

Centralised versus Decentralised Wastewater Systems?

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Abstract

A host of centralised and decentralised systems are available for wastewater disposal purposes. Consequently, selecting the right system calls for a comprehensive and, above all, unbiased assessment of the alternatives. Costs and unsettled ecological issues can be adduced to show that total rejection of one system or the other is not warranted. An ecological assessment that, for example, also covers hygienic aspects is only in its infancy and an intensification of research work is necessary. The example of a conurbation is used to illustrate the interplay of centralised and decentralised elements.

Keywords

assessment, centralised, decentralised, selection, wastewater systems,

INTRODUCTION

Since as early as the 1970s, an intensive search has been going on for the right wastewater disposal system. This search was set in motion by the World Bank (e.g. Kalbermatten et al., 1980) in its efforts to set up affordable wastewater disposal systems in developing countries. As a result, as well as modifications of familiar technologies and some relabelling, a few trailblazing novelties have also emerged, the latter being mainly inspired by people's growing ecological awareness. What started off as a problem for developing countries has now long since turned into a topic of global importance.

However the impression is often created that there is such a thing as "the" right system. A bias for or against a certain system and ideological stances often have an effect on the selection made, especially if the issue of centralised or decentralised systems is being debated. Today, extremely conflicting points of view are being put forward in this debate. Hence, for example, Otterpohl (2006) considers large water distribution and sewage systems to be technically out-dated. On the other hand, Bangkok and Teheran for example, which have so far pursued a policy of treating wastewater on-site, now feel compelled to actually build sewage systems - belatedly and at great expense.

However, opting for the wrong system can lead to horrendous economic losses and result in the setting up of wastewater systems of inadequate hygienic efficiency. This hits the poorer countries particularly hard, where wastewater systems are still in their infancy, and there it is the megacities that are hit worst. Accordingly, to avoid wrong decisions of major proportions, it is necessary to really include all alternatives in an assessment and to be fully aware of any pitfalls possibly ensuing from an assessment.

THE DIFFERENT OPTIONS FOR CENTRALISED AND DECENTRALISED WASTEWATER DISPOSAL AND THEIR OBJECTIVES

The objectives pursued by the designers of the various types of wastewater disposal system are by no means consistent with one another. Consequently, as regards assessment of the alternatives, these objectives and the methods used to achieve them are of fundamental importance:

Centralised systems

Traditional combined and separate sewage systems

In the industrialised countries, traditional combined or separate sewage systems account for the bulk of the wastewater disposal systems. Fairly large wastewater catchment areas can be split up into separate sewage systems, to be subsequently connected up to various treatment plants.

These traditional systems are primarily designed to protect the population from infection due to the discharge of faecal matter, to protect people from material damage caused by rainwater, and to protect receiving waters by purifying municipal and industrial sewage in the treatment plants. Purposes largely identical to those of the traditional sewage systems are served by pressure and vacuum drainage systems and small-bore sewer systems. Given certain structural characteristics of the catchment area, they are more economical.

Storm-water management

Storm-water management systems comprise discharge prevention, discharge retardation, and rainwater treatment or utilisation plants. Storm-water management was developed in the industrialised countries for the purpose of avoiding some of the disadvantages of traditional sewage systems. The factors to be mentioned in this connection are, first and foremost, the material pollution of receiving waters by discharges of inadequately purified combined sewage or rainwater, reduced evaporation, and reduced groundwater replenishment. Another aim is to avoid the costs, sometimes high, entailed by transporting rainwater over long distances and treating it in the treatment plants.

Centralised treatment plants

Centralised systems offer a multiplicity of systems and system variations for wastewater treatment. From an environmental protection angle, mention should be made of the various wastewater treatment levels (mechanical and mechanical-biological treatment, nutrient removal, disinfection, and the use of membranes to remove minute particles) and methods of reusing wastewater constituents (biogas, water, sludge recycling). Development work on fertiliser production (e.g. magnesium ammonium phosphate, ammonium sulphate) is under way.

Decentralised systems

While the aims of the sewage systems in all their different variations are largely uniform, the same does not apply to those of the decentralised systems. These can be broken down into three categories with fundamentally different aims:

Simple sanitation systems

Some of the simple systems that can be mentioned are pit latrines, pour-flush toilets, composting toilets and aquaprivies. The purpose of these systems is to assure minimum hygienic standards for the population, with water pollution control being of minor significance. As a rule, these systems have the effect of retaining faecal matter and other solids while the liquid phase is discharged or allowed to infiltrate. Utilisation of residual substances, e.g. composting and agricultural recycling of

the faecal matter, is often practised or efforts are made to practise it. In terms of engineering, the systems concerned are simple and their cost relatively low.

Small-scale mechanical-biological treatment plants

These plants consist of at least a mechanical and a biological treatment stage. The biological stage may take the form of an industrial-type reactor (fixed film reactor process, activated sludge process) or be of near-natural design (ponds, wetlands). The basic mechanical-biological processes can be supplemented by other steps for the purpose of nutrient removal, disinfection, or removal of most of the solids by means of membranes.

In addition to assuring a high standard of hygiene, these plants are designed to limit water pollution. Therefore, the minimum requirements to be met by the effluent correspond roughly to those to be fulfilled by small-scale municipal treatment plants. In individual cases, higher standards, e.g. nutrient removal, may be required and can be implemented reliably.

The main areas in which the small-scale mechanical-biological treatment plants are utilised are areas devoid of sewer systems in the industrialised countries and commercially-developed regions (e.g. tourist centres) in the developing and emerging countries. These decentralised, small-scale treatment plants are also the type of plant most frequently encountered in countries with a predominantly centralised wastewater system that simultaneously have high wastewater treatment standards.

Recycling systems

In the case of these systems, top priority is given to environmental protection while simultaneously maintaining a high standard of hygiene. In various newly-designed toilet systems, efforts are made to recycle or utilise the urine and faeces. In contrast to the methods of utilisation that used to be quite common in agrarian societies (use as fertiliser), present-day technical facilities permit methods of utilisation that comply with modern hygienic standards and provide great comfort, while also producing high-quality fertilisers and biogas. The liquid phase can be processed to the extent of being reusable as non-potable water.

A common, basic principle of these systems is that they separate the different sewage or material streams (urine, faeces, grey water, storm water) right from the beginning, thus rendering them amenable to special-purpose processing.

ASSESSMENT OF CENTRALISED AND DECENTRALISED WASTEWATER SYSTEMS

General criteria

The multiplicity of the different wastewater disposal options is in itself an illustration of the fact that the boundary conditions under which these systems are to be built and operated and the standards to be met by them vary quite considerably. For it is especially the necessity for adaptation to specific situations that has caused this diversity of systems to evolve. But this is also a clear indication of the fact that there is no system, whether centralised or decentralised, that can cope with all these different situations. Both types of system are legitimate in certain situations and the crucial task is to decide which is the right system in the situation at hand. And this does not only apply to the construction of new wastewater systems. In future, higher water pollution control standards, efforts to economise on resources, changes in water consumption, or new engineering possibilities may lead to alterations to existing systems.

As regards system selection, a host of selection criteria are generally recognised and customarily applied such as cost-effectiveness, requirements as regards operating staff, institutional prerequisites and others. From a present-day standpoint, these criteria have to be supplemented by four others. Although they do partly overlap, it is expedient to mention them individually as far as waste disposal systems are concerned:

- A (more far-reaching) ecological assessment, e.g. as regards water pollution
- An analysis of the degree to which natural resources are drawn on
- Options for recovery of energy, water, and other substances, such as nutrients
- A hygienic appraisal

What is meant by hygienic appraisal is not only an assessment of the disinfectant action of an individual plant, e.g. a treatment plant or an on-site plant (process efficiency), but also an assessment of the aggregate impact throughout the whole of the catchment (system efficiency). Such an appraisal requires an examination of the health status of the population that will provide adequate statistical information. Such examinations are difficult and expensive, and examinations covering entire catchment areas are still quite rare.

The ecological assessment of centralised and decentralised wastewater systems

Decentralised systems are frequently described as being “ecological” for advertising purposes, the implication being that they are good and appropriate. However, such statements are based on a wrong or colloquial definition of the term “ecological” and on simplified reasoning. The impartial term as used in science is made to mean something equivalent to “environmentally-compatible, good and correct”. The existence of short water cycles, and in some cases nutrient recovery too, are usually considered to be reason enough for giving the ecological label. This simple reasoning behind the ecological label combined with a corresponding understanding of the term “ecological” then apparently removes the necessity for providing further justification for a decentralised system. According to this chain of reasoning, the decentralised system is always the right one and the good one, and the centralised system isn’t.

However, if a more accurate definition of the term “ecological” is used as a starting point, it comes to light very soon that a more sophisticated view of the matter is called for. In the first instance, the term “ecological” only indicates that the interrelationships between different organisms and between organisms and environmental factors are affected or are being considered. This also includes the associated flows of materials and energy. The term is value-free, meaning that certain determining factors can have a positive or negative impact and that projects may be ecologically favourable or unfavourable. Consequently, there are still many unsettled issues as regards the ecological assessment of centralised and decentralised wastewater systems. The first one concerns the receiving waters. Which has a greater adverse effect on receiving waters: a few central discharge points into large bodies of receiving water or many discharges into very small bodies of water? Which organisms are more sensitive to discharges: those in the relatively large body of receiving water fed by a centralised plant or those in the relatively small bodies of water linked to decentralised plants, with the latter also possibly being located near the spring of the receiving water? A second question concerns the efficiency of the treatment process and the ecological effects of the constituents remaining in the wastewater after treatment. Let us take hormones and pharmaceuticals as an example. Although some primary treatment methods are investigated, assessment of centralised and decentralised systems is still hardly possible on this basis. What expense is incurred by the corresponding treatment processes in centralised and decentralised systems? How reliably can these processes be carried out in centralised and decentralised plants? What is the impact of the presumably unavoidable residual loads in the event of concentrated

discharges into relatively large bodies of receiving water and what is the impact of discharges spread over a wide area into relatively small bodies of surface water or into groundwater? To what extent can partial flow separation facilitate a solution in the case of decentralised plants? Perhaps partial flow separation will also lead to a combination of centralised and decentralised treatment.

Even with regard to cycles, it is a moot point whether or not the short cycles of decentralised plants are ecologically advantageous. Short cycles reduce both the quantities of water taken from the natural environment and the quantities subsequently discharged, a fact that will be ecologically advantageous in most cases. But long cycles reduce an organism's exposure to the pollutants it has itself caused. In the concrete instance of wastewater disposal, this means that the infection hazards associated with centralised systems incorporating sewage systems will be considerably reduced, as the infectious faeces are transported away from the population's habitat. This together with the concomitant aim of disease prevention was the main purpose behind the construction of the present-day sewage systems. There is no doubt at all that this purpose has been accomplished. Modern sewage systems have protected innumerable people from serious or lethal illnesses. Of course, high safety standards can also be achieved by using short cycles and decentralised systems. But in that case, a great deal of engineering effort is required if there is a high population density, i.e. in urban areas. In this context, it is also essential to point out that centralised systems make only comparatively few demands on the proper behaviour of the population. This may well be a prime reason for the hygienic efficiency of sewer systems. The demands made on the population are greater in the case of on-site systems and this is certainly a major reason for the often unhygienic conditions to be found in them. For example, in her investigations into health aspects of dry sanitation, Peasey (2000) points out that this important aspect attracts little attention.

These are only some of the issues that are unsettled when it comes to making an ecological assessment of centralised and decentralised wastewater disposal systems. They do show, however, that general labels of "ecologically favourable" or "unfavourable" do justice neither to centralised nor to decentralised systems. The assumption is also warranted that there are no general answers, but that the assessment will always very greatly depend on the local conditions. However, the unsettled issues do show, too, that there is considerable need for research, especially as regards the broad appraisal of model projects.

Cost of centralised and decentralised wastewater systems and means of financing them

When comparing the cost of centralised and decentralised systems, it is important to compare only situations that really are comparable. This applies particularly to density of development, standards of hygiene, treatment efficiency, and disposal of residues. Thus, for example, the cost of a sewer system connected up to a mechanical-biological treatment plant with nutrient removal facilities must not be compared with that of simple sanitary systems. Although the latter may well be legitimate, depending on the situation, they are not suitable for general cost comparison purposes on account of the different standard of hygiene and the different impact they have on water pollution control.

Comparisons between the costs of centralised and decentralised systems should also be based on uniform price levels, such as exist within a given economy. As in Germany wastewater charges cover all the costs (capital expenditure or depreciation on the same, plant operation, and environmental costs in the form of the wastewater levy) and roughly the same standards are laid down for small-scale treatment plants as for municipal plants, some costs will now be stated to illustrate this point. In 2003, sewage disposal costs per person averaged € 124 p.a. (wvgw, 2005), i.e. about € 500 p.a. for a family of four. On the other hand, the cost of a small-scale treatment plant for a 4-person property is to be put at € 600-1,500 p.a. (Fröhlich and Seyler, 2005). That means,

therefore, that, for the bulk of the population, centralised sewage disposal is cheaper than on-site systems would be. This comparison does not yet take into account the fact that 94% of the wastewater from the centralised plants is subjected to nutrient removal (wvgw, 2005), whereas this is still rare in the case of small-scale treatment plants. On the other hand, there is no disputing the fact that decentralised disposal is considerably cheaper in outlying areas with a low density of development. The figures quoted show clearly that the claim relatively often advanced in recent years that centralised sewage disposal systems are always more expensive than on-site systems is wrong. It all depends on the individual case.

When comparing the economics of centralised and decentralised systems in developing and emerging countries, an important aspect is also that of financability. Decentralised systems are built by the inhabitants or by commercial enterprises, and as a rule they do this when they use the property for building development. As a result, there is, generally speaking, readiness to provide finance and a means of doing so. The construction of the plants coincides with the need for them. In contrast to this, when new sewage systems are being built, considerable advance payments are required for both treatment plant and sewage system, and these are often only used to the full after a considerable lapse of time. These costs often exceed by far the financial resources of the municipalities concerned.

System selection pitfalls in individual cases

Wrongly-deployed planners

The designers whose help is enlisted for selecting a sewage disposal system often do not have the entire range of engineering options at their command. This applies especially to many of the protagonists of near-nature or decentralised solutions. Such designers can hardly be expected to recommend a solution that departs from near-nature or decentralised thinking. On the other hand, there are so-called “established” experts who view with general suspicion any solutions that differ from those they have already learnt. They can hardly be expected to propose innovative solutions. Accordingly, to avoid having to make a preliminary decision for or against certain systems simply by selecting the designer, the designer concerned with system selection has to be carefully chosen. The latter has to be an expert who is sufficiently familiar with the entire range of sewage disposal systems as to be able to take an unbiased, rational decision. After a certain system has been opted for, other experts with expertise of limited breadth can be called in as specialists.

Inadequate local expertise

In many developing and emerging countries, the environmental administration is still being established. This may have the effect that, in international collaborative projects, the foreign experts are not faced with local experts of equal weight. In such cases, it is easy for local conditions and needs to be inadequately perceived by the foreign experts and to be given insufficient attention as far as the overall result is concerned. This may, in particular, also affect the decision between a sewer system and a decentralised sewage disposal system.

The danger of the opinions and experience of foreign designers having too much weight and impact also exists if a project is integrated into a foreign financial assistance scheme. Whether this is intended or not, financial assistance may be accompanied by very strong pressure on the recipient to conform to the proposals of the funding body.

Abbreviated decision-making processes

Another deficiency affecting the comparison between centralised and decentralised systems is that only a limited selection of decision-making criteria and alternatives is actually considered, with

others being briefly explained away or completely disregarded. In developing and emerging countries, small-scale treatment plants, for instance, are frequently regarded as being second-class solutions, with only sewage systems modelled on those of the industrialised countries being tolerated as the sole modern solution. The new, elaborately-engineered small-scale treatment plants, e.g. involving the use of membrane technology, ought to help to dispel such prejudices.

THE RUHR DISTRICT AS AN EXAMPLE OF SEWAGE DISPOSAL IN A CONURBATION

In the heartland of this industrial area in western Germany that was once characterised by coal-mining and steel industries, the population density is 2,330 p/km², the total population being 3.5 million. With the industrialisation and rapid growth of the area in the 19th century, intolerable hygienic conditions came about. To remedy the situation, the beginning of the 20th century saw the establishment of two river basin associations, which were responsible for wastewater treatment in the two river basins, that of the Emscher and that of the Ruhr. The first treatment plants were Imhoff tanks. In 1911, 83 of these plants (Dunbar, 1912) were in operation in the Emscher basin. 1.2 million inhabitants - equivalent to about 60% of the population - were connected up to them. The prime aim of the sewage disposal system was prevention of the waterborne diseases, primarily cholera and typhoid, prevailing at the time.

The further course of events was marked by the increasing demands placed on water pollution control. Important milestones were the introduction of biological wastewater treatment and, later on, nutrient removal. The introduction of these treatment stages and the considerations of cost-effectiveness associated therewith led to centralisation of the wastewater treatment system. Before the second world war, the Emschergenossenschaft (Emscher Association) operated 23 treatment plants, but in 2001 only four with a total capacity of 4.8 million p.e. The history of the Ruhrverband (Ruhr Association) followed a similar course. Along the stretch of river under examination, the Ruhr Association used to run 20 treatment plants in 1940. Today, there are still 9 of these, with a total capacity of roughly 1.2 million p.e. Despite the merger of the wastewater disposal systems of these two river basin associations the area now encompasses, in addition, roughly 4,100 small-scale treatment plants and about 60 industrial treatment plants employing a wide range of different processes and process combinations.

From the point of view of centralised or decentralised treatment, it can be seen that the constantly increasing demands placed on wastewater treatment and the increasingly complicated systems and increasing expense associated with it led, in the last century, to centralisation of the wastewater treatment system. Nevertheless, what exists is not a completely centralised wastewater treatment system but a composite system made up of centralised and decentralised elements.

CONCLUSIONS

- Neither the dogmatic rejection of sewer systems nor, conversely, the denigration of on-site plants as being of lower quality are justified either in ecological terms or in terms of cost-effectiveness. Rather, the advantageousness of alternative systems depends on the conditions that apply in individual cases.
- Decentralised systems are often claimed to be superior in general ecological respects. However, our current level of knowledge does not permit such a sweeping statement to be made. Consequently, considering the ecological importance of wastewater disposal, efforts aimed at investigating its ecological impact have to be considerably intensified.

- Research into the health aspects of alternative wastewater disposal systems ought to be stepped up considerably too. Organic micropollution should also be covered by such investigations. Especially in developing and emerging countries, investigations should cover not only the process efficiency of the individual plants, but also the efficiency of the system over a wide area.
- As opposed to decentralised systems, systems that are completely centralised are hardly conceivable, or their definition depends on the demarcation of the wastewater catchment area under examination. Systems described as being centralised are, as a general rule, composite systems characterised by small-scale treatment plants and subdivision into wastewater subcatchment areas.

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