

# DEWATS

Decentralised Wastewater Treatment  
in Developing Countries



Ludwig Sasse  
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BORDA



## 3 DISSEMINATION

### 3.1 The Need for Active Dissemination of DEWATS

Planning and implementation of DEWATS is not a very profitable business for engineers and building contractors. Therefore, dissemination of decentralised wastewater treatment systems will need to be pushed by political will and administrative support.

The treatment units are relatively small, nevertheless complicated and are usually spread over a scattered area. The required expertise for their realisation is truly remarkable. Resultantly, general planning must be centralised and designing standardised in order to reduce the overall cost per plant and to maintain the required expertise. On the other hand, any centralisation will involve the setting up of a superstructure with its build-in tendency to create an expensive officer's pyramid. To achieve implementation of a large number of plants, a strong and omnipresent superstructure seems to be required. The dog bites in his own tail. However, this superstructure becomes relatively less expensive if the scale of implementation is large. Therefore, a reasonable, affordable and sustainable dissemination strategy is essential to balance the desired environmental benefits with acceptable social costs. Short-term economic viability of the superstructure cannot necessarily be the yardstick for choosing a dissemination strategy.

### 3.2 Preconditions for Dissemination

There are some preconditions commonly required for dissemination of any decen-

tralised technology or technical hardware. These preconditions have to be fulfilled before one may start thinking about a dissemination strategy:

- The hardware to be disseminated is technically sound
- In principle it is feasible to operate and maintain the hardware on the spot.
- The technology in general is economically and/or environmentally useful.
- The technology is suitable and useful in the particular local situation.

Dissemination would make sense only if these pre-conditions are fulfilled.

There will be no improved  
wastewater treatment without  
technical expertise

DEWATS, as a decentralised technology will always need local adaptation. Even fully standardised designs are constructed locally; for example, they have to be connected to the source of pollution and have to be set at proper level to allow free flow of effluent to the receiving water. Implicit in the decentralisation of technology is the decentralisation of know-how and expertise. Centralised guidance and supervision of decentralised activities is extremely costly. These services would therefore have to be kept to the minimum. This would be possible, only if basic knowledge and a minimum of expertise were locally available.

Local adaptation of DEWATS is influenced by:

- the technical requirements and solutions,
- the geographical or physical environment and
- the social and socio-economic circumstances.

On the other hand, dissemination has to choose a strategy which observes several aspects:

- the social aspect,
- the economic aspect,
- the technical aspect and
- the legal aspect

The dissemination strategy that is ultimately chosen has to include all these aspects.

### 3.3 The Social Aspect

#### 3.3.1 The Status of Waste Disposal in Society

The public is growing in its awareness of wastewater treatment as a result of increasing damage and pollution to the environment from wastewater. However, public interest appears to be confined to the harmful effects of pollution, only. In other words, there is no particular public interest in having a wastewater treatment plant - and there appears to be definitely even less interest in maintaining it. The general attitude is one of "somebody must do something".

The public needs to realise that that "somebody" is they, if nobody else really cares about their problem. The question then is with regard to the preferred treatment con-

cept. It is unlikely that individual DEWATS which must be taken care of by the individual will be very popular. Even if DEWATS were to be the only possibility, public willingness to participate in the programme would still be limited. Therefore, concepts, which require the participation of the general public, are not likely to work too well, and consequently should be avoided whenever possible.

Throughout the ages anything related to wastewater seems to have had very low priority. Even in olden times it was always people of the lowest social status who were put in charge of waste disposal. Unlike carpenters, masons or other professionals, these "scavengers" as they were called were never really interested in upgrading their discriminated skills. Understandably, the knowledge of wastewater disposal lagged behind other basic civic techniques. Strangely that missing interest was found even among royalty whose otherwise impressive castles had all but a primitive toilet outside. The well-designed and elaborate place of Versailles for instance, did not have a toilet. Similarly, the genius engineer Leonardo da Vinci developed weapons, bridges, air planes; but in his model city of 1484, treatment of waste was relegated to just one low-level wastewater canal.

Wastewater engineers are probably the only ones who love handling wastewater

Nonetheless, the taboo on faeces that exists over centuries is perhaps the most efficient sanitary measure, and still is from a health point of view a beneficial habit. However, the phenomenal population growth

easy to calculate, an estimate of realistic running costs would need an in-depth study of the technical requirements of the system as well as the prevailing social environment.

Further, it would need a fairly precise reading into future management structures. Overheads in form of salaries for the management, expenditure for the logistic requirements of operation and maintenance are extremely difficult to foresee, especially in the case of co-operatives. The cost of transporting sludge, for example, can increase manifold if the neighbouring farmer decides not to take the sludge. A new drying or dumping place could be so far away so that trucks would have to be hired instead of oxcarts as planned, sending calculations awry.

A **totally centralised system** would result in the lowest plant construction cost per treated volume of wastewater. On the other hand, connecting individual sources to the treatment unit may result in up to five times the cost for the required sewerage. Management costs are comparatively low because one highly qualified manager cares for a large volume of wastewater, respectively a large number of users. Maintenance costs are quite high, instead, because sophisticated mechanised equipment requires permanent care.

A **semi-centralised system** connects several smaller treatment units to sewerage of shorter overall-length. Construction costs are relatively low, but qualified management may be needed for each plant, thus pushing up the cost.

A **fully decentralised system** would need a natural environment that is capable of absorbing the discharged wastewater of each

individual plant on-site. Structural costs are likely to be the lowest for fully decentralised systems, especially if slightly sub-standard treatment is accepted. Safe sludge disposal must also be possible at site, otherwise the cost of transportation for sludge collection and disposal must be included. Maintenance and management costs are dispensed with when the user of the plant also attends to it. However, if proper operation on a more sophisticated level is to be secured, the need for qualified supervision and service structures may arise, which to a certain extent would need to be organised centrally (for example for collection and disposal of sludge). Regular effluent control is particularly costly in decentralised systems.

### 3.4.2 Treatment Quality

The kind of environmental pollution that exists tends to justify the strict discharge standards that prevail. However, standards that are extremely high, paradoxically may worsen, not improve the situation.

The nature of treatment is first of all a function of the area, for which one may allow a certain degree of environmental pollution. If the area where pollution occurs is infinite, there may be no necessity for treatment. Similarly, when pollution is infinitely small the polluted area is zero. Situations between these two extremes should be open for setting priorities, meaning that the final choice should be open to negotiation. Economic, social and environmental aspects would each merit due consideration to reach the most acceptable compromise with regard to the required treatment quality.

Permitted discharge quality will also depend on the location of pollution. Transport of wastewater to sites further away instead of on-site treatment had been practised since man developed settlements. Today, wastewater transportation to remote land or waters is still common. While this is may be acceptable today, the damage to the environment may become irreversible and in time, the legacy of pollution could hit back at the polluter. In the case of DEWATS dissemination, the decision to treat wastewater on-site and not just send it away is already made.

In most countries national pollution standards allow for higher pollution loads in effluents of smaller plants, and effluent standards are "softer" when the discharge is onto land and into waters that are little used.

Discharge standards in developing countries have often been borrowed from industrialised countries, which are based on highly diluted municipal sewage. DEWATS in developing countries are meant for public toilets, hospitals, schools or smaller communities where it is likely that lesser water is used for household and toilet purposes than in industrialised countries. The high concentration of wastewater from water saving toilets leads automatically to higher BOD concentration of the effluent, even when BOD removal rates are within the technical range of an adequate treatment system. In such case, as saving of water is crucial to sustainable development it would not be reasonable to dilute the effluent "artificially" in order to achieve an administratively imposed concentration. Standards which relate to absolute pollution loads (instead of concentrations) would be more reasonable, at least for small units.

This point is especially important, because one of the great advantages of decentralisation and on-site treatment is that waste transport in short sewer pipes does not require highly diluted wastewater. Despite higher concentrations, the absolute pollution load remains the same. Water saving policies could easily accept higher concentrations at the outlet when other environmental factors being favourable; for example when there is enough land available or the receiving river carries enough water the year round.

Furthermore, it makes little sense to install DEWATS of a high treatment quality, when their effluent joins an open sewer channel which receives other untreated wastewater. In this case, simple, individual septic tanks, which cost less but are albeit less effective in their performance, would be appropriate, because treatment of the main wastewater stream would in any case have to be done.

### 3.4.3 Treatment Cost

Thirty to fifty percent of the pollution load may be removed with simple technology, such as the septic tank. Another thirty to forty percent might be removed with the help of units such as baffled septic tanks and anaerobic filters that are yet simple but far more effective. Any further treatment would require post treatment in ponds or constructed wetlands (conventional systems using artificial oxidation do not belong to the DEWATS family). The higher the relative pollution removal rate, the higher are the absolute treatment costs per kg BOD removed. Additional treatment devices for removal of nitrogen, phosphorous or other

toxic substances are likely to be unusually expensive.

Technically spoken, DEWATS are able to meet any discharge standard. However, since self sustainable dissemination of DEWATS is likely to be strongly influenced by investment and operational costs, the choice of an appropriate treatment standard will not only determine the dissemination strategy but may be vital for the total success of DEWATS.

Treatment efficiency of DEWATS may be as high as that of any conventional treatment plant

Environmental experts and experienced wastewater engineers would need to determine appropriate treatment standards. It is crucial that authorities that administrate pollution control have a understanding of the issue and can be flexible in accepting and legalising deviations from general standards, so long as these deviations are ecologically acceptable.

#### 3.4.4 Investment Capital

As there is generally no financial return on wastewater treatment there is little genuine economic interest to invest in it. Apart from the few persons who act out of a sense of responsibility for the environment, there is rarely anybody who invests in wastewater treatment voluntarily. Only if and until polluters are compelled by law to pay for the pollution they cause will investment capital become available to wastewater treatment, because investment in wastewater treatment will be viable compared to imposed fines.

Construction budgets for new buildings and enterprises are likely to include wastewater treatment costs. Existing units, apart from the problem of having the space for construction may not be able to raise funds for installing a treatment unit at one time. Dissemination programmes must therefore necessarily ensure the availability of credit schemes to polluter's for wastewater treatment.

A sustainable dissemination strategy must take into account the time it may take a polluter to allocate the required capital (for example, to wait until the next board meeting decides on the matter). Practically this could translate into a time lag of a year or more between the time when the planning engineer invites the contractor to see the site and make a realistic estimate for construction and the availability of funds for the purpose. Besides the inflation factor this also implies that a contractor cannot afford to rely solely on DEWATS for his survival. Under these circumstances it may be difficult to recruit contractors who are permanently available to a DEWATS dissemination programme.

### 3.5 The Technical Aspect

#### 3.5.1 Decentralisation

From an economic point of view, decentralisation requires a simplified technology for the reason that it will be prohibitively expensive to permanently maintain the necessary expertise for sophisticated technology on a decentralised level.

It may be possible to actualise decentralised solutions with the help of completely standardised designs based on local con-

struction techniques; in other words, by placing "black-box" hardware packages on the "market". In both cases expertise will be needed for choosing the right design or the suitable "black-box". Expertise will also be needed to advise the user in proper operation and adequate maintenance. Such advice must have a stable address, which might be difficult in case certain operations become necessary after one or two years only, for example in the case of de-sludging. This could also mean that the constructing enterprise would need to be contracted for maintenance and operation on behalf of the customer. The expertise available for on-site operation and maintenance would decide on the nature of required plant management.

Invaluable experience gained from rural biogas dissemination programmes over a span of 30 years in India, China and several other countries confirms that each such project or programme had first to develop an appropriate local design notwithstanding the availability of standardised designs from other projects/countries. Interestingly neither India nor China have been able to sustain the dissemination of their small-scale rural biogas programme from a technical point of view without the support of a superstructure. In most cases it has been difficult to ensure that the user has sufficient expertise to maintain the biogas plants properly. None of the programmes have been able to do without a subsidised after sales service. This scenario is bound to be true to other areas of technology dissemination as well.

DEWATS is far more complicated than rural biogas plants. The bio-chemical and physical properties of wastewater especially in case of wastewater from industrial sources

are far from uniform. Consequently, the expertise required for design, construction and operation of DEWATS become all the more indispensable as compared to rural biogas plants. One of the crucial points is to decide whether a standard design is suitable, or how it should be modified.

The availability of the right expertise is irreplaceable in DEWATS dissemination. It is decisive for a dissemination programme of decentralised plants to clarify the nature of the expertise that is to be maintained, at what level and for which technology. Missing knowledge and expertise cannot be consigned to the insignificance of a so-called "social matter". Professionals and technicians are duty bound to ensure that the goods or structures they provide are technically sound and appropriate. The breakdown of a technical system is not necessarily the fault of the customer. It is the duty of the technician to deliver the right design for a given situation.

<p>It is the duty of the technician to deliver an appropriate design which will be realised with an appropriate technology</p>
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A division of labour between different experts is essential. It is the duty of the non-technical "social" staff to feed the technician with information about social matters and the technician to feed the social experts with information about the technical necessities. What is required is collaboration between the disciplines, not role confusion. It is a known fact that technicians as a rule do not give enough information about technical necessities to social experts. This in all likelihood happens for two rea-

sons: the technicians do not know the technology well enough and/or the social experts are not able to understand the implications of the technical requirements. The problem of sub-standard technical knowledge is likely to be true of most potential DEWATS constructors - and promoters.

### 3.5.2 Construction

The local availability of hardware is a precondition for decentralisation. In case of main structures, appropriateness of local building material plays a decisive role in executing the construction. The kind of filter material available for instance influences the choice of the treatment principle. Expertise is needed to modify standard designs, or if necessary, make new designs, which can be constructed with locally available material. It is also important to decide whether traditional construction techniques are suitable for wastewater treatment systems, especially if biogas is supposed to be used. The expert has also to decide whether the treatment system fits the local geography.

At the level of implementation of small-scale treatment systems, the qualification of craftsmen is usually low. Masons may not be able to read and write and thus, structural drawings are not useful at site. Structural designs would therefore have to be simplified or supervisors who are properly qualified to read the drawing be present regularly.

Familiarity with the design principles apart, a mastery of structural details will be crucial to the proper functioning of the plant. The need for correct execution of the structural details of the design cannot be over-emphasised. Cost or efficiency enhancing modifications of structural details is ill

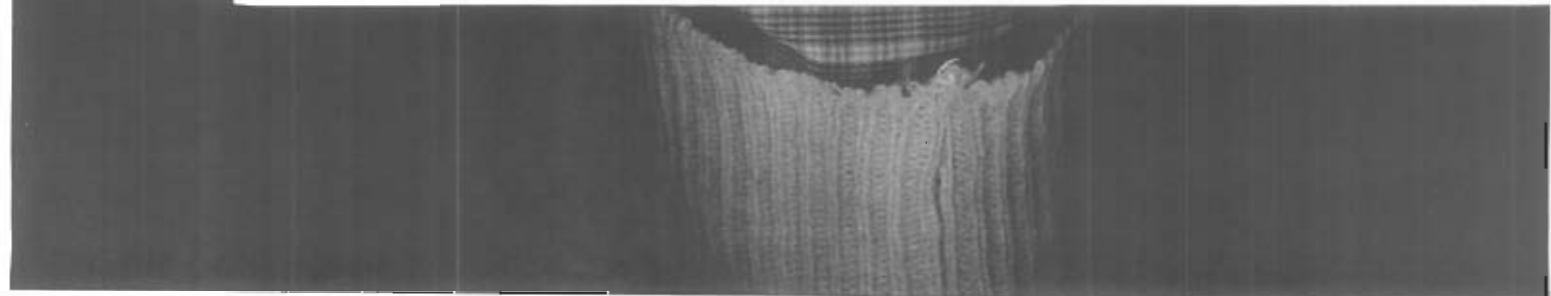
advised in the absence of a deep understanding of the proposed measure. For example, a dentated sill is of no use if the top of teeth, instead of the bottom notches, is kept in level.

### 3.5.3 Substrate

The quality, quantity and other properties of wastewater determine the treatment principle from a scientific point of view. The type of treatment system finally chosen will depend on the geographical, structural and socio-economic conditions. Expertise to analyse and evaluate the wastewater, to choose the most appropriate treatment system and to countercheck the design in respect to its local suitability will be imperative.

In the absence of such expertise at the local level, standardisation on the basis of similar wastewater in the region will be the next step. The local expert should then at least be able to distinguish between "standard" and "other" wastewater. To do this, there must be somebody in the disseminating organisation that can read laboratory results or, at least understands the importance of working with the right data in choosing the appropriate structure. Furthermore, someone would be required to collect representative wastewater samples and interpret the laboratory results for the technician.

Low maintenance is demanded of decentralised wastewater treatment. If structural measures can improve treatment, chemicals such as coagulants are „forbidden“. However, the use of chemicals may be unavoidable if bacterial growth is impaired by nutrient deficiencies, e.g. an unbalanced phos-



phorous-nitrogen ratio. Bio-chemical expertise is required to decide if such measures are really necessary.

### 3.6 The Legal Aspect

#### 3.6.1 The Political Environment

The over all political climate is as important as the administrative framework. It is important to know who the movers are and the different roles each actor plays. It is also important to be familiar with the regulatory framework and more specifically the extent to which rules and regulations are actually enforced. To politicians, inefficiencies of the legal framework are at worst a moral matter, only, whereas to those implementing a DEWATS dissemination strategy, inefficiencies of the socio-political environment are essentially a fundamental planning parameter.

Conventionally, policy is formulated on a bedrock of relevant facts. Familiarity with scientific or technical facts ensure that the right policy and the right laws and by-laws are shaped. Decision-makers should know that each step in the treatment process removes only a portion of the incoming pollution load. It is also important that they know that DEWATS is premised on the belief that wastewater treatment should be permanent and that permanency can only be guaranteed by simple and robust systems. This implies that permanent wastewater treatment is not possible without maintenance. Nonetheless, in DEWATS, maintenance operations are kept to the absolute minimum - necessarily.

#### 3.6.2 Political Priorities

Political and administrative preferences lean heavily towards large scale, centralised wastewater and sewerage systems. Given the fact that most wastewater is produced by urban agglomerations, this is understandable. Domestic wastewater from towns and cities is the largest single source of water pollution. Industrial wastewater from suburban areas comes next. In India it has been estimated that only 50% of the wastewater that finally reaches the river Ganges actually passes through urban wastewater treatment plants. The other 50% of this water flows untreated into the environment. Whether this untreated 50% can be actualised into a potential demand for DEWATS depends on policy making and the seriousness of its application.

Most governments tend to sacrifice environmental concerns on the altar of fiscal demand. The industrialised west has been no different. The history of wastewater treatment in Europe and North America reflects the tug of war between the economy and the environment. Earlier and today, the state-of-the-art of treatment technologies and regulatory framework is the outcome of this dialectic.

The same seems to be happening in developing countries as well, the only difference being in the import of advanced treatment technologies from industrialised countries. Today environmental standards, i.e. discharge standards for wastewater are being based on the treatment technologies that are available, and not on the prevailing state of the economy. This is leading to a strange situation wherein the strict discharge standards are hardly followed because their application is too expensive. Thus, the indi-

vidual polluter gets away by completely ignoring the problem or by setting up a fake treatment system to please the environmental control officer. Either way, the environment is not protected. On the other hand, were environmental standards to be more realistic and feasible there is greater likelihood of adherence to the law by individual polluters.

"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."

(Johnson and Horan: "Institutional Developments, Standards and River Quality, WST, Vol 33, No 3, 1996)

It is also important to apply a law in keeping with its original intention. But this is only possible if the technology is fully understood. It is interesting to know that England at the end of the last century considered case by case assessment of individual polluters but abandoned the proposition fearing administrative snarls and an untenable relaxation of discharge standards. In the current scenario when decentralised wastewater treatment is being taken far more seriously than in the past, such an approach may still be advisable. In the case of pond treatment *Duncan Mara* gives an example:

"If filtered BOD was permissible then a one-day anaerobic pond plus a 4-day facultative pond could reduce the BOD from 300 to 30 mg/l filtered, but to

only 60mg/l unfiltered; two 3-day maturation ponds would be needed to get the BOD down to a 30 mg/l unfiltered - equal to an increase in retention time of 120%! So the filtered, unfiltered question has major cost implications. Those who might worry about the effect of pond algae in a receiving watercourse should remember that they will produce oxygen during the day but, more importantly, they will be quickly consumed by the stream biota,... So maturation ponds are not always required."

(D. Mara, "Appropriate Response" in WQI May/June 1997).

Another obstacle to achieving a better degree of treatment are unrealistic and overly ambitious master plans that could never be successfully implemented in the given time and resource frame; whereas more modest, intermediate solutions would be more likely to succeed. In all fast growing towns and cities, municipal boundaries have been over run by rapidly expanding urban agglomeration; a fact, that is perhaps not even reflected in the master plan. On the other hand, an over extended master plan could be well beyond the financial and logistical strength of the municipality. A more general solution, that includes appropriate decentralised treatment systems could improve the environment considerably, although this measure would have to bear the label of being only "temporary" („temporary" like slums, which by practice became „permanent“).

### 3.6.3 Legal Aspects of Some Sectors of DEWATS Application

#### 3.6.3.1 Human Settlements

Administrative support to disseminate DEWATS must distinguish between low-income areas, middle class housing colonies and high income "enclaves". A pragmatic

approach would be to pass a "temporary" by-law (or short-term master plan) for a specific area, which reflects both, the economic as well as the environmental situation. Making the ultimate degree of treatment the yardstick does not work. A more realistic benchmark ought to take into account the capacity of the administration - financial and logistical - to enforce the feasible standards of those "temporary" by-laws. Since local conditions vary from site to site, the prescription of absolute measures would be self-defeating were administrative guidelines would be more befitting. Such guidelines should take into account:

- Items which can immediately be considered, e.g. treatment systems which can be implemented by the individual polluter or the respective group of polluters at the time of constructing the buildings.
- Items which will remain valid into the future, and will not conflict with future master-plans.
- True temporary items which may have a shorter life time or lower performance than "everlasting" structures.

The key purpose behind temporary by-laws would be to prescribe, rather dictate a set of DEWATS measures, than to set standards of discharge quality which have to be controlled. Durable, anaerobic rough treatment systems such as baffled septic tanks or anaerobic filters may be most suitable in such cases. Smaller sewage diameters could later be used if these pre-treatment systems are kept permanently in operation. A centralised maintenance service or control over a decentralised service would be needed to guarantee that the system works.

In case of high-income enclaves, individual post treatment with planted gravel filters would be appropriate when receiving waters are not located too far away. Otherwise, post-treatment is preferably done in semi-centralised units, e.g. ponds, which might be cheaper to construct and operate. Sewage lines cannot be avoided in that case.

### 3.6.3.2 Hospitals, Schools, Compounds, Army Camps, Hotels, etc.

An institution could sometimes be the only substantial polluter in an otherwise clean and healthy rural environment. In such a case, permanent on-site wastewater treatment is the only solution.

The best approach to achieving the highest degree of environmental protection would be to let realistic assessment of possible treatment methods guide administrative control. The potential of the most appropriate DEWATS should be the basis for setting discharge standards and for dictating compulsory treatment units. Durability and permanence should rule over the tendency to set the highest theoretical standards of treatment performance.

In the case of new installations, only options which fulfil DEWATS criteria stand a chance of providing permanent and viable service. Systems using artificial oxidation technologies should not be permitted, since the system can be switched off without negative impact on the polluter himself. The pollution control authorities have to propose DEWATS if the polluter or his planning architect is not familiar with that option. It should not be difficult to enforce the necessary by-laws, since DEWATS is probably the most economic alternative.

### 3.6.3.3 Industrial Estates

Industrial estates are a conglomeration of enterprises that produce wastewater of varying volume and strength. A common treatment plant for the whole estate may be the best solution. However, it may be difficult to convince all the entrepreneurs to pay towards a co-operative treatment system, particularly if only few members discharge substantial amounts of wastewater.

A co-operative treatment plant may be the right solution, but people forced to co-operate may not think so

In a decision that favours individual treatment systems, the application of general discharge standards may turn out to be unjust to certain enterprises, or may even discourage certain industries from settling in the estate. In a scenario where the wastewater output by the majority of the enterprises is low and only a few industries would merit environmental control, strict discharge standards enforcement for only those few may not lead to an acceptable wastewater quality at the exit of the estate, since the large number of small polluters may have greater impact than one or two severe polluters. A more moderate application of the law could be more productive because of its inherent feasibility. However, it is the decision of the administration to allow such exceptions. If discharge standards are strictly enforced, larger cash rich enterprises may opt for conventional (non-DEWATS) solutions, which are quite likely to succeed if control and operational management will be maintained. Fund starved, small-scale

units on the other hand are bound to cheat on pollution control whenever possible due to financial constraints.

Small-scale industries that have substantial wastewater production need land for final treatment systems, such as ponds or constructed wetlands which depend on natural oxygen supply via surface area. The required land ought to be provided to the individual enterprise or to the estate as a whole at a lower rate. New industrial estates are seldom connected to sewer lines immediately. Thus, provision of land for such post-treatment systems would need to be made right at the planning stages. If the pollution control officer could agree to apply the legal discharge standard at the outlet of the total estate, instead at the boundary of the individual enterprise, existing estates could use open drains as natural oxidation ditches for post treatment.

### 3.7 Dissemination Strategy

It would be overbearing, or at least premature to pretend to know *the* dissemination strategy for DEWATS without having in mind a particular situation. Dissemination strategies for decentralised technologies must be based on local facts and actors, explicitly, however under consideration of general factors, such as:

- the requirements of the technology itself (first of all!)
- the legal framework, and
- the conditions for funding of the necessary infrastructure, including a likely superstructure.

### 3.7.1 Components of Dissemination

#### 3.7.1.1 Information

The terminology "awareness building" does not appear to do justice to the subject. While there may be a need for awareness building with the administration in some places, the existence of rules and regulations are indicative of awareness in most countries. After becoming aware of their problems, clients want information on solutions. Implicit in knowing the technology is knowledge of the limitations and conditions under which the potential of the technology can be put to use. Beside direct customers, administrators, and potential implementers (contractors and engineers, etc.), the general public also needs to be informed.

Low maintenance does not mean  
NO-maintenance.

#### 3.7.1.2 Regulation

Regulation of discharge standards play an important role to create the need for treatment and to choose the appropriate technology for it. Regulations should be flexible enough to allow appropriate alternatives without putting at risk the environmental needs.

#### 3.7.1.3 Financing

Wastewater treatment is a cost factor and represents a substantial investment to most polluters. While financial incentives may accelerate the introduction of new technology, their prescription as a general instrument for implementation is ill advised. Nevertheless, access to soft bank loans is essential, particularly to small-scale enterprises.

#### 3.7.1.4 Implementation

Characterised by a small building volume as base for calculating engineering fees, DEWATS understandably does not attract engineers. Engineering companies would need to be seriously persuaded to design DEWATS instead of "conventional" treatment systems of which components can be bought ready made. It may be worth subsidising engineering fees as a promotion instrument until at least that time when DEWATS becomes popular. These incentives are social investments which ought to be calculated against the future gains of a pollution free environment. In the same vein, it may be necessary to pay engineers to train contractors in DEWATS construction. One precondition for that is that expertise and knowledge about DEWATS is available with the free-lanced engineers.

#### 3.7.1.5 Operation

Treatment plants that work without a minimum of maintenance and supervision are non-existent. It seems difficult to keep the knowledge about maintenance for sure with the polluter until maintenance becomes necessary for the first time. User training and professional maintenance would have to be guaranteed for some years at least, through a contract between the customer and the supplier.

#### 3.7.1.6 Control

Control is the flip side of regulation. If an improved control system cannot be part of the dissemination strategy for financial or other reasons, then control must insist on the implementation of reliable technology options, such as DEWATS.

### 3.7.1.7 Reuse of Resources

Treating of wastewater requires a different expertise than for the re-use of wastewater and sludge in agriculture or fishery. Similarly the utilisation of biogas also requires special expertise. If the re-use of by-products is to be part of the dissemination strategy, the engagement of other appropriate agencies or individual experts to attend to this purpose may become expedient.

## 3.7.2 The Motors of Dissemination

### 3.7.2.1 The Government

As governments are primarily responsible for environmental protection, by the same convention, the responsibility for the dissemination of DEWATS should essentially also vest with the government. The government's major guiding instrument is reliable control of reasonable discharge standards. Nonetheless, a suitable legal framework may also include tax exemption, the provision of subsidies - direct or indirect- and surety for bank loans. Direct subsidies, which are perceived to distort economic competition, are no longer in vogue. Consequently it may be necessary to structure indirect financial support to activities such as awareness building, research, training, or infrastructure to non-governmental organisations (NGOs), private enterprise and professional associations to enhance the scope of dissemination. Project ideas would principally have to come from these agents.

### 3.7.2.2 Non-Governmental Organisations

Characteristically, NGO's play a variety of roles foremost of which is their innate support to weaker groups of society to fight

private or governmental abuse of their right as citizens. Today a large number of NGOs are committed to environmental justice. It is not uncommon to find NGOs protesting against the violation of pollution standards and succeeding in getting the government to bring the law to bear against careless offenders or to even get the government to change archaic rules and regulations.

The role of the NGO may be extended to implementation and technical training as long as the normal "market" forces consisting of engineers and contractors have not become involved adequately. However, it is important to realise that wastewater treatment is not a matter of propaganda but a matter of applied natural science. No NGO can become an implementing agency without permanently involving persons of sufficient scientific and technical knowledge.

Wastewater treatment does not happen through propaganda, but through applied natural science.

NGOs start traditionally from acute single cases and then, with growing experience and knowledge move towards a more general approach. NGOs have the inherent potential to effectively disseminate DEWATS provided powerful persons and institutions support them in overcoming administrative bottlenecks and in accessing the funds that are needed for their activities.

### 3.7.2.3 Development Projects

At the one hand, development projects may either create a model reality, and try to manage it well for demonstration purposes,

or at the other hand, execute and support measures which directly influence the prevailing reality outside and beyond the project.

For demonstrating a general idea it might be effective to create a limited and controllable model reality wherein everything works well. However, it would be dangerous to believe that the model is a reflection of reality, because of the expenses involved this proposed reality can never come true.

Rural biogas dissemination and other development programmes have proved that such well-designed projects are not examples of what is really possible. The lavish organisational structures that such programmes demand are counter productive. The pressure to present a perfect project solution has proved not to bring forth a sustainable solution for the time after the project is over.

Decentralised wastewater treatment is a very complex subject that is greatly influenced by socio-economic and political circumstances. A development project is at best a modest contribution towards eliminating bottlenecks in the overall complex reality of a specific development sector.

Foreign aided development projects that are partnered by government agencies or local NGO's may be a suitable instrument to overcome financial and structural shortcomings. The character of the local partner organisation and its need for support determine the nature and character of any aid from outside.

### 3.7.3 Approach to Dissemination

#### 3.7.3.1 Individual Implementation

Dissemination of DEWATS means first of all, the construction of as many plants as possible. Any private engineer who designs and initiates the construction of DEWATS for his customers, provided his plants are well designed, well constructed, well operated and well maintained is the perfect disseminator. However, his efficiency depends on the ability to acquire new customers through the propaganda about his good service.

Buildings and other structures, including established treatment systems such as septic tanks are conventionally implemented by individual contractors. Designs for septic tanks of different sizes are easily available and their construction does not require more than the usual building practice. Building contractors install septic tanks as effortlessly as they put up buildings. Anaerobic filters or constructed wetlands are not that easy to disseminate. Rigid standardisation tends to jeopardise the economy and the design principles of these systems. Consequently a deeper understanding and a higher degree of expertise is required at the level of direct implementation. This could be achieved through training or qualified supervision during construction of these "unusual" structures. However, both options would require a superstructure to execute and finance these services. Baffled septic tanks and pond systems could be disseminated with less specialised expertise.

#### 3.7.3.2 Sector-wise Dissemination

Individual implementation would be the best approach to dissemination provided standardised designs were to be available, at least

for those cases that are most common in a given situation. Any dissemination strategy, which relies on relatively low professional standards for implementation, should best follow a sector-wise approach. For example, there could be standardised treatment systems for housing colonies of one city, for rural hospitals in a hilly area or for hotels and holiday resorts at a scenic lake. Latex sheet processing plants at small rubber farms could as well be standardised, so could plants for wastewater from rice mills or canning factories.

**Tab. 2.**

*Average data of domestic wastewater at various places*

Some selected domestic wastewater data					
examples	COD g/cap.*d	BOD <sub>5</sub> g/cap.*d	COD / BOD <sub>5</sub>	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	200
France rural	78	33	2,36	28	150
France urban	90	55	1,64	60	250

BORDA

Before the propagation of standard designs for a whole sector, it is essential to build and operate some plants in order to obtain reliable data for the calculation of dimensions and to gain overall experience. The question of who will finance and execute those trials necessitates the installation of a superstructure for planning and other supervisory purposes.

However, the pure sector-wise approach is likely to fail under the sheer weight of demand on an expertise, which is still rare. Potential customers, who have other than the standard problem, are likely to approach anyone constructing such standardised plants regardless of sector specific exper-

tise. The engineer or contractor is likely to waste a lot of time in visiting such places and in finding technical solutions in order to build up the reputation of his enterprise or simply for want of other customers.

A wastewater treatment plant is NOT just another pair of shoes

### 3.7.3.3 Marketing

Ultimately technology finds its justification in the "market". If DEWATS cannot find a market it will be out of business. So, beyond doubt DEWATS must marketed. However, the marketing concept of DEWATS has to be based on the specifics of the technology; it is not comparable for instance with the marketing of a brand of ready-made consumer goods.

For marketing sports shoes such as "Nike" or "Adidas" for instance, one needs the product and a lot of ballyhoo to make the name known to the target group. The brand name carries an image that fetches prices far beyond the total cost. The shoes are easily transportable to any spot on planet earth and when the shoes are sold, the business is over.

It may not be that easy with other products. When "Toyota" conquered the European market, or "Volkswagen" entered the US-market for selling their cars, the first thing they did was to set up a network of service stations. They knew that no one would buy a car without having access to professional service facilities. Only after the service network was installed, was the proc-

Tab. 3.  
Average data of industrial wastewater

Average qualities of industrial wastewaters					
production	COD mg/l	BOD <sub>5</sub> mg/l	settleable solids mg/l	COD / BOD <sub>5</sub>	other indicators
leather	860	290	1.168	3,0	pH 8,8
glues from skin	6.000	3.100	25	1,9	
glues from leather	1.600	340	75	4,7	
fish meal	6.100	1.560	20	3,9	pH 8,2
paper	820	410		2,0	Cl 6400 mg/l
pharmaceutica	1.920	1.000		1,9	pH 6,5 - 9
starch - maize	17.600	11.540	25	1,5	N 800 mg/l
-dito- (water recycl.)	2.920	1.700		1,7	N 25 mg/l
pectine	13.800	5.800		2,4	pH 2; N 700 mg/l
vegetable oil	600	350	1	1,7	pH 5-9
potato chips	1.730	1.270	820	1,4	
canned juice	550	800	20	0,7	pH 4,6 - 11,4
tinned fish	1.970	1.390	60	1,4	Cl 3020 mg/l
beer	1.420	880		1,6	
yeast	15.000	10.250	5	1,5	pH 4,8 - 6,5

ATV

ess of selling started. The customers know that if service was neglected the result could be unreliable performance and/or low resale value. As with sport shoes the price of cars depends not only on the cost of production and on expectations of economic benefit but ultimately it is the image that the car lends to its owner that counts.

DEWATS are neither shoes nor cars. DEWATS are different. It does not belong to these categories. DEWATS are costly, space consuming, demand attendance and may even be stinking structures, which cannot be produced under controlled factory conditions. Their design is often to be adapted locally and constructed on-site by craftsmen of uncertain qualification. The customer does not love the plant, as he would love his car or even his shoes (only wastewater engineers love wastewater plants). All the customer wants is a service, but he wants not to be bothered with the inner workings of the plant. Understandably the marketing of DEWATS will have to be different.

DEWATS is not likely to have the backing of a financially strong company behind the product that could invest in preparing the market prior to the release of the product. The marketing strategy for DEWATS will have to depend first of all on the immediate availability of the product. To sell DEWATS one needs engineers and contractors being present at remote sites which may be several hours away from their office. Howsoever, advertising, which introduces the product to the public could start well before the product is available. The subject of such an advertising campaign remains a question, when nothing is truly ready to be sold and the price of the product is not known, yet.

Marketing experts know that any marketing strategy has to start from the technical and economic potential of the company that is selling; and that a marketing strategy is reaching its target when customers actually put money on the

desk for buying the product. Successful marketing strategies are premised on buying power and supply capacity, which have to be known in the local context. The best salesmen usually cannot sell a product that is not available, to a customer that does not have the money to buy it.

A product that is not available to be shown to customers is by no means easy to sell. By this logic, the existence of well-functioning wastewater treatment demonstration plants are a vital pre-condition for successful marketing.

## 4 ECONOMICS

### 4.1 Economy of Wastewater Treatment

Wastewater, as the name suggests is a waste, which is left over after using water for a specific purpose. Treating wastewater to get back its original quality is an additional process, which has its price. If wastewater treatment would be profitable in itself, the *perpetuum mobile* would have been invented. Instead, wastewater treatment is by scientific principle a cost factor.

The cost of treatment depends on the degree and the kind of water pollution as well as the degree of purification to be achieved. Treatment costs can be reduced by reducing the pollution, by choosing an appropriate degree of treatment, and in some cases by reusing water and sludge and/or by utilising the biogas. The recovery of other valuable raw material for reuse within the industrial production process does rarely take place in the case of DEWATS.

The objective need (and legal demand) for wastewater treatment today is a result of environmental pollution that has taken place in the past. The extent to which wastewater treatment can be justified in economic terms will depend on the parameters that are included in the economic calculation. One rather unfamiliar parameter is the valuation of environmental protection. How should environmental protection be valued remains a question, however, the issue of whether water should at all be treated is passé. Fact is that there are laws and by-laws, which demand a certain effluent quality of any wastewater discharged into the environment.

This to the polluter means that water must be treated at any cost, or not discharged at all. And this is the starting point for economic considerations.

The first economic question is "Why", only the second question is "How much"

In the first instance, the economy of wastewater treatment demands the reduction of unavoidable expense. Economising measures primarily recognise the prevailing economic environment and adapt the treatment system accordingly; or if possible, create an economic environment that suits and supports the preferred treatment system.

Treatment cost for a given wastewater are influenced by:

- the legal discharge standard,
- the chosen treatment system, and
- the degree of reusing water, sludge and energy (biogas)

The treatment system to be chosen and whether the reuse of by-products is advisable will depend on local prices for building materials and service manpower. The question of reasonable discharge standards has been dealt with in chapter 3, already. It is not discussed here.

### 4.2 Treatment Alternatives

The question at a policy or development planning level relates to the extent to which water should be treated and its discharge

centralised, and whether on-site treatment and individual discharge into the environment should be available as an option at all. The decision is influenced by environmental, social, technical and economic parameters within which the place of final discharge is likely to play a decisive role. *Alaerts et al* suggests a population density of above 200 to 600 capita/ha for centralised treatment of domestic wastewater. However, such a general rule of thumb cannot be taken as valid for conglomerations including industries; it demands cautious application.

The following considerations in balancing centralised against decentralised treatment systems are recommended:

- ❑ There are clear cut economies of scale for treatment plants so long as the level of technology is not changed.
- ❑ DEWATS in principle - but not always - are cheaper because they are of lower technological standard than conventional treatment plants.
- ❑ The unavoidable costs of sewer lines in case of centralised systems may threaten the economies of scale; sewerage may cost up to five times more than the central sewage plant itself.
- ❑ The cost of treatment increases proportionate to the degree of treatment.
- ❑ Management costs are in principle - but not necessarily - in direct relation to plant size or to the number of plants.

There are several organisational alternatives for treatment and discharge of wastewater. These are:

- ❑ Controlled discharge without treatment (ground percolation, surface water dilution).

- ❑ Treatment in a centralised plant that is connected to a combined or separate sewer system.
- ❑ Treatment in several medium sized treatment plants that are connected to a combined or separate sewer system.
- ❑ Primary and secondary treatment in decentralised plants that are connected to a sewer line, that leads to a common plant for final treatment.
- ❑ Completely decentralised treatment with direct and final discharge, or connection to communal sewerage.

This book deals with DEWATS as an option and tries to describe its specificities. It would be beyond the scope of this handbook to deal with the general subject of sanitation concepts suitable for communities. Enough work of excellence has been done and published by specialist groups in different countries. For example:

*Alaerts, G.J., Veenstra, S., Bentvelsen, M., van Duijl, L.A. at al.:" Feasibility of anaerobic Sewage Treatment in Sanitation Strategies in Developing Countries" IHE Report Series 20, International Institute for Hydraulic and Environmental Engineering, Delft 1990.*

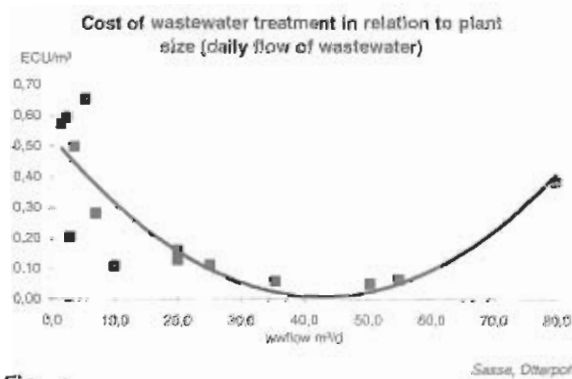


Fig. 4. Cost of treatment per m<sup>3</sup> daily flow. Larger plants require a more sophisticated technology which may increase treatment costs.

Once the decentralised option has been chosen, it is the individual polluter who should decide on the treatment system he thinks is most suitable to his circumstance. However, realistic alternatives based on true economic considerations are rare. *The Danish Academy of Technical Sciences* writes in its evaluating report 1984:

"...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 of purely economical 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."

*(The Danish Academy of Technical Sciences: "Industrial Wastewater Treatment in Developing Countries", 1984)*

The above citation supports the view that comparison of several alternatives is not possible on a general level, and in most cases true alternatives for the customer do not exist. There are many cases, where a DEWATS concept is the only solution that promises some degree of continuous treatment. Most often, it is not worth comparing DEWATS with non-DEWATS solutions if obviously the cost and management effort of keeping a conventional system permanently in operation is formidable. It could

be very expensive for instance, to keep a qualified engineer at a remote location for operating a conventional, albeit small treatment plant.

Field experiences indicate that there are factors other than economic, which induce the polluter to opt for a treatment plant. In most cases the pressure to comply with discharge standards that meet the law compel polluters into the decision. However, there could be other reasons as well. For example, an entrepreneur would like a treatment plant to present a "clean" factory to his foreign partners, a housing complex that has no future unless wastewater is reused for irrigation, or a doctor in charge of a teaching hospital who wants to treat the hospital wastewater to safeguard his reputation. In all these cases the immediate motivation to go in for wastewater treatment is other than economic (notwithstanding the fact that some economists consider „everything“ an economic question).

After deciding in favour of a treatment plant, the polluter would want to compare different systems of the same size under similar conditions. He would want to consider the space he has to spare for the treatment system, the level of maintenance he is willing to shoulder, and ultimately if he should rather re-organise his water consumption in order to reduce the pollution load or quantity of discharge. The geography of the neighbourhood and the prevailing wastewater discharge standards and regulations would determine the range of alternatives available to an individual polluter. Similarly the prevailing socio-political framework is also likely to have a strong bearing on the decision of the polluter, e.g., are the fees or penalties imposed based on pollution loads, or are they independent from it.

Finally, the ultimate destination of the effluent will also influence the choice of treatment system. For instance, the necessity of nitrogen or phosphorous removal may be greater when the receiving water is an isolated lake of particular ecological importance, in which case other treatment options with other influencing factors may become valid.

First think of ponds, then of tanks,  
at last of filters

The following chapter describes the parameters that influence economic calculation. Those parameters help in deciding on the most suitable system for standardisation for a particular group of polluters in a defined local situation. For relatively small plants, however, it is not very likely that the supplier would offer comparative economic calculations for different treatment systems to a potential customer. If such were to be the case, the cost of planning would be unaffordable, as several plants would have to be designed on the table purely for the purpose of economic comparison. More practically, the potential supplier is more likely to discuss various alternatives with the potential customer (without going into detailed economic calculations) based on which the customer would then choose the most appropriate and convenient solution.

### 4.3 Parameters for Economic Calculation

#### 4.3.1 Methods of Comparison

Wastewater treatment as a rule does not produce profit. Resultantly methods of economic analysis such as cost-benefit or break even point, to which profit calculations are important, do not fit the economy of waste-

water treatment. On the other hand, the annual cost method, which includes depreciation on capital investment and operational costs, appears to be more apt as an economic indicator. With this method it is easy for the polluter to include expenses such as discharge fees, or income from re-use of by-products on an annual base, to get a comprehensive picture of the economic implications.

The annual cost method could also be used for estimating social costs and benefits. The economic impact of treatment on the environment and on public health is related primarily to the context in which a treatment plant operates. For example, if properly treated wastewater is discharged into a river that is already highly polluted the yield from fishing will surely not improve. On the contrary, if all the inflows into the receiving water were to be treated to the extent that the self-purifying effect of the river would allow the fish to grow, this would have considerable economic impact. This economic impact of a cleaner river is crucially dependent on the total number of treatment plants installed along the river, and not only on the efficiency of one single plant.

A spreadsheet for computerised calculations is presented in chapter 13.2.

#### 4.3.2 Investment cost

##### 4.3.2.1 Cost of land

For economic calculation the value of land remains the same over years and thus, land has unlimited lifetime. However, the price of land is never stable. It usually goes up in times of growth and may go down in times of political turbulence. In reality, the actual availability of land is far more important

than the price; new land will rarely be bought only for the purpose of a treatment plant. The density of population usually determines the price of land. Land is likely to cost more in areas with a high population density and vice versa. The choice of treatment system is severely influenced by these facts.

In reality, the cost of land may or may not be essential to the comparison between different treatment systems. Wide differences in the cost of land notwithstanding, it may contribute in the range of 80% of the total cost of construction. It follows that at least in theory, the choice of sand filters and of ponds will be more affected by the price of land than compact anaerobic digesters. In any case, it is most likely that where land prices are high compact tanks - not ponds and filters - will be the natural choice. *Alaerts et al.* assume that ponds are the cheapest alternative when the cost of land is in the range of less than 15 US\$/m<sup>2</sup> in case of post treatment and 3 - 8 US\$/m<sup>2</sup> in case of full treatment. Such figures nonetheless have always to be checked locally.

#### 4.3.2.2 Construction cost

Annual costs are influenced by the lifetime of the hardware. It may be assumed that building and ground structures have a lifetime of 20 years; while filter media, some pipelines, manhole covers, etc. are only likely to last for 10 years. Other equipment such as valves, gas pipes, etc., may stay durable for 6 years. Practically it suffices to relate any structural element to any one of these three categories.

It is assumed 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. For dissemination programmes, it may be assumed that planning will be carried out by a local engineering team of sound experience to whom the design and implementation of DEWATS is a routine matter. However, this might not be so in reality. At the contrary, of all costs, engineering costs are likely to be the most exorbitant and to remain so until such time as the level of local engineering capacity improves. An estimation of planning work-days for senior and junior staff forms the basis of calculation to which 100% may be added towards acquisition and general office overheads. Transport of personnel for building supervision and sample taking - and laboratory cost for initial testing of unknown wastewater's must also be included.

#### 4.3.3 Running Costs

Running expenses include the cost of personnel for operation, maintenance and management, including monitoring. Cost may be based on the time taken by qualified staff (inclusive of staff trained on the job) to attend to the plant. The time for plant operation is normally assessed on a weekly basis. In reality, the time estimated for inspection and attendance would hardly call for additional payment to those staff who are permanently employed. The case would be different for service personal that is specially hired. Facilities that are shared, as in the case of 5 to 10 households joining their sewers to one DEWATS, are likely to be 10% cheaper than individual plants. However, operational reliability of such a facility cannot be guaranteed if someone is not specially assigned to the task of maintenance.

Cost for regular attendance could be higher for open systems such as ponds or constructed wetlands due to the occasional damage or disturbance by animals, stormy weather or falling leaves. The cost of regular de-sludging will be higher for tanks with high pollution loads, than for ponds which receive only pre-treated wastewater. The cost of cleaning the filter material is not considered to be running cost as these costs are taken care off by the reduced lifetime of the particular structure. So also the cost of energy and chemicals that are added permanently are not included, as such costs are not typical of DEWATS.

#### 4.3.4 Income from Wastewater Treatment

The calculation of income from by-products or activities related to wastewater treatment calls for careful selection of the right economic parameters. Biogas could be assumed to have economic value as it is seen to substitute other fuels, whereas in reality it may be only an additional source of energy of nil utility and consequently zero economic value. Just as the use of water and sludge for agriculture may require the establishment of additional infrastructure and staff to manage its utilisation. As is apparent, economic calculations if not reflective of all these costs and future implications could become redundant.

Biogas production should be taken into the calculation only if the biogas is likely to be used. The biogas production available to use may be to the extent of 200 l per kg COD<sub>removed</sub>. The actual gas production is 350 l methane (500 l biogas) per kg BOD<sub>total</sub>, however a part of the biogas would be dis-

solved in water; the portion increases with decreasing wastewater strength. Biogas contains 60% to 70% methane. 1 m<sup>3</sup> methane is equivalent to approximately 0,85 litre of kerosene.

The moot question is really not if the use of biogas will improve the profitability of the wastewater treatment plant but whether the additional investment to facilitate the use of biogas is economically justified. If biogas were to be used, the storage of the gas would demand additional volume and a gas-tight structure. The gas would then need to be transported to the place of consumption, requiring pipes and valves. The proper utilisation of the gas and maintenance of the gas supply system will entail additional management and thereby additional costs. The additional investment to facilitate the use of biogas is likely to add up to 5% of the cost of long lasting structures

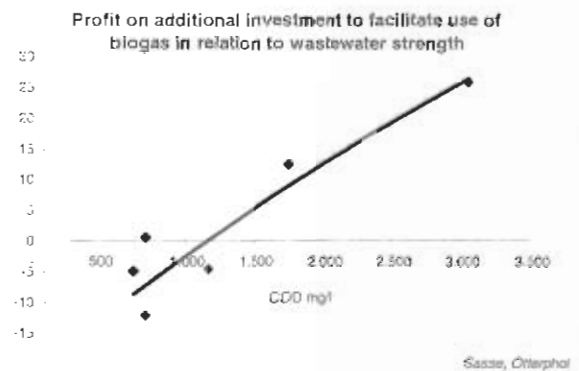


Fig. 5. Cost-benefit relation of biogas utilisation. It is not economical to use biogas from low strength wastewater.

(20 years lifetime), 30% of the cost of internal structures (10 years lifetime) and 100% of the cost of equipment (6 years lifetime). The cost of the additional capital for such investments is not to be forgotten

Furthermore the cost of operational attendance is likely to be 50% more if the biogas was to be used. If agriculture and fish-farming were to be attached to the wastewater treatment plant the economic implications are much more complex and therefore much more difficult to assess *a priori*. The size and organisation of the farm together with the marketing of the crops would be important parameters to consider.

#### 4.3.5 Capital Costs

If the investment capital were to be borrowed from the bank on interest, such investment would attract direct capital costs. On the contrary, when one's own money is invested which if used otherwise could be profitable (purchase of raw material for production, investment in shares or bank de-

posits, etc.) the cost of this capital is indirect. The risk of the investment is another factor that may have to be taken into account and that can make the calculation of the cost of capital extremely complex.

In case of wastewater treatment plants since other profits are in any case not expected, the investment risk is limited to the technical risk of the reliability of performance. However, if profits from wastewater related agriculture is expected, the investment risk could become expensive. Capital costs are to a certain extent speculative by nature. Nevertheless, the fact that capital costs money remains.

For strategic calculations one may consider annual capital costs of 8% to 15 % of the investment; exclusive of inflation as inflation affects both the creditor and the debtor in equal measure.