4 Mainstreaming DEWATS – strategic planning and implementation of sustainable infrastructure

Nowadays public authorities are challenged to provide sanitation and wastewater-treatment services on a large scale. Mainstreaming decentralised wastewater-treatment solutions is one of the key elements for sustainable infrastructure development.

4.1 Strategic planning of sanitation programmes

Comprehensive wastewater strategies may consider different options for the treatment and discharge of wastewater:

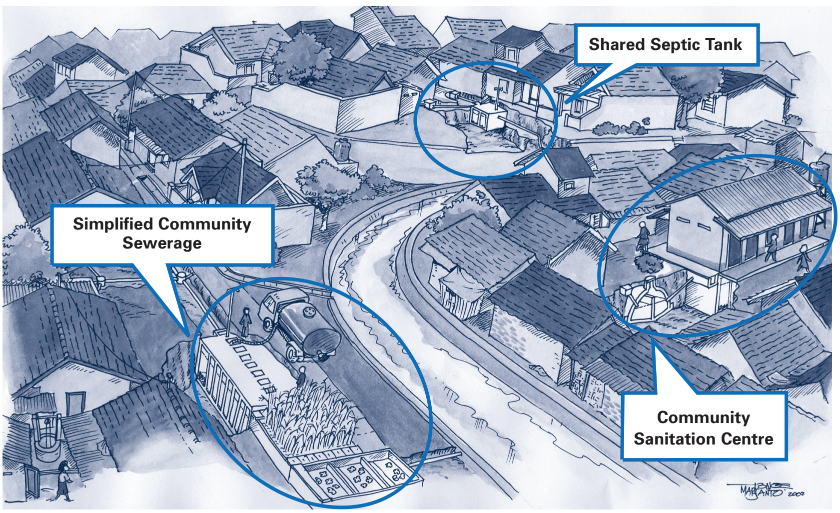
- treatment in a centralised plant, which is connected to a combined or separate sewer system
- treatment in several medium-sized treatment plants, which are connected to a combined or separate sewer system
- primary and secondary treatment in decentralised plants, which are connected to a sewer line, leading to a common plant for final treatment
- completely decentralised treatment with final discharge, reuse, or connection to communal sewerage
- controlled discharge without treatment (ground percolation, surface-water dilution)

The final decision, on which treatment option is most suitable for a given water pollution problem, should be based on a number of different considerations, which are discussed in greater depth later in this book. Different options may be considered for residential areas:

- Simplified community-sewerage systems with household-based sanitation systems are preferred in areas where the residents have sufficient financial resources and households have sufficient space. On average, 20 to 100 families are connected to one system. The system consists of toilets and bathrooms within each household. The wastewater is directed to a DEWATS by shallow, narrow sewer lines.
- Shared septic tanks present a simpler version of the household-based sanitation system with off-site treatment. A smaller cluster of about 10 to 50 households is connected to a community septic tank. The system treats toilet and bathroom effluent from each household. Wastewater is channeld to the septic tank by shallow small-diameter sewer lines. The wastewater cannot be discharged directly to the aquatic environment, due to the low effluent quality of the septic tank. The system is, usually only applied, therefore where soil conditions allow the direct infiltration of the effluent without any harm to the groundwater.

- Community Sanitation Centres (CSCs) are appropriate in areas where financial resources are very limited and most residents live in rented rooms or huts, leaving no space for in-house sanitation. The centre is established at a central location within the settlement and offers different services as requested by the community. Services can include water points, toilets, bathrooms and laundry areas. Each CSC is connected to a DEWATS, usually located underground below the Centre. CSCs are usually guarded and operated by paid staff.

The experience gathered in multiple efforts to create efficient and cost-effective sanitation and wastewater-treatment strategies clearly shows that, without comprehensive legal frameworks and efficient law enforcement, without institutional capacities within public and private services, without relevant financial resources, and without awareness at the household or enterprise level, the hoped-for health and environmental standards cannot be achieved.



Picture 4_1:
Different treatment options within a CBS programme

In many countries, new legal regulations have favoured a rapid increase in the demand for decentralised wastewater-treatment systems. For many public and private entities DEWATS poses the only solution for complying with legal requirements within the time constraints. The situation raises the question: How can these technical options be integrated effectively into regional and municipal planning processes, in order to reach an economy of scale?

Since the goal of public authorities is not to promote specific technical solutions, but rather to achieve political and administrative targets, the following questions must be considered by all key decision-makers:

- Under which conditions should DEWATS be preferred over other technical solutions?
- What are the advantages of DEWATS over other wastewater-treatment options?
- How can a legal and institutional framework be created, which facilitates comprehensive sanitation and efficient wastewater-treatment schemes?
- What are the core elements of such schemes?
- Who are the stakeholders, who should be involved in the process?
- What kind of approach is required to ensure efficient, cost-effective and sustainable implementation?
- How can the implementation of such schemes be initiated and maintained?

The government of Indonesia, for example, evaluated multiple efforts in the sanitation sector, as a basis for creating an implementation scheme for a nation-wide programme. It was concluded that the exclusive top-down approach must be replaced by a conceptual framework, which includes “demand-driven services”, “multi-stakeholder involvement”, and “multi-task planning” as guiding principles.

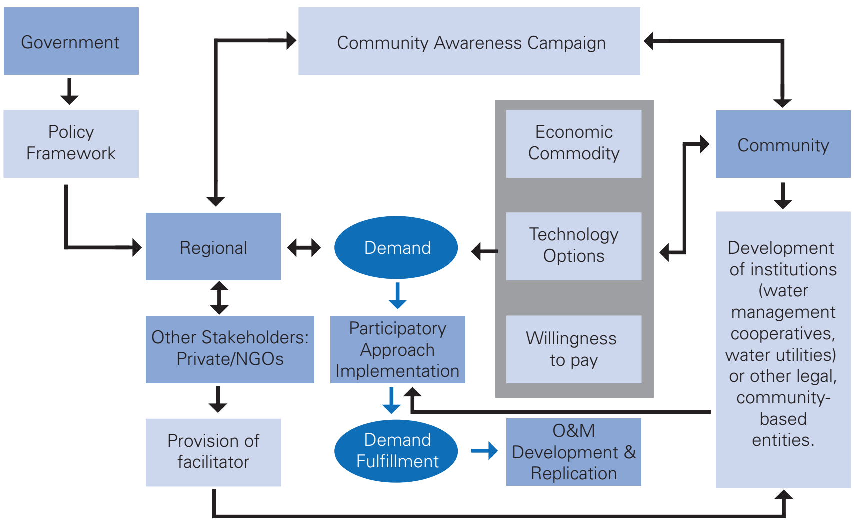
In order to overcome the poor long-term performance of many projects and initiatives, the government of Indonesia has decided that further guiding principles should play an integral part in any planning and implementation activities:

- sustainability of financing
- sustainability of technical know-how
- sustainability of environmental management
- sustainability of infrastructural management
- sustainability of social interaction

This conceptual framework reflects the international discussion about how sanitation and wastewater treatment services can have the optimal sustainable impact.

The following features present the underlying principles of an efficient and cost-effective programme:

- comprehensive legal regulations
- efficient law enforcement
- target-orientated local and municipal planning
- demand-responsive approach
- comprehensive assessment of local and community needs
- service orientation
- multi-stakeholder involvement
- appropriate choice of technology
- multi-task planning
- financial analysis and long-term financial planning
- sound planning and monitoring of the implementation process
- capacity building
- step-by-step implementation



Picture 4_2: Conceptual framework of Indonesia's National Sanitation Programme

4.2 Legal framework and efficient law enforcement

A comprehensive legal framework and its efficient enforcement at the local level are essential to the success of sanitation and wastewater-treatment strategies.

Wastewater-treatment schemes must meet the legal discharge standards, defined within the legislation of each country. Those standards, however, are rarely met in developing countries. The reasons for this are manifold.

In most countries, legal environmental and discharge standards are based on the most scientifically advanced treatment technologies available on the market. Discharge standards in developing countries often refer to those from industrialised countries, where sophisticated treatment technologies can be applied to treat the highly diluted municipal sewage. The different prerequisites in developing countries, including wastewater composition, economic and socio-economic conditions as well as financial and organisational restrictions, create large discrepancies between desired effluent standards and the actual services that can be provided. In some cases, standards thereby achieve adverse effects, as they are considered unrealistic and ignored.

Table 4: Some selected domestic wastewater-data. Source: BORDA

examples	COD g/cap.*d	BOD_5 g/cap.*d	COD/ BOD_5	SS g/cap.*d	Flow l/cap.*d
India urban	76	40	1.90	230	180
USA urban	180	80	2.25	90	265
China pub. toilet	760	330	2.30	60	230
Germany urban	100	60	1.67	75	130
France rural	78	33	2.36	28	150
France urban	90	55	1.64	60	250

At point-source effluent sources, like hospitals and small-scale industries, compliance with given discharge standards often proves too expensive. Thus, individual polluters frequently decide to either completely ignore the problem or to set up a fake treatment system to please the environmental authorities. In other cases, complicated technology is implemented, but often soon results in the described performance problems.

Indian National Discharge Standards					
			discharge into		
parameter	unit	inland surface water	public sewers	land for irrigation	marine coastal area
SS	mg/l	100	600	200	100
pH		5.5 to 9	5.5 to 9	5.5 to 9	5.5 to 9
temperature	°C	<+5			<+5
BOD_5	mg/l	30	350	100	100
COD	mg/l	250			250
oil and grease	mg/l	10	20	10	20
total res. chlorine	mg/l	1			21
NH_3-N	mg/l	50	50		50
N_{kjl}-as NH_3	mg/l	100			100
free ammonia as NH_3	mg/l	5			5
nitrate N	mg/l	10			20
diss. phosphates as P	mg/l	5			
sulphides as S	mg/l	2			5

Table 5:
Source: Central Pollution Control Board, Delhi

It is becoming increasingly apparent that a more realistic approach must be sought:

> "Undue haste in adopting standards, which are currently too high, can lead to the use of inappropriate technology in pursuit of unattainable or unaffordable objectives and, in doing so, produces an unsustainable system. There is a great danger in setting standards and then ignoring them. It is often better to set appropriate and affordable standards and to have a phased approach to improving the standards as and when affordable. In addition, such an approach permits the country the opportunity to develop its own standards and gives adequate time to implement a suitable regulatory framework and to develop the institutional capacity necessary for enforcement."[20]

20 Johnson et all, Institutional Developments, Standards and River Quality, 1996

Recently, an increasing number of countries have launched initiatives to draft more realistic legal frameworks. Regulations cover a wide range of topics, including the practices of service providers, design standards, tariffs, discharge standards and contracts. These regulations, especially design and discharge standards, are carefully adapted to local conditions and no longer just copied from regulations applied in industrialised nations.

For example, in its Water Act the Government of the Republic of South Africa defines differentiated wastewater-treatment and disposal standards, according to wastewater type, quantity and the location of generation. While high standards are applied to areas of high risk, in terms of ecology and health, lower standards are defined for other locations, such as sparsely populated areas. This pragmatic approach widens the scope of applicable technological solutions, ensuring a more site-specific treatment-option selection and thereby increasing the positive impact on health and environment on a larger scale.[21]

21 Ref. Government Gazette No. 20526 8 October 1999.

Comprehensive law enforcement was and is one of the major challenges to the successful implementation of wastewater strategies. Due to weak institutional capacities, the adherence to regulations was and is seldom properly monitored by public bodies. In many countries, the relevant authorities are rarely prepared to carry out performance-orientated site monitoring. Public agents frequently request the implementation of sophisticated hardware, even in cases where a decrease of wastewater pollution might be more efficient and less expensive achieved by wastewater-prevention measures. There is a great necessity for institutional capacity building. On the other hand, the corruption in many countries must be overcome, if the legal framework is to be enforced effectively.

The enforcement of comprehensive legal standards can be perceived as a major driving force for improving the current sanitation situation with efficient and cost-effective wastewater solutions:

- existing small and medium-scale industries are urged to comply with discharge standards in short term
- new industrial sites, slaughterhouses and hospitals only receive clearance once reliable wastewater treatment is provided
- new housing colonies and residences are only approved if they ensure efficient treatment of the generated domestic wastewater
- municipalities and local governments are urged to protect surface and ground-water bodies from the intrusion of domestic and industrial wastewaters

A reliable legal framework must be backed up by an efficient policy framework and law-enforcement procedures. Institutional capacities must be created, and standardised law-enforcement procedures must be developed.

Awareness-building campaigns within the civil society can help to create leverage for law enforcement. In many countries, cases have been filed by individuals, neighbourhood groups and NGOs, forcing polluters to close down operations because they were not willing or not able to meet discharge quality standards.

It seems obvious that recent and future ecological developments will be reflected in the legal frameworks. The extensive use of natural resources requires more stringent regulations. Surely economic instruments on the macro level will influence the sanitation sector in the near future. The more fresh-water resources are perceived as a valuable and scarce public asset, the higher water will be priced. Pricing directly influences water consumption and the search for wastewater solutions, which are based on reuse or "closed loop" concepts.

4.3 Target-oriented local and municipal planning

4.3.1 Features of urban infrastructure development

A closer look at the socio-economic structure of a city can provide a first overview of relevant decision parameters for the final selection of appropriate technology.

The dynamic economic growth of most cities in the developing world caused deep social transformation within these societies. Rural areas and villages were rapidly integrated into spreading urban settlements. Agricultural land was converted into new residential and industrial areas. These trends can be still observed almost everywhere.

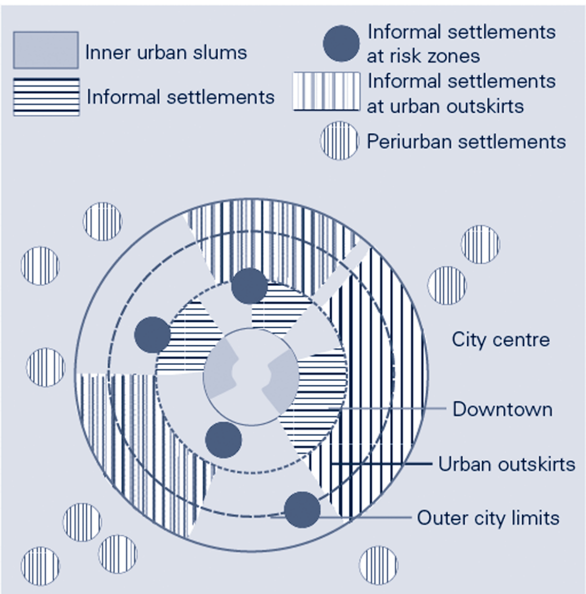
In most cases, this development lacks systematic planning of land use and adequate infrastructural development. By studying urban land-use patterns, one can gain insight into the social stratification and economic diversification of an area. While "wealthy neighbourhoods" are supplied with relevant infrastructure, informal settlements are left with only limited or no access to basic infrastructure. Even if a central sewage system cannot be extended everywhere, "formal" settlements are usually connected to septic tanks, while "informal" settlements have no treatment at all. Wastewater from industrial areas is commonly channelled directly to the closest surface waters.

Since informal settlements are a major driving force in most urbanisation processes, the following land-use pattern is quite common in the larger cities of developing countries.

Close to the city centre, a number of informal settlements exist. These are often found in so called "risk areas", such as dump sites, railway crossings, etc. The livelihood of the dwellers is usually dependent on activities in the informal sector or day labour.

Similar "peri-urban" settlements are found at the outskirts of urban areas. Dwellers of these settlements commonly generate income from day labour and small-scale commercial activities or business. If possible, self-subsistence farming is practised on nearby lands. Due to the unclear situation regarding land ownership – and the general negligence towards the urban poor, there is little public investment in infrastructure in these regions.

Since these areas are most responsible for urban growth, their importance to comprehensive urban-infrastructure development is obvious. Particular entities, such as small-scale industry clusters, schools and hospitals in semi- and peri-urban areas, face the greatest problems in meeting discharge standards.



Picture 4_3:
Informal settlements in greater urban areas of developing countries
Source: GTZ, 2002

4.3.2 Sanitation mapping as a tool for efficient urban-infrastructure development

In recent years Geographic Information Systems (GIS) have become an integral part of comprehensive urban-development strategies. GIS is a tool for visualising parameters, which are relevant for infrastructure development. Sanitation mapping permits the analysis of collected data, like the current situation of sanitation infrastructure, the impact of poor infrastructure on environment, and the driving forces, such as the socio-economic dynamics, of a given location. A database of the following parameters is beneficial for efficient sanitation mapping:

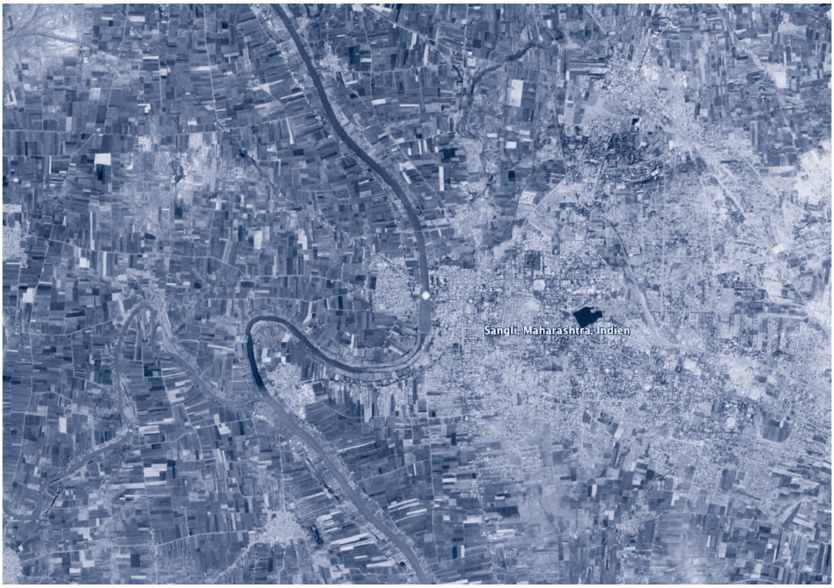
- topography
- natural water-drainage systems – rivers, streams, creeks
- land-use patterns – residential zones, industrial and agricultural areas
- existing city master-plan
- existing water-related infrastructure – sewers and water supply
- main water-pollution sources
- residential structure
- population density
- socio-economic situation of residents
- existing sanitation facilities
- community health conditions

GIS can be a powerful tool for poverty-alleviation programmes. Shelter Associates, an NGO based in Pune, India, implements housing programmes in poor areas. Shelter Associates applies GIS to generate a reliable database, which supports systematic programme approaches, as practised at the "Community Water and Sanitation Facility" at Sangli-Miraj-Kupwad Municipal Corporation (SMKMC).

SMKMC is located on the banks of the Krishna River in southern Maharashtra. In 2001, SMKMC had a population of 478,500. It covers about 118 km². Although the Municipal Corporation is only four years old, almost 15 per cent of its population live in slum settlements. The lack of access to basic infrastructure and civic amenities is a main feature of the area.

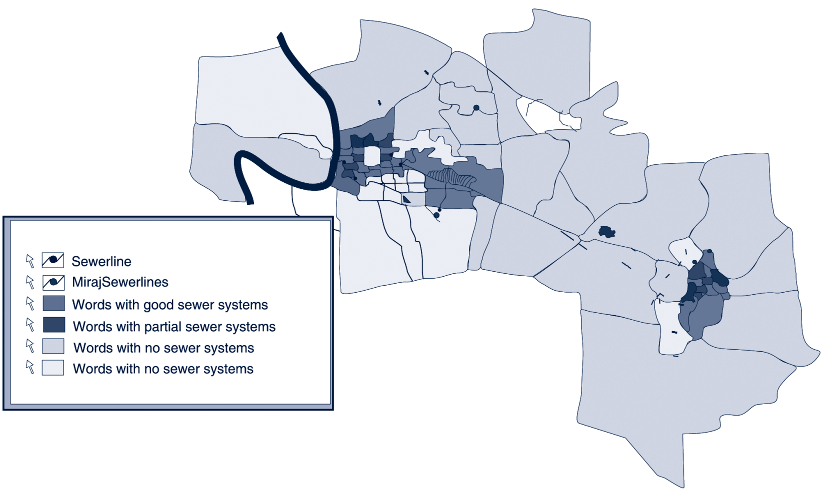
In order to get an overview of the existing sanitation situation, all the SMKMC settlements were mapped by plane table survey methods and each household was surveyed individually. The information was entered in GIS software and a detailed analysis of each slum pocket was compiled. The data generated gave a detailed picture of the existing water and sewage situation. Maps of the dilapidated water-supply network and sanitation facilities were developed.

It became apparent that the city has not undertaken any major improvements or extensions in the past 20 years. As a result, more than 11,500 households in Sangli were left without any basic sanitation access. Information gathered on a household level underlined the linkage between poor sanitation and weak socio-economic structures.



Picture 4_4: Satellite photo of SMKMC (Source: by google earth)

Picture 4_5:
Existing sewage system in SMKMC



Picture 4_6:
Sanitation-relevant data on household level in SMKMC

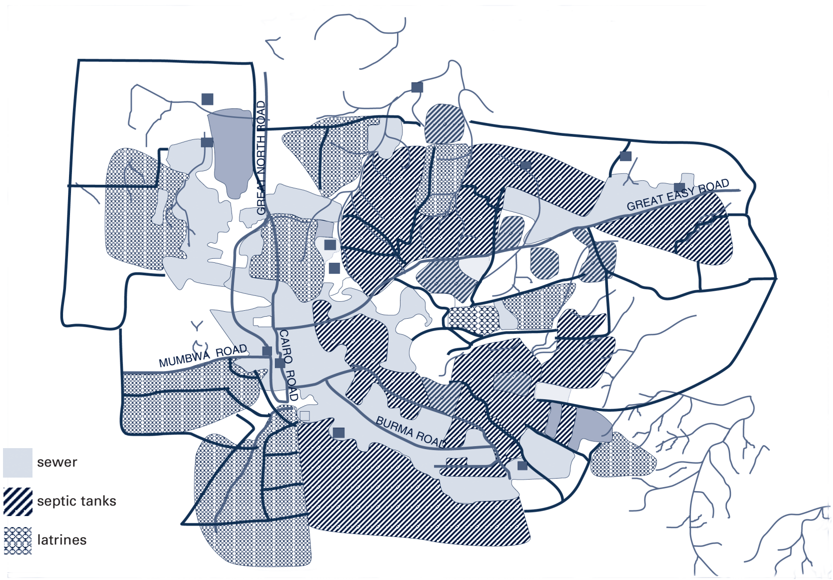
Similar features can be observed in the City of Lusaka, Zambia. A GIS-generated sanitation map shows that there are two main sewage-disposal methods within the urban area:[22]

- centralised waterborne methods, which comprise a sewer network, sewage-pumping stations and sewage-treatment works and
- on-site sanitation methods, like septic tanks and soakaways, pit latrines, aqua privies and cesspools

Additional information, relevant to the future development of a wastewater strategy and the identification of suitable technological options, was compiled:

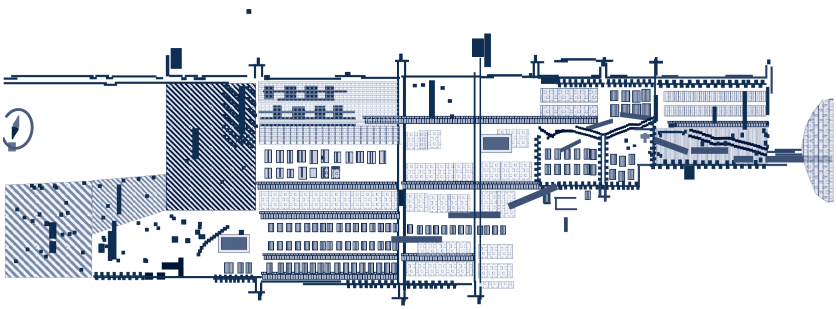
- only about 30% of the areas, which receive water supply from the Lusaka Water and Sewerage Company, are serviced by a sewer network
- the sewer network is divided into six catchment areas, each serviced by a sewage-treatment plant
- storm water and sewage waste are drained through separate systems.
- the sewage network operates mainly on gravity flow; few areas are served by pumping stations

22 Urban Development Plans and Infrastructure Services for the City of Lusaka., Lusaka Water and Sewerage Company, 2005



Picture 4_7: Lusaka Sanitation Map

The Community-Based Sanitation programme in Ullalu, Upanagara, Bangalore, India, described in section 3.3.2 also applied sanitation mapping to find the most effective way to improve the sanitation situation of the large slum's dwellers. Besides the careful assessment of physical parameters, such as topography, land availability and existing infrastructure facilities, comprehensive household surveys were carried out. After detailed analysis, participatory methods for project planning were applied. The combination of physical and social data within the same maps showed the connections between the availability of sanitation facilities at the household level, the socio-economic situation of the dwellers and their preparedness to contribute to the overall improvement of sanitation infrastructure (willingness to pay). The insights-gained were key decision parameters for sanitation-centre site selection. Chosen sites provide both the required physical preconditions as well as a strong acceptance of the new utility by the users.



Picture 4_8: Position of two sanitation complexes within Ullalu slum

For application in full-scale urban planning, sanitation mapping must combine a wide range of relevant parameters. Besides all the data mentioned above, the overall dynamics of current developments and the available resources within the sanitation sector should be included. The tool can then be used to assess whether decentralised wastewater-treatment solutions are appropriate for a given location.

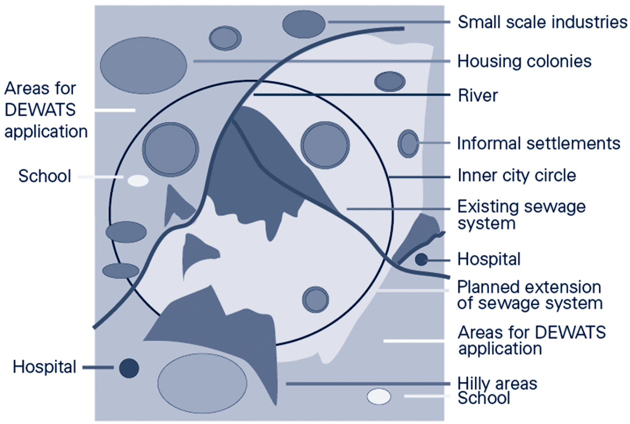
The following locations are the most favourable types for the implementation of DEWATS:

- locations far away from central sewerage and wastewater-treatment systems, or where a connection to such a system is unlikely due to financial reasons
- locations suffering from water scarcity

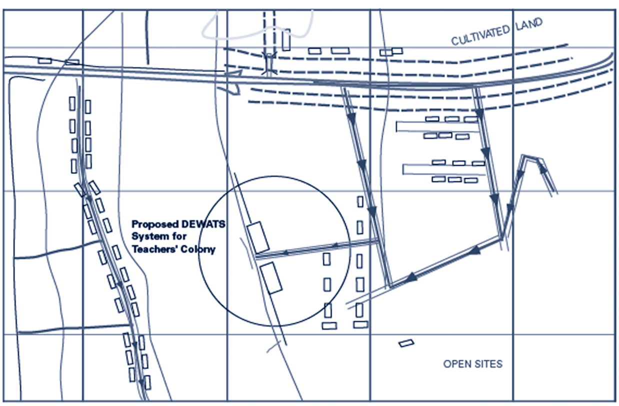
- locations which are difficult to attach to central sewage systems, due to the topographical profile of the area (hilly areas, ravines, etc.)
- locations with polluters, such as schools, hospitals, slums, new housing colonies, and small and medium industries, needing immediate and intermediate wastewater-treatment solutions[23]

23 Further planning details will be discussed in chapters 5 and 6

A sanitation map – containing all relevant data and parameters – should help identify those areas of a city, that are most suitable for centralised and/or decentralised wastewater-treatment approaches.



Picture 4_9: Example of how a sanitation map, detecting areas suitable to centralised and decentralised wastewater-treatment solutions might look



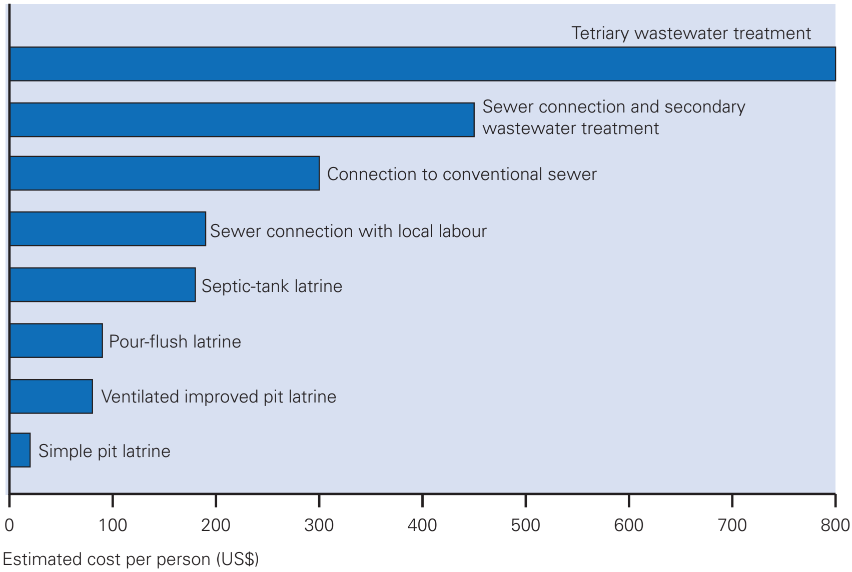
Picture 4_10: GIS-optimised positioning of decentralised sewage and wastewater-treatment facilities within a housing scheme in Karnataka, India

4.4 Financial analysis

4.4.1 Comparative cost analysis for infrastructure development

Economic parameters have a major influence on technology selection. Available funds must be allocated in such a way that the required treatment efficiency is met, while being cost-efficient in providing treatment of the desired quantity of wastewater.

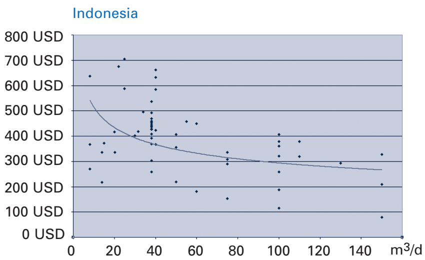
Centralised sewage-treatment systems usually require high investments – not only for the treatment unit itself, but particularly for the sewerage system. Decentralised solutions, therefore, often have a comparative advantage over conventional systems, especially when they are located in dispersed settlements or serve scattered pollution points.

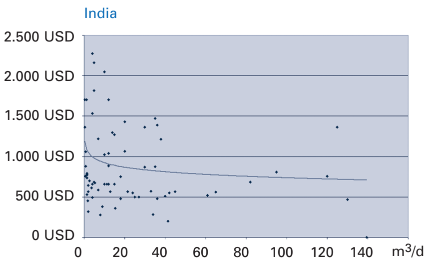


Picture 4_11: Costs of different sanitation options. Source: UNDP, HDR 2006

Solutions such as VIP latrines and pit latrines are at the other end of the investment scale. Their safe application, however, is usually restricted to rural areas with low groundwater levels, in order to prevent negative effects on the environment and on public health.

The highest potential of DEWATS lies in peri-urban areas. Costs for the sewerage network of a centralised system can be up to five times higher than the sewage treatment plant itself. On-site DEWATS reduce sewerage network costs significantly. Furthermore, the cost of the treatment unit should also be lower, due to a less-sophisticated technical layout.





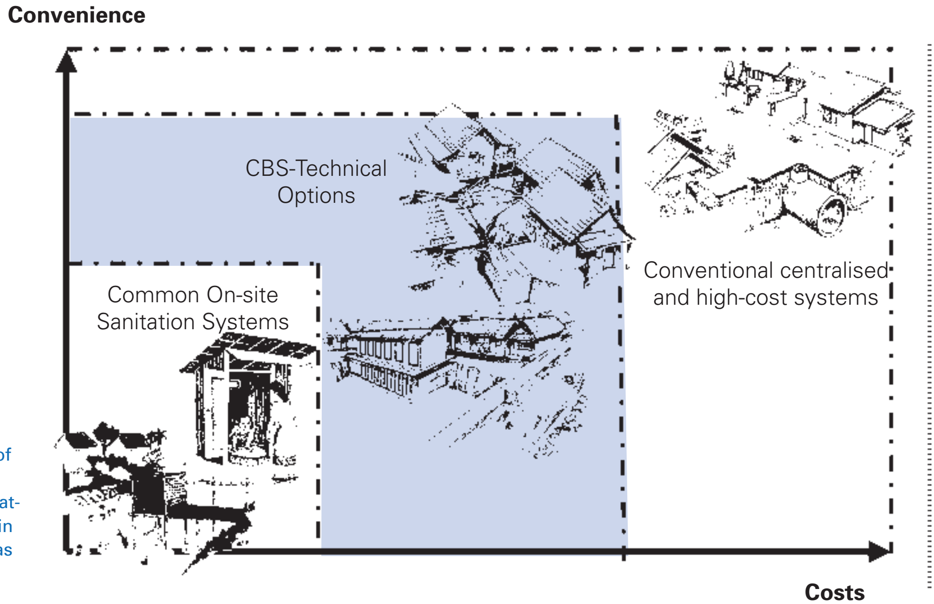
Picture 4_12: DEWATS, Indonesia: Initial investment costs vs. daily treatment capacity in m^3, 2004

Picture 4_13: DEWATS, India: Initial investment costs vs. daily treatment capacity in m^3, 2004

The exact cost of a DEWATS unit depends on the configuration of the system and the location. DEWATS are configured according to the desired treatment efficiency and various site-specific conditions. Since highest priority should be given to treatment efficiency and smooth handling of operation and maintenance, ponds rather than tanks and tanks rather than filters are recommended.[24]

24 Additional parameters, such as insect breeding, may need to be considered as well.

However, the ever-increasing value of real estate – not only in city centres, but also in fast growing peri- and semi-urban areas – eliminates treatment ponds as a viable option, due to their requirement for large surface area. Intensive treatment in compact anaerobic digesters proves more cost-effective in many locations. Due to restricted land availability, DEWATS are frequently constructed as a series of underground settlers, baffled reactors or anaerobic filters, followed by constructed wetlands and polishing ponds.



Picture 4_14: Cost and Convenience – a comparison of sanitation and wastewater-treatment systems in peri-urban areas

A study carried out in India and Indonesia shows the relationship between the scale of a project and the required DEWATS investment costs (land, materials and construction). The cost per volume of treated wastewater per day decreases significantly as the treatment capacity of the plant increases. The high variation of cost data within the study results mainly from varying property prices at the different locations.

In comparing different wastewater-treatment options, a comprehensive financial analysis should consider the following:

- investment in equipment and construction
- price of the land
- costs for financing
- operation and maintenance cost

4.4.2 Economic analysis in times of global warming and energy scarcity

The advantages of DEWATS over centralised systems become more apparent when external costs are included in the financial analysis. At a time of water scarcity, of rising energy prices and of global warming, decision-makers have to find their way through a multitude of important economic and ecological parameters. For example, most centralised systems rely on flush toilets, which contribute significantly to water consumption in growing urban water systems and, along with the increase in demand for clean safe water and the problem of large water losses, contribute to the deterioration of water resources. Particularly in present and future regions of water scarcity, this leads to greater water stress and higher prices for fresh-water generation. Increased water usage reduces the natural recovery capacity of water-catchment areas and, thereby, increases the cost to the national economy, as more of its environmental assets are depleted. Furthermore, the energy need for water transport and wastewater treatment is far higher than commonly perceived.

Given the complexity of the issue, it is obvious that the discussion about sustainable energy and water use has just started. But there is evidence that such strategies have to consider the "real costs" of the use of resources. Incorporating "real costs" into water and energy prices will influence utilities and institutions in their search for the most cost-effective technological option. In particular, technologies permitting water reuse – as DEWATS do – may gain significant, comparative advantages. Addressing complex urban water systems with a more holistic view can be achieved through the framework of life cycle management (LCM). At the core is the application of environmental life cycle assessment (LCA) as one of the most important tools.[25]

25 See publications by Pillay, Friedrich & Buckley on the LCA of sanitation systems.

As mentioned earlier, wastewater management plays an important role with regard to the sustainable use of water. According to the California Energy Commission, about 4% of California's demand for electricity is for the purpose of water transport and water treatment. Though such a figure might differ significantly from region to region and country to country, this electricity demand results in an important generation of CO_2 emissions. Looking at the impact of wastes and waste treatment, analysis data from the US EPA show that in the year 2000, 4% of the world's greenhouse gas emissions are caused by methane (CH_4) and nitrous oxide (N_2O) from anthropogenic wastewater, manure and solid waste. Wastewater itself represents about 1.3% of these emissions mostly generated in ponds, septic tanks and sewer lines where the methane is not collected and burned.[26]

26 See: Perry L. McCarty: "Towards Sustainability – A Paradigm Shift in Concepts, Analyses, and Goals", presentation at WEFTEC, 2007

In order to find out how energy consumption and greenhouse gas emissions from wastewater treatment can be reduced, Perry L. McCarty did a comparative analysis of three treatment layouts in California.

- the first: a "traditional" aerobic treatment with nitrification of the excess sludge
- the second: a "traditional" aerobic treatment with nitrification followed by anaerobic digestion of excess sludge
- the third: high-rate aerobic ponds for algae production followed by anaerobic digestion of the removed algae. The further treatment steps after algae removal are: stabilisation ponds, flotation, nitrification, filtration and disinfection

In this calculation it is taken into account that

- CO_2 emissions will be penalised and
- biogas generated in anaerobic digestion is used for cogeneration of heat and power

The analysis shows, that the third layout not only produces 80% less greenhouse gas emissions than the first layout; moreover, the absence of both oxygen supply and incineration allow for an unrivalled positive energy balance (Table 6).

The study concludes that wastewater treatment alternatives need to be evaluated against climate change concerns:

- methane from wastes must be contained
- desired alternatives are those that reduce both greenhouse gas emissions and power consumption
- anaerobic digestion is likely to be an attractive component of the alternatives and
- wastewater is considered a resource for water, energy and plant nutrients

Figures on how the energy consumption and greenhouse gas emissions from production of manufactured mineral fertiliser and its transport over long distances can be prevented through recovery of nutrients from wastewater is given in the SuSanA factsheet "Links between sanitation, climate change and renewable energies" (Sustainable Sanitation Alliance, working group 3).

As shown in section 3.3 (good practice), DEWATS solutions can serve as a model case for sustainability coming in response to climate change concerns:

- securing access to basic sanitation services,
- protecting natural resources and
- providing opportunities for reuse of water, energy and nutrients.

		CO_2 equivalents (1,000kg/day) based on the treatment of 10,000kg BOD_5/day							energy costs – US$ 1000/year treatment of 10,000kg BOD_5/day			
No.	layout	BOD re-moval	incine-ration	digestion CO_2	CH_4 oxi-dation	CH_4 losss [1%]	nitrifica-tion	energy usage	Total	oxygen supply	CO_2 penalty [US$20/ tonC]	excess power	Total
1	Aerobic + Incineration	3.6	20.4				2.8	2.2	29	178	58		236
2	Aerobic + Digestion	3.6		2.6	5.4	1.1	2.8	(3.3)	12.2	178	24	(299)	(97)
3	Algae + Digestion			3.4	6.8	1.4	1.2	(6.6)	6.2		12	(378)	(366)

Table 6: Greenhouse gas emissions and energy consumption from wastewater treatment in California Source: Perry L. McCarty, 2007[26]

Picture: 4_15: Timbuktu, Mali. Not only in semi-arid regions: flush-based toilet systems are often economically and ecologically unsustainable

4.4.3 Economic considerations for point-source polluters

Regional or urban planners may apply different economic-decision criteria to those of the owners of hospitals, small or medium enterprises, or residential estates, who are urged to find an efficient and cost-effective wastewater-treatment solution. While planners focus on the long-term overall development of a region, those running institutions or businesses are concerned with the compliance of legal-discharge standards, often at short notice. In these cases, decentralised wastewater-treatment solutions are frequently the only option; so the most appropriate decentralised option must be chosen. Decentralised treatment can be provided by:

- rotating, biological disc reactors
- trickling filters
- activated sludge processes
- fluidised bed reactors
- sequencing batch reactors
- or DEWATS, as described in this book

Picture 4_16
Many high-tech wastewater-treatment systems function inefficiently because it's not possible to have qualified staff to operate and maintain them

Since DEWATS are based on simple technology, which requires minimal operation and maintenance, they are favourable with regard to investment and running costs. Other technologies may require continuous support by qualified staff – often this is neither available nor affordable.

In theory, sound economic analysis requires comparable data about the various systems to be compared. In reality, the specific site conditions and the priorities of the decision-makers prevent the formulation of a standardised comparison and decision process. Every site requires its own assessment.

At the very least, the following parameters should be considered:
- potential for reduction of wastewater quantity
- potential for reduction of pollution load
- geography, geology and topography
- space availability
- availability of qualified staff for the required tasks
- discharge standards
- social environment and neighbourhood

Depending on the situation, the final decision usually has a strong socio-economic bias:

> "It has been shown that, under certain local circumstances, large variations in economy are to be expected, but the general conclusion (...) is that the economy of the various treatment processes does not differ that much. In many cases the costs are approximately the same. This increases the importance of those factors which cannot be included in an economic survey. Some of these factors are limiting factors in the sense that they limit the "free" selection between the various methods. If large areas of land are not available, then oxidation ponds must be disregarded even if it is the most economically favourable solution. If electricity supply is unreliable, then activated sludge systems cannot be considered. (...) It can be argued that the factors mentioned above are purely economic in nature, e.g. a reliable electricity supply is merely (!) a matter of economy. However, the costs involved in changing these factors to non-limiting factors are so high that there is no point in including such considerations here."[27]

27 The Danish Academy of Technical Sciences: industrial wastewater treatment in developing countries, 1984

4.4.4 Parameters for economic calculation

Global estimates of return on investments in water and sanitation published by WHO and the World Bank show that the return on a US$1 investment is in the order of US$ 5-34, depending on the intervention.
The benefits reflect a range of expected financial and economic savings to the intervention beneficiaries, including time savings due to easier access, gain in productive time and reduced health care costs saved due to less illness, and prevented deaths. The results are impressive and provide evidence that all water and sanitation improvements are cost-beneficial in all developing world sub-regions.
While investments in water and sanitation today are recognized as highly cost-effective interventions contributing to all Millennium Development Goals, it has to be added that the above mentioned studies are based on social and not financial cost-benefit analysis: costs reflect mainly financial costs whereas economic benefit is measured in terms of public health and social welfare (focussing on a real but hypothetical set of benefits) and not financially measurable benefits.
In other words: wastewater-treatment systems are not implemented to generate income. Although valuable by-products are created, such as biogas as a renewable-energy source, sludge as an organic fertiliser, or recycled water for the reduction of overall fresh-water consumption, wastewater-treatment systems are primarily infrastructural services, which must be financed by public/private bodies or individuals.
As the price of natural resources, such as oil or phosphorus, continues to increase, the valuable by-products of wastewater-treatment units will begin to play a greater role. In most cases, these products currently do not generate

Picture 4_17: The integration of DEWATS into the infrastructure – here is a parking lot in Java – can reduce investment costs

enough return to reach a financial break-even point. However, new macro-economic tools, like regulations that promote electricity supply to the grid and new power-generating technologies, are beginning to affect the market. Significant returns should be possible at sites with intensive animal husbandry in the very near future. As a general rule of thumb, however, classical financial cost-benefit analysis does not fit the economy of wastewater treatment – yet.

The annual cost method appears to be a more apt economic indicator. It creates a more comprehensive picture of the economic implications by factoring depreciation on capital investment and operational costs into the calculation. Expenses to the polluter, like discharge fees, or income from the reuse of by-products are analysed on an annual basis. A spreadsheet for computerised calculations is presented in chapter 10.

Cost of land

Data about the cost of land may be essential when comparing different treatment systems. The applicability of sand filters or ponds is affected more by the price of land than the applicability of compact anaerobic digesters; where land prices are high, compact tanks – not ponds or filters – will be the natural choice. The value of real estate can vary widely, depending on the location. In some cases, it may contribute up to 80% of the investment cost.

Construction costs

Annual costs are influenced by the lifetime of the hardware. It may be assumed that the building and ground structures have a lifetime of 20 years, while filter media, most pipelines, manhole covers, etc. are only likely to last for 10 years. Other equipment, such as valves, gas pipes, etc., remains durable for six years. All structural elements should be categorised into one of these three categories.It is assumed

Picture 4_18: DEWATS are quality products – planning and monitoring of implementation must be carried out by experienced staff

that full planning costs will reoccur at the end of the lifetime of the main structure, i.e. in about 20 years. In any individual case, the costs of planning can be estimated. Costing will be carried out by an experienced local engineering team being also responsible for designing and supervising the implementation of DEWATS used for. Due to the high-quality requirements of decentralised systems, engineering costs are likely to be relatively high. In addition, other labour costs plus laboratory costs for the initial testing of unknown wastewaters must also be included.

Table 7: Materials required to construct DEWATS to treat the wastewater of approximately 1,000 people (sewage production per day $80m^3/d$)

	Items of work	Unit	Quantity
1	Earth work, excavation for baffled reactor	m^3	478.40
2	Plain cement concrete (PCC), 10cm thickness, floor of the tank	m^3	23.92
3	Sand filling, 10cm thickness	m^3	23.92
4	Reinforced cement concrete (RCC), vertical slabs for outer walls, internal baffle walls	m^3	70.65
5	RCC, cover slab, 15cm thickness	m^3	23.23
6	Plastering inside the baffled reactor using 1:4 mortar	m^2	1,078.00
7	Pre-cast ferrocement baffle walls, 3cm thickness with necessary brick pins	m^3	236.87
8	Supplying and fixing 6-inch pipes for inlet & outlet	m	12.00
9	Supplying and fixing 6-inch T-pipes	no	4.00
10	Filter media for anaerobic filters	m^3	18.50
11	Manhole, size: 450mm x 450mm	no	15.00
12	Manhole, size: 600mm x 600mm	no	2.00
13	Filter drains for reusing treated water for irrigation	m	200.00

Running costs

Running expenses include the cost of personnel for operation, maintenance and management, including monitoring. Cost is based on the amount of time needed for qualified staff (including staff trained on the job) to attend to the plant. The time required for plant operation is normally assessed on a weekly basis. If inspection and attendance are covered by permanent staff, cost calculation is simple. Special services, requiring external work force, incur additional costs. Shared facilities, created by attaching 5 to 10 households to one DEWATS, are likely to be 10% cheaper than individual plants. In such a case, operational responsibility must be clearly defined to ensure reliable maintenance and sustainable operation.

Open systems, such as ponds or constructed wetlands, require more regular attendance than closed systems, as they may be damaged or disturbed by animals, stormy weather or falling leaves. The cost for desludging and sludge treatment, however, will be higher for heavily loaded tanks than for ponds, which receive only pre-treated wastewater.

Picture 4_19: Service vehicle in Vietnam – desludging costs are important for financial analysis

Additional benefits from wastewater treatment

The market value of wastewater treatment by-products can be estimated by calculating the price of the products that they substitute.
Especially in dry regions, water is a major cost factor for consumers. Recycling DEWATS-treated wastewater, therefore, may considerably reduce the water bills of private consumers, companies and other entities. As described in section 3.3 "good practices", the Aravind Eye Hospital in Pondicherry, India reuses 307m³/d of its treated wastewater for gardening or toilet flushing purposes, while the Bangalore-based Alternative Food Ltd. feeds a major part of its daily treated 30m³/d of wastewater back to its production processes.

Biogas has an economic value as a renewable-energy source, which can substitute other fuels. Approximately 200 litres of usable biogas are produced per kilogram of removed COD. The actual gas production equals 350 litres of methane (500 litres of biogas) per kilogram total BOD; however, a part of the biogas remains dissolved in water, especially at low wastewater strength. Biogas contains 60 to 70% methane. One cubic metre of methane is equivalent to approximately 0.85 litres of kerosene.

To allow biogas utilisation, the structure must be gas-tight and additional volume must be provided for storage. Pipes and valves are required to transport the gas to the place of consumption. The cost of operational and maintenance attendance is likely to be approximately 50% higher if biogas is used. Further additional investments enabling the use of biogas include, approximately, 5% to the cost of long-lasting structures (20 years, lifetime), another 30% to the cost of internal structures (10 years, lifetime) and an additional 100% of the cost of equipment (6 years, lifetime). The finance costs of the additional investment must also be considered.

If the use of biogas proves to be too costly or complicated, capturing and flaring (direct burning without use) should be considered for environmental reasons: methane is a greenhouse gas with a high global warming potential.

Picture 4_20: Aravind Eye Hospital reduces its water bill reusing treated significantly by wastewater

Picture 4_21: Modern rice boiler – the use of biogas is not only of interest as a way of creating return; it should be mandatory for ecological reasons

Treated wastewater can also be used to generate income through agricultural production or fish-farming. Safety issues are treated in section 11.4 "Reuse of wastewater and sludge" (page 318). Knowledge about the size and management of the farm, as well as an assessment of the market for selling the products, will assist in making economic predictions. Experience has shown, however, that exact predictions are difficult to make.

Capital costs

If investment capital is borrowed from a bank, direct capital costs – in the form of interest – must be paid. On the contrary, if one's own money is invested, the cost of this capital is indirect because it could be used in other profitable ways (purchase of raw material for production, investment in shares or bank deposits, etc.).

For calculation purposes, annual capital costs of 8 to 15% of the investment can be assumed, depending on location and current economic-market developments.

Picture 4_22: Floriculture in China – slurry from bio-digesters is a resource for organic farming

4.4.5 Sustainable financing schemes for sanitation programmes – multi-source financing and willingness to pay

At point-source discharges, such as small and medium enterprises, hospitals, etc., wastewater-treatment may be financed exclusively by the polluter – with or without subsidies or credit lines. Generally, however, sanitation and wastewater treatment must be viewed as a service provision, similar to water and electricity supply. Comprehensive analysis of local conditions is necessary to develop reliable financing schemes for residential areas.

The economic situation of the users plays a large role in the determination of applicable financing schemes. In industrialised countries, sanitation services are in most cases, paid for by the users themselves (in-house toilets are paid for directly, sewage lines and treatment systems are paid for through user-fees and tax systems). In most developing countries, however, large sections of the population cannot afford to participate in a full-cost coverage system. So the question arises: to what extent are users able to participate financially, and what alternative cost-recovery systems can be applied?

The World Bank promotes the following financing schemes for improvements in the sanitation sector:

- "Households pay the bulk of the cost incurred in providing on-site facilities, including on-site sewer connections
- Residents of a block collectively pay the additional cost incurred in collecting wastes from individual houses and transporting these to the boundary of the block
- Residents of a neighbourhood collectively pay the additional cost incurred in collecting wastes from blocks and transporting these to the boundary of the neighbourhood
- Residents of a city collectively pay the additional cost incurred in collecting wastes from blocks and neighbourhoods and transporting these to the boundary of the city or treating it in the city"[28]

28 Source: www.irc.nl/page/6456

Full-cost coverage should be achieved in residential areas with higher income levels. In poorer areas this cannot be expected, as surveys frequently indicate that "sanitation" is rather low on residents' priority lists for spending. At the same time, 100 per cent of charity driven approaches have failed repeatedly in the past; A substantial contributions from users, therefore, is perceived as an indicator for community appreciation of the project and should be considered a "must" for successful sanitation programmes, even if the contribution covers only a small fraction of the total cost. No sanitation activities without a substantial contribution by users!!

The local situation and relevant financial-boundary conditions of all stakeholders must be assessed to determine the appropriate contribution levels for the poorer members of the population. In dealing with sanitation issues, public decision-makers must achieve balance between social-equity issues and their financial constraints. Sanitation and wastewater-treatment services can be provided through multi-source financing, based on recovering costs from users and from public sources from local, regional and central governments and/or international donor organisations.

Alternatively, good experience has also been gathered in projects, where well-off areas cross-subsidised their poorer counterparts. No matter which approach is favoured, financial schemes should always focus on the long-term objective, to ensure sustainable operation of the sanitation and wastewater-treatment systems.

The following elements are essential in the development of a financial scheme for a sanitation programme:

- assessment of available public and private funds, users' economic status, willingness to pay, etc.
- technical feasibility study – identification and analysis of different layouts for sanitation and wastewater-treatment facilities
- calculation of overall project costs, including operation and maintenance – based on experience from pilot projects and/or preliminary tendering
- informed-choice assessment of different long-term, multi-source financing schemes – resulting in development of financing mechanisms and definition of user fees

Sound financial planning must take not only the initial investments into account, but also the long-term costs of continuous operation!

Sanitation programmes must gain the acceptance of the user; without user acceptance any financial scheme will fail. Users must express a definitive "willingness to pay" to guarantee sustainability. Experience shows that "willingness to pay" is often restricted to amounts, perceived by the user as benefiting them and in line with their priorities. Public health benefits like reduction in medical cost and lost working time do not necessarily rank very high among these. In many cases, studies to determine the "willingness to pay" show that users in weak economic situations are not willing and/or not in the position to pay for wastewater treatment (sewage systems and wastewater-treatment units). Under these circumstances, user fees covering the cost for operation and maintenance services can be considered a substantial and acceptable contribution.

Picture 4_23: In developing financial schemes, sanitation and wastewater treatment should be viewed as a service provision, comparable to energy and water supply

Picture 4_24: Residential areas with high income levels should achieve full-cost coverage for sanitation and ideally assist in cross-subsidising poorer areas

Picture 4_25: Community Sanitation Centre in Bali, Indonesia – unlike water and energy supply, sanitation service provision has few mechanisms for making users pay

Besides this problem, providers of sanitation and wastewater-treatment services face an additional challenge: unlike water and electricity supply, the service cannot be cut off if users refuse to pay. Once sanitation and wastewater equipment has been installed, few sanction mechanisms exist; users will find other ways to dispose of their waste – with adverse public health consequences for the whole community.