reforestation measures and regulating small creeks.

With the active participation of residents, numerous smaller stairways and drainage channels were built, and residential areas were made greener by planting trees and shrubs. In order to ensure proper maintenance of the erosion protection structures, comprehensive awareness campaigns and training activities were put into effect.

** Programa Integral de Mejoramiento de Barrios Subnormales en Medellın*

Erosion Protection

Main Features
Well-targeted construction measures or solid structures to slow down water flows in order to prevent soil washing away or being undermined, and to prevent landslides and soil erosion

Application
For topographically disadvantaged locations on steep slopes, river banks, etc.

Costs
Depending on type of construction measures necessary: often low costs for construction, materials and labour; more complex slope stabilisation or bank reinforcement measures can be very expensive

Operations
Individual self-help initiatives possible for smaller measures on private land; larger-scale measures can be undertaken by community groups or associations; more complex and technically challenging measures require specialised construction firms and external financing will be necessary

Interfaces
For larger construction measures, support from municipal or other public institutions will be needed, since collected water will usually have to be discharged into municipal or other public networks

Advantages
Erosion protection measures can, in the main, be implemented by residents when they receive adequate financial support

Disadvantages
Successful measures need a high level of community organisation and ownership, and regular year-round maintenance and care

To be Considered
Recurring necessities:

- All structures must be well-maintained.
- Adverse risks resulting from clearing of trees and shrubs, or from building activities should be avoided.
- Erosion control structures should be improved by planting trees, terracing and drainage

Suitability for Self-help

Most of the measures described here require only limited external resources for their implementation; they are, however, labour-intensive. Given sufficient resident mobilisation and organisation, they are well suited to be undertaken through self-help initiatives. As most of the required work is beyond the scope of individual initiatives, a functioning community, which could organise self-help or neighbourhood groups, will be needed. Imparting technical know-how and raising awareness of the advantages of erosion protection could possibly be another function of such groups.

Residents of urban poor settlements, who are more concerned with securing their livelihood, often give little attention to erosion protection. Therefore the allocation of energy, time and money needed for it is frequently not forthcoming.

Assessment of Costs

As mentioned before, many erosion protection measures can be realised through self-help. However, larger-scale construction measures will often require the acquisition of special building materials. This can possibly be financed by community contributions, small-scale loans or municipal subsidies.

The more risk-prone the location, the more expensive the erosion protection measures will be.

4.4 Rainwater

Rainwater Harvesting

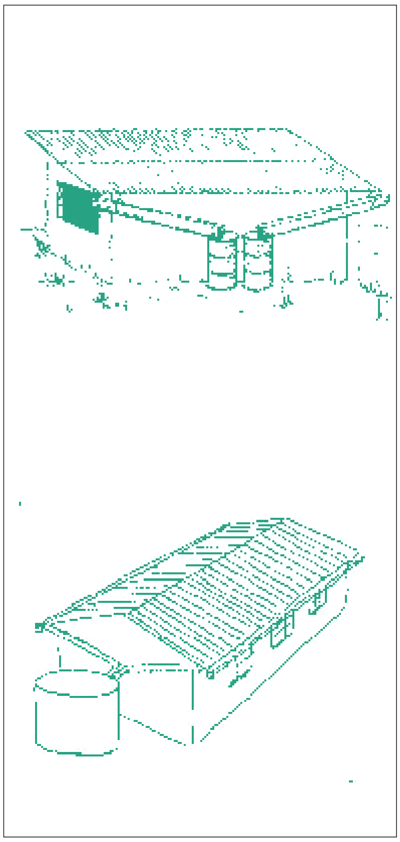
Rainwater Harvesting at Household Level • Storage Containers Above and Below Ground

Application

In many cases, households in urban poor settlements are not connected to centralised (municipal) water supply networks. Residents must therefore get water from faraway wells or public faucets, or buy it at high cost from water tanker trucks or other private providers.

In regions with sufficient rainfall, collecting and storing rainwater can be a simple, relatively cheap way to provide for at least part of a household's water demands (e.g. for washing laundry, toilet flushing, cleaning, irrigation of gardens). Collected water, if it is sufficiently clean, can even be used for drinking when properly boiled.

Harvesting rainwater from roofs /127/



Technical Solutions

Roofs and paved or water resistant ground surfaces (asphalt, concrete, tiles or stone slabs, stamped clay etc.) can be used for **harvesting rainwater** at household level.

Rainwater is commonly harvested from roofs, where water will generally be cleaner. Depending on the shape of the roof, water can be collected and discharged from one or more of its sides.

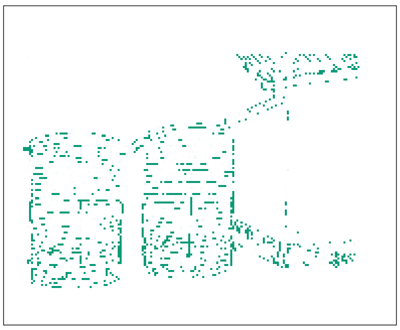
When rainwater is harvested from courtyards or other ground surfaces, it will be necessary to ensure that:

- the collecting surface is impermeable;
- the surface is sufficiently sloped in one direction;
- a collecting pipe or channel is installed at the lower end;
- the collecting pipes or channels have sufficient falls to storage tanks or containers;
- if necessary a sieve or interceptor should be installed for debris and material such as sand.

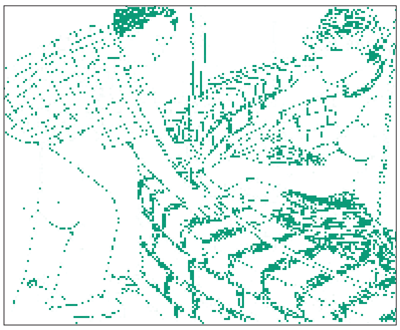
Storage tanks or containers will be needed for **collecting and storing rainwater**. These are normally installed aboveground, but can also be built underground. In some countries, underground rainwater cisterns have been a traditional solution for centuries.

Rainwater storage tanks can be made in many forms and materials, and can range from the inexpensive and simple to the sophisticated and expensive. The simplest are well-cleaned used oil barrels. Common and traditional materials for manufacturing water storage tanks are corrugated iron sheets, reinforced concrete and reinforced brickwork. In industrialised countries, they are injection moulded from plastics or assembled from prefabricated concrete segments.

Rainwater storage in barrels /128/



Brickwork rainwater storage tank /129/



RAINWATER HARVESTING

Dimensioning

Roofs with one or more sloping surfaces are best-suited for rainwater harvesting. As a general rule, eaves gutters should have a minimum gradient of 1% (3% is better).

Flat roofs can also be used for rain-water harvesting when they are built with perimeter upstands and a controlled water outlet, or outlets.

Not all roofing materials are equally suited for rainwater harvesting. Clay tiles, corrugated iron and aluminium sheets are particularly appropriate materials. Grass roofs can also be used, but collecting and discharging of water will be more difficult because of their irregularities.

The selection of construction materials and the sizes of rainwater storage containers or tanks will have to take account of the following determining factors:

- volume, distribution and seasonal variation of annual rainfall;
- duration of dry periods, in particular in years of drought;
- area of available collection surfaces;
- number of persons using the collected water;
- intended use of collected water (for drinking water, laundry and cleaning, washing, irrigation, etc.);
- locally available technical skills for manufacturing water tanks;
- available construction materials;
- necessary investment costs and their affordability;
- life span of tanks;
- maintenance requirements;
- pollution avoidance measures (e.g. for reservoirs used for potential drinking water);
- safety aspects (e.g. for accessible above ground storage tanks).

In arid regions where water is harvestable from only a few rainfalls, storage tanks should be large enough to take in the total annual precipitation.

In tropical or sub-tropical regions where a single heavy downpour produces more water than can be sensibly stored, tanks or container sizes should be determined by households' annual water consumption.

In regions with regular and reliable rainfall, storage capacity can be based on either monthly water demands or monthly precipitation volumes.

Depending on how full they are, substantial water pressure can occur in large storage tanks, and this should be taken into consideration in their fabrication. Above ground tanks should therefore only be designed and built by experienced skilled persons.

Water tanks built of brickwork or concrete will never be totally leak-proof. Their insides will therefore have to be coated with sealant, such as waterproof plastic paint (e.g. swimming pool coating). Tanks aboveground should have an outlet near their lowest point for the removal of sediments from time to time. The outlet for usable water should be about 10-15cm above the lowest level, in order to avoid possible soiling with sludge.

Water pressure is less of a problem in underground water tanks, since the surrounding earth absorbs most of its force: they will therefore need less reinforcement. A sufficiently large manhole will be required for cleaning and inspection. Water is usually taken out with a hand operated or motorised pump.

Operations

In order to harvest the cleanest possible rainwater, the following precautions should be taken:

- Branches of close by trees should not reach over roof surfaces from which water is taken.
- Before the beginning of the rainy season, all collection surfaces, gutters and storage containers should be thoroughly cleaned.
- The water collecting during the first moments of rainfalls contains the most dirt and should not be harvested, but be diverted from containers for about one minute. For this purpose, so-called "rainwater separators" can be used. Incoming water has to pass across a gap in the pipe or channel leading from the collection surface to the container inlet: water will only be able to bridge this gap when it flows sufficiently fast. The first water that arrives here during a rainfall will be moving too slowly to cross the gap; therefore it will not be able to reach the storage container, and instead will discharge, together with the dirt it is carrying, through the gap to the ground.

Rainwater Harvesting

Rainwater Harvesting at Household Level • Storage Containers Above and Below Ground

For collecting rainwater from ground surfaces, an interceptor basin for separating sediments should be installed above the (usually underground) storage tank. The basin should be large enough to allow the incoming water to settle and its solid components to sediment. Collection surfaces should be kept clean of oil (e.g. motor oil from vehicles) and any chemical residuals (e.g. fertiliser, herbicides, fungicides, detergents, etc.). Other possible water contaminants (e.g. bird or other animal droppings) should also be taken into account.

To avoid leakages, tanks should be checked for the early signs of cracks at least once per year, preferably before the beginning of the rainy season. Sediment sludge should be removed from the tank before this is done, and in any case, from time to time, as mentioned earlier. This will maintain the tank's storage capacity and hinder fermentation processes.

Limitations and Restrictions

Rainwater can be harvested effectively when rainfalls occur not only during short seasons, but over the whole year. When there are only a few heavy downpours per year, they must be taken advantage of to the maximum possible extent. Large collection surface areas, collecting pipes and storage containers will therefore be needed. The investments required for them may not be affordable for poor target groups.

Suitability for Self-help

Collecting and storing rainwater does not usually require major investments and is well-known and traditional in many regions of the world. Most components of rainwater harvesting systems can be installed through self-help.

In urban poor settlements, where space for large individual storage containers is often scarce and individual solutions may not be affordable to residents, community

Botswana

Locally manufactured rainwater storage tanks

In Botswana, a local firm markets a special type of rainwater storage tank. The firm recycles waste from another local enterprise that produces large water pipes from fibre-glass reinforced synthetic resin. Reject pipes (with diameters up to 2 m and wall thicknesses of up to 3 cm) that have not passed pressure tests, are cut into segments, and openings for manholes are made in them. They are then closed at both ends with plates, also made from fibre-glass reinforced synthetic resin.

They are used, vertically or horizontally, to store rainwater from private or commercial roof surfaces in single tank or joint tank systems. Due to their thick walls, the tanks are very stable and solid, and free from corrosion. They can be installed without foundations or further reinforcement. One disadvantage is their weight, and equipment is needed to transport and install them.

Water storage tank from reinforced sythetic resin in Botswana /130/

Rainwater Harvesting

installations can be a viable alternative. In such systems, rainwater collected by a number of households is stored in a large joint reservoir. However, this requires a high level of community organisation and ownership, and will need to be promoted and supported by community associations or local governments.

Assessment of Costs

Compared to the total construction costs of a house, the additional investments needed for collecting and storing rainwater from roofs or groundwater surfaces will not be very high. The construction of an appropriate storage tank will usually the main cost item. The volume of water to be stored will therefore be the main factor in determining investment costs. On the other hand, when water supply is expensive, e.g. when water has to be purchased from tanker trucks, rainwater harvesting can provide significant cost savings.

Main Features
Harvesting of rainwater from roofs and ground surfaces; storage in tanks or reservoirs for use as drinking water (boiled), for laundry, cleaning and/or irrigation

Application
For all buildings with impermeable slopping roofs and paved ground surfaces; possible application at household level and for small-scale enterprises.

Costs
Reasonable; mainly depends on the required sizes of containers or tanks; where water supply is expensive, significant water cost savings are possible

Operations
Individual self-help initiatives on private land; larger installations by community or neighbourhood groups

Interfaces
None

Advantages
Generally technically simple and low-cost solution

Disadvantages
If rainfall is limited to short seasons with only a few heavy downpours per year, large collection installations and containers will be needed for storing water over longer periods of time. The required investments may not be affordable for individual households in poor areas

To be Considered
To obtain the cleanest possible water, collection surfaces and storage tanks must be regularly cleaned; limited usage as drinking water is possible (but only after boiling).

Due to high water pressure that can occur in tanks, above ground tanks should only be designed and built by technically skilled persons.

In order to avoid fermentation processes, sediment sludge has to be regularly removed from tanks, e.g. before each rainy season.

ANNEX

- **Solid Waste**
  - Checklists
  - Tables
  - Design Criteria and References
- **Wastewater**
  - Checklists
  - Tables
  - Design Criteria and References
- **Literature**
- **Photo and Illustration Credits**

ASSESSMENT OF SOLID WASTE TRANSPORT OPTIONS

Transport Option / Important Factors	Individual	Manual Push-cart	Donkey Cart	Collector Truck / Municipal Operator
1. Requirements:				
- procurement	- not necessary	- necessary	- necessary	- necessary
- street network	- foot paths sufficient, stairways possible	- foot paths sufficient, no stairways	- foot paths necessary	- street network necessary
- topography	- low relevance	- difficult in areas with steep slopes	- application difficult in areas with steep slopes	- not applicable in areas with steep slopes
2. System features:				
- procurement / manufacturing	-	- locally possible / simple	- locally possible (carts)	- must be imported in most cases
- material	-	- locally available	- locally available	- must be imported
- operations and maintenance	-	- low requirements	- animal husbandry must be possible	- medium requirements
- procurement costs	-	- very low	- low	- medium to high
- operating costs	- possibly wages	- possibly wages; otherwise low	- wages and costs for fodder; otherwise low	- high (fuel / repairs)
3. Risks of contamination	- low to medium	- low to medium	- low to medium	- low to medium
4. Down times:	- none	- low	- low	- medium
5. Other:	- well suited for areas with difficult topographical conditions - appropriate for densely built-up areas - intermediate storage or transfer stations necessary	- allows transport of larger waste volumes in densely built-up - intermediate storage or transfer stations necessary	- improvement on manual pushcarts as larger transport distances are possible - intermediate storage or transfer stations necessary	- requires operations by professional (municipal) service providers - intermediate storage or transfer not necessary

ASSESSMENT OF INTERMEDIATE STORAGE AREAS AND TRANSFER STATIONS

Important Factors / Storage option	Unorganised Storage Area (Dumping)	Organised Storage Area (walled or fenced)	Containers
1. Requirements:			
- space needed	- needs sufficient space (>100m²)	- needs sufficient space	- needs sufficient space (>30m²)
- accessibility	- must be accessible for collector trucks	- must be accessible for collector trucks	- must be accessible for collector trucks
2. System features:			
- construction / manufacturing	-	- locally possible	- often must be imported
- material	-	- locally available	- often must be imported
- operations and maintenance	- regular cleaning necessary	- regular cleaning necessary	- regular cleaning of container site necessary
- investment costs	- none	- low	- medium
- operating costs	- none	- very low	- very low
3. Risk of contamination:	- very high; breeding ground for vermin (rats, flies, etc.) - contents scattered by animals and the wind	- very high; breeding ground for vermin (rats, flies, etc.) - contents scattered by animals and the wind	- high, when not adequately covered and irregularly emptied - soiling of site in when container has insufficent capacity and when children or smaller people cannot reach up to the container
4. Down times:	- none	- none	- only in the case of irregular or insufficient emptying
5. Other	- should be avoided, as nuisance to residents in the vicinity is high - very precarious hygiene aspects, - risks of flooding and dispersion of waste during rainy seasons	- significant improvement on unorganised storage and dumping - regular collection and transport needed in order to avoid contamination	- containers should be designed so that children and smaller people can also use them - regular collection and transport needed to avoid nuisance and hazards similar to those of unorganised collection areas

ANNEX

SOLID WASTE

CHECKLIST TO ASSIST IN THE LAYOUT OF PROJECTS IN THE RECYCLING SECTOR

A. Raw material

- What types of waste material will be collected?

For each type:
- From which places is the waste material collected or purchased?
- What will be the monthly amount of collected waste?
- What is the average distance to drive for collection or purchase?
- What means of transport are required?
- What is the waste material quality?
- Is the material free of charge or must something be paid for the material?
- Do people bring the waste? For what price?

B. Waste handling technologies and administration

General set-up:
- Where will the waste be accumulated/stored?
- What type of premises are needed?
- What type of infrastructure is required at the premises?
- What will be the total investment for establishing the infrastructure?
- How many people will be employed and what organisational structure will be needed?

For each type of waste:
- What is the quality of the entering material?
- What type of up-grading process will be applied?
- What type of machinery is necessary?
- How many labourers are needed for up-grading?
- What will be their productivity?
- What is consumed during processing (energy, fuel, lubricants, water, ets.)?
- What investment will be required to buy the required machinery, means of transport, office equipment, etc.?
- What will be the quality of the products to be marketed?
- What will be the operational costs?

C. Marketing of products

For each product:
- Who are the customers for the product?
- Where are the customers located?
- What is the market price of the product?
- What is the transport distance and what are the transport costs?
- What will be the monthly amount to be shipped and sold?
- What means of transport are needed?
- What will be the operational net profit of the total operation?

CHECKLIST TO ASSIST IN THE SELECTION OF APPROPRIATE PROCESSES AND MACHINERY

A. Production Process

- Application of processes
  - Feed preparation?
  - Main process?
  - Final handling, e.g. canning, packaging, storage, etc.?
  - Auxiliary machinery?

- Location of manufacturers/suppliers of the machinery
  - Locally?
  - In neighbouring countries?
  - Overseas?
  - Do they provide service, maintenance and spare parts?

- Purchase conditions of equipment
  - Price of equipment?
  - Transport costs to premises?
  - Import taxes?
  - Price of spare parts including tax and transport?
  - Lifetime of machinery and guarantees?

- Operation characteristics
  - Manual, semi-mechanised or automatic operation?
  - Batchwise or continuous operation?
  - Is operation of low or high productivity?
  - Energy intensive?
  - Noisy and polluting?
  - Risky for the worker's health?
  - Generates reasonable amounts of waste and residues?
  - Generally environmental friendly or unfriendly?

B. Economic factors

- Labour market
  - Availability of skilled labour?
  - Level of wages aud related labour costs?
  - Availability of technical assistance by local reseach and tenchnology institutions?

- Capital market
  - Level of self-financing by the entrepreneur?
  - Level of interest rates?
  - Availability of favourable investment loans?
  - Existence of government support schemes?

EXAMPLE OF A BUSINESS PLAN FOR REFUSE RECYCLING

- Description and history of company
  - How and what the company is?
  - Status of project/company?
  - Key goals and objectives?
- Product and Services
  - What the product or service is?
  - How it works?
  - What it is for?
  - Proprietary advantages?
- Markets
  - Who the prospective customers are?
  - How many customers there are?
  - Market growth rate?
  - Competitors?
  - Industry trends?
  - Estimated market share?
- Operations
  - How the product or service will be manufactured/provided?
  - Facilities/equipment?
  - Special processes?
  - Labour skills needed?
- Channels of distribution
  - How the product or service will be distributed?
  - Means of transport?
  - Advertising and marketing?
- Management
  - Who will do what?
  - Staff qualifications?
  - Availability of skilled labour?
- Financial prospects
  - Investment costs?
  - Capital costs?
  - Operational costs?
  - Monthly turnover?
  - Prospected yearly revenues?
  - Tax, social and legal costs?
  - Cash flow analysis (one year)?
  - Feasibility study?
- Sources and application of funds
  - Present needs?
  - Future needs?
  - Own funds?
  - Required loans or grants?

OVERVIEW AND ASSESSMENT OF DIFFERENT SANITATION OPTIONS

	Total Initial Costs	Construction Labour Required as Fraction of Total cost	Operating Costs	Land Requirements	O & M Skill Level	Degree of Treatment	Possible Participation
On-Site Ssystems							
VIP Latrines	low	high	low	moderate (if superstructure is moved when pit is full)	low	low (unsuitable with high water table)	users, community, government
Double Vault Above Ground Latrines	low to moderate	high	low	low	low	moderate	users, community, government
Batch Composting Latrines	low	high	low	low	low	moderate (unsuitable with high water table)	users, community, government
Continuous Composting Latrines	moderate	moderate	low	low	low	moderate (unsuitable with high water table)	users, community, government
On-Site Liquid Disposal with Offsite Solids Disposal							
Pour Flush Toilet with Soakaway	low to moderate	moderate	low	moderate	low	low (unsuitable with high water table)	users, community, government
Pour Flush Toilet with Septic Tank	moderate	moderate	low	moderate	low	moderate	community, government
Cistern Flush Toilet with Septic Tank	moderate to high	moderate	high	high	low	moderate	community, government
Off-Site Disposal							
Vault or Pit Toilet with Cartage	low to moderate	high	moderate	low	low	Depends on final disposal	users, community, government
Bucket Latrine	low	high	moderate	low	low	Depends on final disposal	users, community, government
Water Borne Sewage Collection							
Simplified	moderate	moderate	low	moderate	low	none	government
Solids Free	moderate	moderate	moderate	moderate	low	none	community, government
Condominial	low to moderate	high	low	low	low	none	users, community, government
Conventional	high	moderate	high	moderate	high	none	government

ASSESSMENT OF DRAINAGE OPTIONS (SURFACE WATER)

Drainage Option	**Simple Earth Trench or Canal**	**Reinforced Trench or Canal**	**Covered Culvert / Canal**	**Paved Road (Trough Road)**
1. Requirements:				
- topography	- low slopes (<1%)	- low slopes (<2%)	- low slopes (<2%)	- low slopes
2. System Features:				
- construction	- simple - with advisory assistance	- advisory assistance necessary	- requires skilled labour	- advisory assistance necessary
- material		- locally available material can be used	- importing (e.g. cement) may be necessary	- generally, has to be be imported
- operations and maintenance	- high effort for cleaning	- high effort for cleaning	- medium effort for cleaning	- low effort for cleaning
- construction costs	- low	- medium to high	- very high	- included in road construction costs
- operating costs	- high, when contracted out (payment of wages)	- high, when contracted out (payment of wages)	- medium	- included in road maintenance costs

Costs of Sanitation Options per Household (1990 Prices)

Sanitation Option	Costs (USD)
Twin-pit pour-flush latrine	75-150
VIP-latrine	68-175
Shallow sewerage	100-325
Small-bore sewerage	150-500
Conventional septic tank	200-600
Conventional sewerage	600-1,200

ANNEX

WASTEWATER

CONTAMINATED LOAD OF WASTEWATER

Components of Human Excrements in Different Regions

Faeces components	Europe and North America	Developing Countries (rural)	Developing Countries (urban)
Assumed weight of adult faeces [g/d]	150	250	350
Assumed weight of adult urine [kg/d]	1.2	1,2	1,2
Estimate water components of faeces [%]	75	80	85
In wet faeces [mg/g][a]	96	77	58
Faeces per adult [g/d]	14.4	19.3	20.3
Urine per adult [g/d]	10.3	10.3	10.3
Total excrements per adult [g/d]	24.7	29.6	30.6
Anal cleaning material per adult [Cg/d]	3.5[c]	3.0[d]	2.0[d]
BOD_5-concentration [mg/l][b]	18.8	21.7	21.7

Note: This table provides general orientation only. The data in it should be verified against concrete evidence and analysis.
a. Calculated on the assumption that the BOD_5 per weighed dry faeces unit is constant.
b. Based on the assumption, that 1.5 litres per adult per day are produced.
c. Von Laak (1974).

BOD_5 Concentration in Wastewater in Different Countries

Country or Region	BOD_5 per-capita-Concentration in wastewater (g/d)
Brazil (Sao Paulo)	50
France (rural)	24-34
India	30-55
Kenya	23-40
Nigeria	54
Southeast Asia	43
UK	50-59
US	45-78
Zambia	36

Note: These data were calculated by measuring BOD_5-concentrations in raw sewage and multiplying it by daily water consumption per inhabitant. The results only provide a rough orientation, since urban wastewater con contain considerable amounts of commercial and industrial waste.

PROPOSED QUALITY STANDARDS FOR WASTEWATER EFFLUENT AND SLUDGE

Type of Wastewater	**maximum contamination with:**			
	COD (mg/l)	NH_4-N (mg/l)	Helminth eggs (No./l)	Faecal coliforms (No./100ml)
Liquid Wastewater				
Quality of effluent for discharging into receiving water:				
• into to seasonally flowing watercourses (wadis, arroyos)	< 300-600	10-30	<2-5	$<10^4$
• into always flowing rivers or the sea	<600-1.200	20-50	<10	$<10^5$
Quality of effluent for recycling[1, 2]:				
• limited irrigation	n.c.	1)	<1	$<10^5$
• irrigation for growing vegetables	n.c.	1)	<1	$<10^3$
Sludge[3]				
Use in agriculture	n.c.	n.k.	<3-8/g TS	low risk when, max. no. of Helminth-eggs is not exceeded

n.c. = not critical

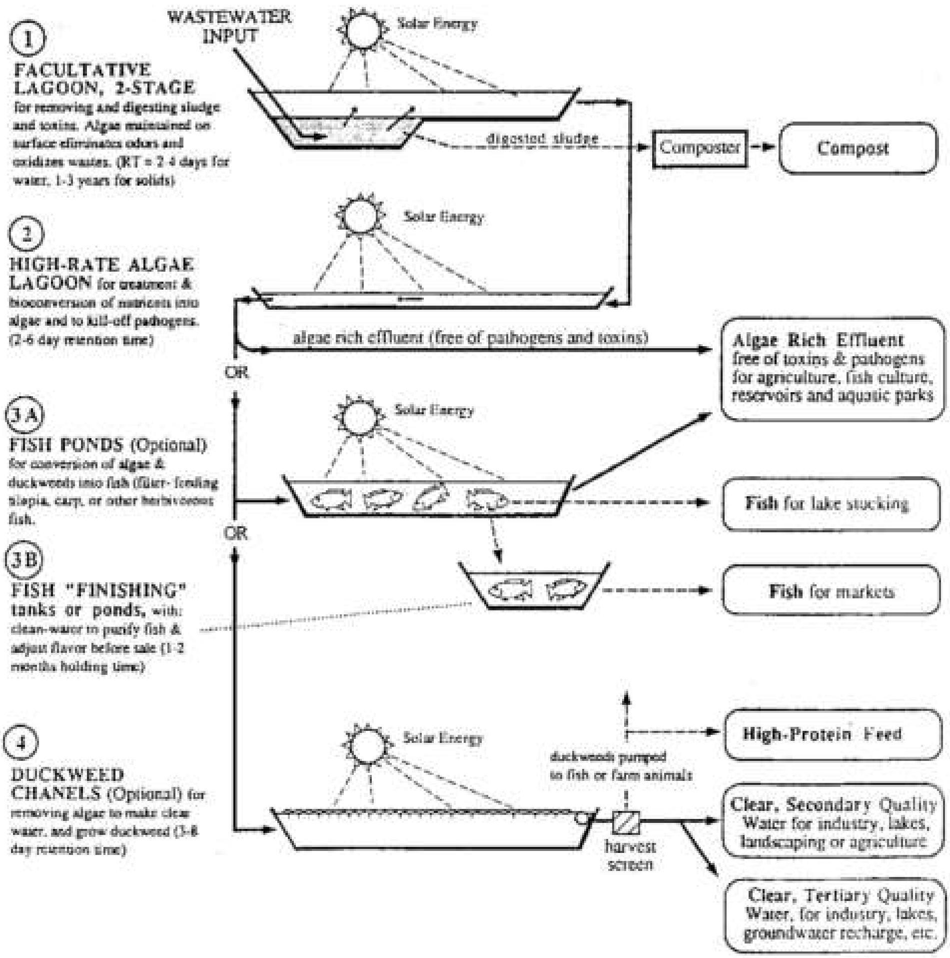
1) Nitrogen load should not exceed 100-200 kg per/ha per year.
2) WHO 1989
3) Xenthoulis and Strauss 1991

Annex
Wastewater

Schematic Sketch of a Wastewater Treatment Plant at Settlement Level

A Low Cost, Low-Technology Sunwater System for Small Flows and Rural Villages

Section View of components and processes for simple, low-cost wastewater treatment for rural villages. The process can produce water free of toxins and disease organisms, safe for agriculture, aquaculture, and other reuses, with no mechanical equipment or chemicals. The Facultative Cell removes and digests toxins and sludge. The High-Rate Algae Cell oxidizes wastes, kills all pathogens, and grows high volumes of algae. This water is then safe for any reuse. The algae makes an excellent organic fertilizer for agriculture, or food for fish. If clear water is desired, a special pond covered with duckweeds will function to settle and convert algae into high protein feed.



Literature

Literature quoted in the Text

(1) **Jaradat** I.S.Y.: Municipal Solid Waste Management in Jordan, Aqaba: International Institute for Infrastructural, Hydraulic and Environmental Engineering, University of Delft, The Netherlands, 1999

(2) **Vest** H., **Jantsch** F.: Untersuchung des Aufkommens fester Abfälle in Koulikoro, Mali; GTZ, 1999

(3) **Seghezzo** L., **Galdeano** R., **Montiel** E., **Schindler** M.: Integrated Waste Management in Argentina; Warmer Bulletin No. 71; March 2000, p. 18-19

(4) **Warmer** Bulletin No. 69

(5) **Constantinou** D.: Municipal Solid Waste Management in Cyprus; Warmer Bulletin No. 53, March 1997, p. 20-21

(6) **Hassan** M.N.: Waste Management in Malaysia; Warmer Bulletin No. 51, November 1996, p. 18-19

(7) **N.N.**: MSW in The USA; Warmer Bulletin No. 67; Novemver 1999, p. 8-9

(8) **Gupta** S, **Kansal** A.: Solid Waste Management in Indian Cities; Warmer Bulletin No. 60, May 1998, p. 4-6

Other Literature

Austin L.M., **van Vuuren** S.J.: Case Study: Urine Diversion Technology 25th WEDC Conference, Addis Ababa, Ethiopia 1999

Austin L.M., **van Vuuren** S.J.: Technical Aspects of Ecological Sanitation. Department of Civil Engineering, University of Pretoria, South Africa 1998

Baumann W., **Karpe** H.J.: Wastewater Treatment and Excreta Disposal in Developing Countries. Institute of Environmental Protection (INFU) Dortmund, March 1980

Bark K. et al. (Gutachterteam): Modellhafte nachhaltige Sanitärsysteme für Mali – Mission/Vorstudie zur Erarbeitung eines nachhaltigen Sanitärkonzepts am Beispiel der Städte Koulikoro und Kati, Bericht Phase A. CD-ROM, April 2000 (Fa. OtterWasser GmbH on behalf of the GTZ)

Black M.: Mega-Slums. The Coming Crisis. WaterAid, 1994

Brikké F.: Management of Operation and Maintenance in Rural Drinking Water Supply and Sanitation. WHO, Geneva, August 1993

Cairncross S., **Feachem** R. G.: Environmental Health Engineering in the Tropics. John Wiley and Sons 1983

Chleq J.-L., **Dupriez** H.: Vanishing Land and Water. Macmillan Publishers, Hong Kong, 1988

Coad A.: Lessons from India in Solid Waste Management. WEDC UK

Cointreau-Levine S.: Urban Management Programme – Participation in Municipal Solid Waste Services in Developing Countries, Volume 1 UNDP/UNCHS/World Bank 1994

Cotton A., **Franceys** R., **Pickford** J., **Saywell** D.: On-Plot Sanitation in Low-Income Urban Countries. WEDC, UK, September 1995

Cotton A., **Saywell** D.: On-Plot Sanitation in Low-Income Urban Communities – Guidelines for Selection. WEDC, 1998

Feachem R.G., **Bradley** D.J., **Garelick** H.; **Mara** D.D.: Sanitation and Disease Health Aspects of Excreta and Wastewater Management. John Wiley & Sons 1983

GFA-Umwelt: Utilisation of Organic Waste in (Peri-) Urban Centres – Supraregional Sectoral Project. Bonn/Eschborn, 1999 (on behalf of the GTZ)

Hasse R.: Rainwater Reservoirs above Ground Structures of Roof Catchment Botswana 1987

Hogrewe W., **Joyce** S.D., **Perez** E. A.: The Unique Challenges of Improving Peri-Urban Sanitation. WASH Technical Report No.86, July 1993

Holmes John R.: Managing Solid Wastes in Developing Countries. J. Wiley and Sons, 1984

Kalbermatten J.M., **Julius** DeAnne S., **Mara** D, **Gunnerson** C. G.: Appropriate Technology for Water Supply and Sanitation – A Planner's Guide. Transportation, Water and Telecommunication Department; The World Bank, December 1980

Kalbermatten J.M., **Julius** DeAnne S., **Gunnerson** C.G.: Appropriate Sanitation Alternatives – A Technical and Economical Appraisal. The Johns Hopkins University Press Baltimore and London1982

Kerr C.: Community Health and Sanitation. Intermediate Technology Publications, UK 1990

Mara M., **Cairncross** S.: Guidelines for the Safe Use of Wastewater and Excreta in Agriculture. WHO, Geneva, 1989

LITERATURE

OTHER LITERATURE

Muguti E., **Everts** S., **Schulte** B., **Smallegange** L.: Energy Efficiency for Medium and Small Enterprises; Intermediate Technology Publications, London, 1999

Nill, D., et al: Soil Erosion by Water in Africa. GTZ, TZ-Verlag Roßdorf, 1996

N.N.: Abfallwirtschaft mit Bevölkerungsbeteiligung, Ein Beispiel aus Nepal. GTZ, Eschborn 1988

N.N.: Conversion of Wastewater into Safe, Clean Water using Low-Cost Natural Methods. Biogas Forum No. 62, 1995

N.N.: Drainage. GTZ, Eschborn 1992

N.N.: Environmental and Health Aspects of Planning Urban Areas WHO, Geneva 1993

N.N.: Fact Sheets on Environmental Sanitation. WHO, Geneva 1996

N.N.: Technical Brief No.52: Water. Quality or Quantity? Waterlines Vol.15 No.4 April 1997

N.N.: Urban Environmental Management Guidelines Thailand; Solid Waste Management. GTZ, Eschborn 1994

N.N.: Urban Environmental Management Guidelines Thailand; Environmental Health. GTZ, Eschborn 1994

N.N.:Technical Brief No. 54: Emptying Latrine Pits. Waterlines, Vol. 16, No. 2, Oct. 1997

N.N.: Conversion of Wastewater into Safe, Clean Water using Low-Cost Natural Methods; Biogasforum 1995/III No.62, BORDA, Bremen

N.N.: Public Health Engineering in Emergency Situation. Médecins Sans Frontières, Paris, 1994

N.N.: La Lutte Anti-Erosive. Republique du Burundi, 1990

N.N.: The Soil – How to Conserve the Soil. FAO, Rom, 1976

N.N.: Erosion Control in the Tropics; Agrodok 11. Agromisa, Wageningen, 1987

N.N.: Simple Soil and Water Conservation Methods for Upland Farms; Maguugmag Foundation, Inc.; Cebu, Philippines,

N.N.:Utilisation of Organic Waste in (Peri-)Urban Centres. GTZ/GFA-Umwelt, Eschborn 1999

N.N.: Sanitation Promotion Kit, Dry Toilets in El Salvador; WHO, Geneva 1997

N.N.: Decentralised Disposal of Communal Waste Water. BWSS-ISP, GTZ, Eschborn/Bengkulu, 1996

N.N.: Cholera and other Epidemic Diarrhoeal Diseases – Fact Sheets on Environmental Sanitation; WHO, Genf, 1996

Otis R.J., **Mara** D.: The Design of Small Bore Sewer Systems UNDP, World Bank, May 1985

Pfammatter R., **Schertenleib** R.: Non-Governmental Refuse Collection in Low-Income Urban Areas – Lessons Learned from Selected Schemes in Asia, Africa and Latin America. SANDEC Report No. Switzerland March 1996

Pickford J., **Barker** P., **Coad** A., **Ince** M., **Shaw** R., **Skinner** B., **Smith** M.: Water, Sanitation, Environment and Development. Selected Papers of the 19th WEDC Conference Accra, Ghana 1993

Proyecto Atención Primaria de Salud – APS (GTZ): Microempresas de Recolección Manual y Transporte de Basuras Domésticas. Bogotá

Reed R.A.: Sustainable Sewerage WEDC, 1995

Reed, R.A.: Sustainable Sewage. Intermediate Technology Publications, London, 1995

Sasse, L.: DEWATS – Dezentrale Abwassserreinigung in Entwicklungsländern; BORDA, Bremen, 1998

Schweizer F., **Collins** K. A.: The Privatisation of Solid Waste Management in Ghana. Trialog 48, 1996

Simpson-Hebert M., **Wood** S.: Sanitation Promotion Kit. WHO, Geneva 1997

Sobral M., **Florencio** L., **Kato** M.T.: Abwassernachbarschaften – eine wirksame und billige Alternative für Entwicklungsländer. Diskussionsforum, TU-International 34/35 November 1996

Strauss M., **Heinss** U., **Larmie** S. A.: Solids Separation and Pond Systems for the Treatment of Faecal Sludges in the Tropics. EAWAG, SANDEC, Switzerland1998

Vest H., **Jantsch** F.: Management of Solid and Liquid Waste at Small Healthcare Facilities in Developing Countries GTZ, Eschborn 1999

Vest H., **Jantsch** F.: Umweltkatalog: Abfälle aus medizinischen Einrichtungen. BMZ/GTZ, 1999

Wehenpohl G.: Abfallbeseitigung in Marginalsiedlungen von Entwicklungsländern. Darmstadt 1987

Wehenpohl G.: Selbsthilfe und Partizipation bei siedlungswasserwirtschaftlichen Maßnahmen in Entwicklungsländern – Grenzen und Möglichkeiten in städtischen Gebieten unterer Einkommensschichten; Schriftenreihe WAR 30. Darmstadt 1987

Winblad U., **Kilama** W.: Sanitation without Water. SIDA, Stockholm 1985

Annex

Illustration Credits

List of Photos and Illustrations

Fig. 1-4:	B.U.S. photo archive
Fig. 5-7:	Frank Samol
Fig. 8-9:	B.U.S. photo archive
Fig. 10-11:	Photo archive Dr. Heino Vest
Fig. 12:	GTZ
Fig. 13:	Photo archive Dr. Heino Vest
Fig. 14:	KfW Annual Report 1997
Fig. 15:	Prof. Peter Herrle
Fig. 16:	Photo archive Dr. Heino Vest
Fig. 17-20:	Frank Samol
Fig. 21:	B.U.S. photo archive
Fig. 22:	Photo archive Dr. Heino Vest
Fig. 23:	B.U.S. photo archive
Fig. 24-26:	Photo archive Dr. Heino Vest
Fig. 27-29:	Frank Samol
Fig. 30-32:	Photo archive Dr. Heino Vest
Fig. 33:	Frank Samol
Fig. 34-36:	Photo archive Dr. Heino Vest
Fig. 37-38:	Frank Samol
Fig. 39-43:	Photo archive Dr. Heino Vest
Fig. 44:	Environmental Health Engineering in the Tropics; John Wiley and Sons, 1983, S.199, 201
Fig. 45-48:	Photo archive Dr. Heino Vest
Fig. 49:	Frank Samol
Fig. 50-53:	Photo archive Dr. Heino Vest
Fig. 54:	Business brochure Gross Apparatebau GmbH, Heilbronn
Fig. 55-64:	Photo archive Dr. Heino Vest
Fig. 65:	Public Health Engineering in Emergency Situation; Médecins Sans Frontières, Paris, 1994, S. II-32, II-33
Fig. 66-67:	Photo archive Dr. Heino Vest
Fig. 68-70:	B.U.S. photo archive
Fig. 71:	Prof. Peter Herrle
Fig. 72-73:	GTZ
Fig. 74:	Frank Samol
Fig. 75	Prof. Peter Herrle
Fig. 76:	Photo archive Dr. Heino Vest
Fig. 77:	Photo archive Dr. Heino Vest
Fig. 78:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 6
Fig. 79:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 9
Fig. 80:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 11

Annex

Illustration Credits

List of Photos and Illustrations

Fig. 81:	B.U.S. photo archive
Fig. 82:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 7
Fig. 83:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 7
Fig. 84:	Ecological Sanitation; SIDA, Stockholm 1998, S. 51
Fig. 85:	Sanitation Promotion Kit, Dry Toilets in El Salvador; WHO, Geneva 1997, S. 2
Fig. 86:	Sanitation without Water; The Macmillan Press Ltd., Hong Kong 1992, S. 33
Fig. 87:	EcoSan Center; www.cepp.cc/ecosan/ecosanphotos.html
Fig. 88:	Frank Samol
Fig. 89:	Photo archive Dr. Heino Vest
Fig. 90:	EcoSan Center; www.cepp.cc/ecosan/ecosanphotos.html
Fig. 91:	B.U.S. photo archive
Fig. 92-93:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 24
Fig. 94:	Decentralised Disposal of Communal Waste Water; BWSS-ISP, GTZ, Eschborn/Bengkulu, 1996, Annex 2.1
Fig. 95a/b:	Energy Efficiency for Medium and Small Enterprises; Intermediate Technology Publications, London, 1999, S. 47
Fig. 96:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 36
Fig. 97:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 38
Fig. 98:	GTZ, Klaus Weistroffer
Fig. 99:	DEWATS – Dezentrale Abwassserreinigung in Entwicklungsländern; BORDA, Bremen, 1998, S. 74
Fig. 100:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 29
Fig. 101:	Cholera and other Epidemic Diarrhoeal Diseases; Fact Sheets on Environmental Sanitation; WHO, Genf, 1996
Fig. 102:	Sim Van der Ryn; The Toilet Papers Recycling Waste and Conserving Water; Ecological Design Press, 1995
Fig. 103:	Emptying Pit Latrines; Technical Brief No. 54; Waterlines Vol. 16, No. 2, October 1997
Fig. 104:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 53
Fig. 105:	Wastewater Treatment and Excreta Disposal in Developing Countries; gate/INFU, Eschborn/Dortmund, 1980, S. 56
Fig. 106:	Mega-Slums – The Coming Crisis; WaterAid, 1994, S. 22

Illustration Credits

Fig. 107:	John M. Kalbermann, DeAnne S. Julius, D. Duncan Mara, Charles G. Gunnerson; Appropriate Technology for Water Supply and Sanitation; A Planner´s Guide, World Bank, 1980
Fig. 108-110:	Photo archive Kraft Engineering
Fig. 111-112:	PRIMED – Programa Integral de Mejoramiento de Barrios Subnormales en Medellin: Una Experiencia Exitosa en la Intervencíon, Medellin 1996
Fig. 113:	Frank Samol
Fig. 114:	PRIMED – Programa Integral de Mejoramiento de Barrios Subnormales en Medellin: Una Experiencia Exitosa en la Intervencíon, Medellin 1996
Fig. 115:	GTZ sectoral project “Ecological Sanitation” and GTZ project “Verbesserung des kommunalen Managements der Wasser- und Abfallwirtschaft Koulikoro, Mali”; Modellhafte nachhaltige Sanitärsysteme für Mali, Mission/ Vorstudie zur Erarbeitung eines nachhaltigen Sanitärkonzeptes am Beispiel der Städte Koulikoro und Kati; Bericht Phase A, April 2000
Fig. 116:	John M. Kalbermann, DeAnne S. Julius, D. Duncan Mara, Charles G. Gunnerson; Appropriate Technology for Water Supply and Sanitation; A Planner´s Guide, World Bank, 1980
Fig. 117:	PRIMED – Programa Integral de Mejoramiento de Barrios Subnormales en Medellin: Una Experiencia Exitosa en la Intervencíon, Medellin 1996
Fig. 118-119:	GTZ sectoral project “Ecological Sanitation” and GTZ project “Verbesserung des kommunalen Managements der Wasser- und Abfallwirtschaft Koulikoro, Mali”; Modellhafte nachhaltige Sanitärsysteme für Mali, Mission/ Vorstudie zur Erarbeitung eines nachhaltigen Sanitärkonzeptes am Beispiel der Städte Koulikoro und Kati; Bericht Phase A, April 2000
Fig. 120	B.U.S. photo archive
Fig. 121:	La Lutte Anti-Erosive; Republique du Burundi, 1990
Fig. 122:	PRIMED – Programa Integral de Mejoramiento de Barrios Subnormales en Medellin: Una Experiencia Exitosa en la Intervencíon, Medellin 1996
Fig. 123:	La Lutte Anti-Erosive; Republique du Burundi, 1990
Fig. 124:	Frank Samol
Fig. 125:	Photo archive Dr. Heino Vest
Fig. 126:	PRIMED – Programa Integral de Mejoramiento de Barrios Subnormales en Medellin: Una Experiencia Exitosa en la Intervencíon, Medellin 1996
Fig. 127:	Compilation from: Management of Operation and Maintenance in Rural Drinking Water Supply and Sanitation, WHO, Geneva August 1993; S. 3 Rainwater Reservoirs above Ground Structures of Roof Catchment, Botswana 1987, S. 23
Fig. 128:	Rainwater Reservoirs above Ground Structures of Roof Catchment, Botswana 1987, S. 24
Fig. 129:	Rainwater Reservoirs above Ground Structures of Roof Catchment, Botswana 1987, S. 74
Fig. 130:	Photo archive Dr. Heino Vest

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

Dag-Hammarskjöld-Weg 1-5
Postfach 5180
65726 Eschborn
Telefon: ++49 (0)61 96 79-0
Telefax: ++49 (0)61 96 79-11 15
Internet: http://www.gtz.de

ONE WORLD
Deutsche Entwicklungspolitik