Wastewater Management Strategy: centralized v. decentralized technologies for small communities

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1. Introduction

Adequate water and wastewater management, essential for human health and economic development, poses a major challenge to many countries around the globe. Whereas in the industrialized countries water and wastewater control had reached a fairly high standard, in lower and middle income countries[1] severe problems with respect to water supply and wastewater management are still apparent (Wilderer and Schreff, 2000). As priorities are usually given to large urban centers, many problems remain in the smaller communities. As priorities are further given to water supply systems, wastewater treatment lags behind and remains a major challenge in many countries.

The scope of this paper is wastewater management with focus on small communities: townships (~10,000 inhabitants) and rural settlements in the middle-income countries such as the CEE[2] and the Western Balkans[3]. In these cases, the conventional solutions may be less suitable due to lack of economies of scale and weak financial and managerial capacities, and less conventional alternatives should be considered. Nevertheless, the discussion in this paper is relevant to many other cases where the conventional strategy may not be feasible and alternatives should be considered.

The paper reviews the two wastewater management strategies: centralized and decentralized solutions, as well as different alternatives within these strategies, as a general background for decision makers. It does not aim to suggest that one strategy is

[1] The World Bank classifies its member economies and all other economies with population of more than 30,000 to income groups according to Gross National Income (GNI) per capita. The groups are: low-income, $875 or less; middle-income, $876 - $10,725 (lower middle-income, $876 – $3,465; upper middle-income, $3,466 - $10,725); and high-income, $10,726 or more (World Bank, undated).
[2] Central and East European countries - Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.
[3] Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Serbia

better than the other, but rather to present both as viable options in making the decision regarding wastewater management in smaller communities.

2. Background - a description of the problem

Water and wastewater management are still lacking in many countries. Whereas in most industrialized countries safe water is supplied to the population and wastewater pollution control has progressed substantially, in the low and middle income countries the situation is different, with lower coverage of both water supply systems and sanitation services. Still, water supply coverage is usually higher than the sanitation coverage. In developing countries, for example, 85% of the population has access to safe drinking water, whereas only 32% has access to sanitation services (UNEP/GPA, 2000). Similar situation can be found in middle income countries where water supply coverage is higher than sewerage systems coverage (see table 1).

The relatively high percentage of people with access to safe water in low and middle income countries in comparison to access to sanitation services reveals that water supply gets higher priority whereas sanitation and wastewater treatment suffer from inaction. This is because some communities are still likely to prefer water supply over sanitation and are reluctant to pay for a facility where direct benefits are unclear (Jackson, 1996; UNEP/GPA, 2000). In middle-income countries, lower coverage of drinking water services in the poorer areas means that if they would succeed to provide their entire population with safe centralized drinking water services, it is not likely that sufficient additional financial resources will remain for proper wastewater collection and treatment (UNEP/GPA, 2000).

Thus, wastewater management seems to lag behind water supply management in low and middle income countries.

Table 1: water supply and sewerage systems coverage in middle income countries, selected countries		
Country	% of population served with piped public water supply systems	% of population served with sewerage systems
Serbia	81.8	57.2
Bosnia and Herzegovina	~ 50 (mainly in urban areas).	~ 30
Romania	65.5	50.4
Hungary	98	56.1
Croatia	63	35

Source: UNECE, 2002; UNECE, 2004; UNECE, 2001; UN, 2004; Croatian Ministry of Environmental Protection, undated.

Wastewater management is comprised of wastewater collection, treatment, and reuse or disposal of effluent and sludge (Crites and Tchobanoglous, 1998). It is essential for several reasons: (1) protecting public health and the well-being of the communities; (2) protecting the water resources and the environment; and (3) in water-scarce regions for reuse purposes in order to reduce the pressure from the potable resources (Bakir, 2001; Friedler, 2001). Some note that even in regions with abundant water, reuse of water and nutrients is essential for a sustainable use of these resources (Hedberg, 1999). Nevertheless, wastewater management, and especially treatment and safe disposal, is neglected in many countries.

As the world population, urbanization and economic activities rapidly increase – the pressure on the fresh water resources, increases. Steady increase in living standards, economic development and piped water supply means an increase in water consumptions. These lead to increasing volumes of wastewater and if untreated – increasing volumes of pollution. Pollution load into the environment has caused and continue to cause gradual but steady deterioration of water resources and the ability to provide safe drinking water to the population decreases. As a result, the basis of economic activities becomes threatened. With strong sustained growth in population and economy, these problems are expected to increase (UNEP/GPA, 2000).

As aforesaid, in most industrialized countries wastewater pollution control has progressed substantially. In many Northern European countries wastewater is treated to tertiary level[4] or at least to secondary level, and the main problems remain in rural areas – very small communities or individual farms. In lower income countries, however, many problems still remain.

Based on all the abovementioned, the scope of this paper is wastewater management in townships (<10,000 inhabitants) and rural areas in middle-income countries, such as CEE and Western Balkans countries.

These countries are transitional economies that need to address many infrastructure development issues, neglected in the past. In the CEE countries, for example, sewerage systems are supplied to less than 50% of the population. Many of these countries also need to comply with the relevant EU water Directives[5] (new Member States as well as countries aspiring to become EU Member States), implying that decisions and actions need to be taken.

The scope is further narrowed down to smaller towns and rural areas. The reason for that is that wastewater schemes expected to serve large populations are generally considered to have a higher priority. Such schemes tend to have lower per capita cost, produce greater social and environmental gains, and maximize the number of people with access to improved sanitation (Reed, 1996). Thus, governments tend to address the big cities first, then the secondary cities and only then the smaller communities (Bakir, 2001). As a result, many of the remaining problems today are is smaller communities. Accordingly, the coverage rate of sewerage systems in rural areas lag behind the urban areas in most of these countries (see table 2). In Croatia, for example, existing sewage systems are mostly constructed in major towns where about 75% of population is connected. In settlements with up to 10,000 inhabitants the majority (85%) has no sewage system constructed (Croatian Ministry of Environmental Protection, undated). This trend is similar in other

[4] Wastewater treatment can be categorized as primary; secondary; and tertiary. Primary treatment generally consists of physical processes involving mechanical screening, grit removal and sedimentation; Secondary treatment mainly reduce BOD by converting biodegradable organic matter; Tertiary treatment is designed to remove nutrients (N and P) (WHO/UNEP, 1997).

[5] Such as: the Water Framework Directive (2000/60/EC), the Nitrate Directive (91/676/EEC), and the Urban Wastewater Treatment Directive (91/271/EEC).

countries as well. In addition, in the case of the big cities the conventional centralized strategy is the prevailing one, due to clear case of economies of scale in wastewater infrastructure (UNEP/GPA, 2000) whereas the issue of choosing between wastewater management strategies is relevant mainly in small towns and rural areas. As the percentage of rural population in these countries is very high (in comparison to Western Countries) (see table 3), decision makers will need to face many difficulties.

Table 2: sewerage systems coverage in middle income countries, urban and rural population, selected countries

Country	% of pop/households served with sewerage systems		
	Total	urban	rural
Serbia	57.2	87.5 (p)	22.2 (p)
Bosnia and Herzegovina	~ 30	56 (h)	10 (h)
Romania	50.4	86 (h)	10 (h)
Poland	-	97 (p)	73,5 (p)

- no data; (h) households; (p) population;
Sources: UNECE, 2002; UNECE, 2004; UNECE, 2001; WHO/UNICEF, 2004; UN, 2002

Table 3: rural population in CEE and Western Balkan countries, selected countries (2002)

Country	Rural population (%)
Bosnia and Herzegovina	56
Bulgaria	31
Croatia	41
Hungary	35
Poland	38
Romania	45

Source: WHO/UNICEF, 2004

Two main problems pose constrains on adequate wastewater treatment: high costs and institutional low performance. These constraints are likely to be more sever in the smaller settlements, as their ability to cope with wastewater management is lower due to financial and institutional weakness. This increases the challenge of promoting solutions for these communities.

2.1 High costs of wastewater management

Wastewater management is capital intensive for both investments and operation and maintenance costs. It tends to be two or three times more expensive than the costs of abstracting, treating and distributing tap water. In the Netherlands, Germany and other European countries, for example, water agencies spend more money on treating wastewater than on all other water-related activities. Thus financing wastewater infrastructure can be a difficult issue and in fact only a few countries in the world manage to cover all costs (construction, operation and maintenance) directly from their customers through user charges. Even in countries where labor and materials are cheap, cost is high and can be prohibitive, and households prefer not to use scarce income to address wastewater problems. It is note that countries need a GNI[6] above US$2,200/cap to finance sanitation and basic wastewater collection and treatment across their territory (UNEP/GPA, 2000). Thus, in order to solve local water qualities problems, authorities prefer to invest in water treatment and supply and not in wastewater treatment. This is also in accordance with the historical development of wastewater treatment in the industrialized countries. For example, in their review of wastewater management trends in the USA, Burian et al, 2000, note that in the beginning of the twentieth century municipalities in the USA and their consulting engineers favored the implementation of only water treatment, for economic reasons. The prevailing opinion was against the need for wastewater treatment. This coincides with the statistics of access to safe drinking water and sanitation services in low and middle income countries nowadays, and with the notion that water supply gets a higher priority.

The costs related to wastewater management are especially prohibitive in areas with lower population density, such as small towns and rural settlements. This is the case even in industrialized countries and poses higher constraints on low and middle income countries. As wastewater management and infrastructure benefit from economies of scale, the per capita cost in small communities is much higher than in urban areas. This is due to the longer length of sewer per user and other factors. In the USA, for example,

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[6] Gross National Income. This term replaces the previously used term of Gross National Product and has the same meaning (World Bank, undated).

residents of small communities will pay two to three times as much as residents of larger municipalities for sewer services only. The impact of these higher costs on family budget is severe especially because the annual income in rural communities is significantly lower than in urbanized areas. As a result, many small communities throughout the USA still suffer from inadequate wastewater management (Otis, 1996).

2.2 Weak national, regional and local institutions

Water pollution control and wastewater control is typically one of the responsibilities of the government: national, regional and local. Governments should undertake to do this by establishing appropriate organizations and launching programmes. National government tasks include policy, regulation, planning, monitoring and partly financing. Local governments typically implement local plans and finance and own wastewater infrastructure. However, wastewater management is complicated and requires managerial and technical high capabilities. Thus, it strains the already stretched technical and managerial competence of many governmental agencies and poses real obstacle. Agencies' capacities to address this issue is very often inadequate, even in some industrialized countries; professional often lack the expertise regarding the impacts of pollution and the tools to address it; institutional mechanisms are absent; and managerial, technical and financial know-how is commonly poorly developed to set up and run effective wastewater management. Broadly, these institutional weaknesses are a major cause of under-performance (UNEP/GPA, 2000; WHO/UNEP, 1997).

Most low and middle income countries have, over the past years, developed environmental legislation with respect to effluent standards but implementation is slow. The burden on the low and middle income countries is even heavier, as they are less wealthy and have weaker institutions. Nevertheless, action in these countries has to be taken. This will require the development of schemes for the selection and construction of wastewater collection and treatment technologies and strategies (UNEP/GPA, 2000).

Although traditionally centralized solutions are perceived to be the most acceptable solutions, alternative strategy is developed in recent years that may be more suitable for rural areas in these countries. The following section discusses these two main wastewater management strategies.

3. Strategies for actions

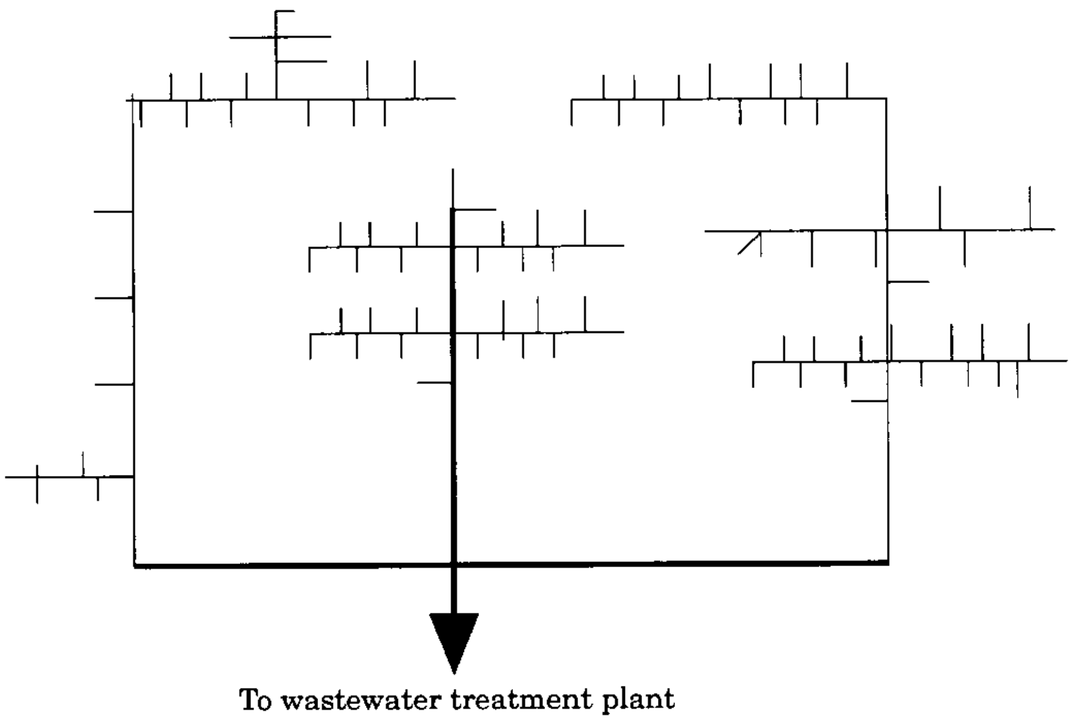
3.1 Wastewater management strategies

Broadly, wastewater management strategies can be categorized as centralized or decentralized systems. Each of these strategies can be applied in different scales.

3.1.1 *Centralized wastewater managements*

Centralized wastewater management consists of: (1) centralized collection system (sewers) that collects wastewater from many wastewater producers: households, commercial areas, industrial plants and institutions, and transports it to (2) centralized wastewater treatment plant in an off-site location outside the settlement, and (3) disposal/reuse of the treated effluent, usually far from the point of origin (Wilderer and Schreff, 2000; Crites and Tchobanoglous, 1998). Thus, it is also referred to as off-site management (see figure 1). This strategy was developed in the middle of the nineteenth century and it is connected to the development of urbanization and urban life style, as big concentrations of people resulted in more wastewater generated locally. At that time households were served by cesspools or simply deposit their waste in the streets, and outbreaks of cholera, typhus and other fatal diseases occurred in the major cities of Central Europe and the USA. Looking to solve these problems, pioneers of bacteriology and hygiene discovered that these diseases are caused by the direct contact of human beings with their own excreta and by the spread of pathogenic microorganisms contained in the excreta. The technical answer developed as a solution to the problem was constructing public sewer systems for wastewater collection and transportation. This resulted in wastewater being transported out of the cities into the nearest waterway where self-purification could take place. As a result, outbreaks of cholera and typhus were reduced and eventually completely prevented. The first comprehensive sewer network was built in the Hamburg, starting 1842, and soon other cities followed. European cities were constructing large-scale centralized waste-carriage sewer systems, and proving them successful for removing wastewater from urban areas. This technology was transferred to the USA as well and by the end of the nineteenth century most of the major cities in the USA had also constructed some form of a central sewer. However, as more wastewater was discharged into surface water, the self-purification capacity of the receiving waster body was exceeded and the water quality gradually deteriorated. Since surface water was increasingly required to serve the needs for potable water supply, wastewater treatment technology had to be developed. Mechanical treatment such as settling tanks to remove the settleable solids and later on bacterial purification, were developed. The latter, intensive treatment technologies on a microbiological basis, were suitable for larger cities, and were used on a large scale. Trickling Filters was the dominant technology until the end of the 1950's when it was taken over by the Activated Sludge technology (Hartmann, 1999; Wilderer and Schreff, 2000; Burian et al, 2000).

Figure 1: schematic diagram of centralized wastewater collection and treatment (off-site)



Source: Bakir, 2001: 323.

Throughout the twentieth century this centralized wastewater management has been continuously extended to spreading urban areas, especially in the industrialized countries, with developments in the treatment technology only, to adapt to changing needs of the population served and to adjust to changing requirements with respect to public health and environmental concern. Also today the trend in these countries is towards further development and improvement of the centralized systems. Indeed, since the large-scale introduction of centralized wastewater infrastructure cities in industrialized countries have been essentially free from waterborne diseases. Thus, this strategy became the standard tool of environmental protection and control and from the end of the nineteenth century to the present day has remained the preferred urban wastewater management method in these countries, serving the major cities and towns in most European countries as well as other industrialized countries (Burian et al, 2000; Wilderer and Schreff, 2000; Marriott, 1996; UNEP/GPA, 2000). In Germany, for example, over 95% of the population is currently connected to sewer systems; In Israel 96% of the population is connected to sewer systems, etc. Thus, it is referred to as the conventional wastewater management. As the preferred and conventional strategy in the industrialized countries, centralized management was extended to other low and middle income countries as well. In Middle East and North African countries (middle income countries), for example, centralized wastewater collection systems are typically provided to large cities and secondary towns. Tunisia's main cities and secondary towns are served with wastewater collection systems and central wastewater treatment plants; in Jordan 65% of the population is connected to collection systems and the largest towns are served by central treatment plants, etc. (Bakir, undated). In other developing countries there is also a tendency to copy and apply the same collection and treatment technologies as applied in the industrialized countries, although these are expensive solutions and many believe that applying them as standard solution for developing countries, is not feasible (UNEP/GPA, 2000).

Centralized wastewater management - as the preferred choice of planners and decision makers, is often applied also to smaller communities (Bakir, 2001). However, as planning wastewater treatment on the basis of the administrative boundaries of small municipalities is rarely reasonable, regional or inter-municipal cooperation for that purpose can create major financial gains – as wastewater management and infrastructure enjoys economies of scale, and offers a strong option for municipalities. In this case wastewater is transported from several adjacent communities to a centralized treatment plant that is constructed to serve them all (UNEP/GPA, 2000; Reed, 1996). In Germany, for example, wastewater management is the responsibility of the municipalities. If they are too small to address the financial and technical complexity of this task, they form inter-municipal joint-venture. In France municipalities commonly establish joint-ventures to carry out the task of wastewater management (WHO/UNEP, 1997) and so is the case in Israel. In the Fayoum region – a predominantly rural region in Egypt, a master plan for wastewater treatment was prepared based on this principle, and 70 towns and villages were clustered into 11 central treatment plants (Abd El Gawad and Butter, 1995). Thus, centralized wastewater management – either for large cities, secondary towns, or few smaller communities, is the conventional strategy. It is applied for most cities and towns in the industrialized countries and is the preferred choice of most planners and decision makers in other countries as well.

Available technologies of the centralized management

Within the framework of the centralized strategy, few treatment technologies can be applied. Ranging from simple screening and settling operations to sophisticated biological and chemical operations – many technologies exist. Basically, two main approaches for wastewater treatment can be identified: intensive and extensive.

Intensive treatment is the most common approach in the industrialized countries with Activated Sludge as the conventional technology. This conventional treatment is based on intensive biological treatment to remove pollutants, in relatively short time and confined space. Additional advanced treatment can be added such as disinfection unit (chlorination, ozonation, UV) and removal of nutrients (N and P), depends on the disposal/reuse requirements. These intensive technologies require smaller space area than the extensive technologies and thus have financial benefits especially in densely populated urban areas where land value is high. In addition, they can reach very high treatment efficiencies. However, they are energy intensive, require highly skilled manpower (for design, construction, operation and maintenance), and require large amount of capital for both construction and operation (Friedler, 2001; UNEP, undated; UNEP/GPA, 2000).

Extensive treatment (also referred to as natural treatment or ecological engineering) includes methods such as lagoons, stabilization ponds, and constructed wetlands. These are non-mechanical biological treatment systems in which natural processes of dissolution occur. The design of these "natural" systems is based on the stimulation of self-purification of water bodies or on the stimulation of natural biological processes. These systems are simple in operation and maintenance and have relatively low construction and operation costs. Their biggest disadvantage is that they have substantially greater land area requirements and thus they are only feasible when land is available and land prices are sufficiently low. In arid and semi-arid areas, however, where the effluent can be reused for irrigation, storage capacity is needed anyway in order to regulate between wastewater "production" which occurs throughout the year and effluent demand for irrigation which occur only through the dry summer months. Thus, ponds and lagoons can serve this need as well. These processes are well established and can fit to low-income rural communities. Most of them provide adequate treatment in terms of removal of organic matter, but some fail in removal of nutrients (UNEP/GPA, 2000; Friedler, 2001; UNEP, undated).

Although traditionally cost-effectiveness of various wastewater treatment alternatives is commonly evaluated prior to selecting a treatment technology, alternatives for wastewater collection systems are rarely considered (Otis, 1996). The collection systems available today are the conventional system and the unconventional systems (Mara, 1996). The conventional system goes back to the historical development of wastewater management. It can be combined system or separate system. Combined systems carry sewage and storm water (urban run-off) at the same conduit. Separate systems transports storm water in water drains and sewage in sanitary sewers. The conventional system is commonly used (hence "conventional") without consideration of alternatives. Its construction costs are high because it requires a minimum depth for protection against traffic loads, a minimum slope to avoid sedimentation of solids, and a minimum diameter to avoid blockage. Thus, it accounts for 80-90% of the total capital cost of the collection and treatment facility (Otis, 1996; UNEP/GPA, 2000). Another problem of the conventional collection system is that these systems are waterborne and use water as a transportation medium. Without water, sewer systems can rapidly block. Thus, they require adequate and reliable water supply system and consumption of more than 100 liters/cap/day. In water-scarce countries these systems may be inappropriate due to large usage of fresh water, whereas in other places inadequate water supply systems alone will preclude the possibility of reliable conventional systems (UNEP/GPA, 2000; Jackson, 1996; Bakir, 2001)

Less costly but equally effective alternatives to the conventional collection systems have been developed. These systems, developed to address the need for cheaper collection alternatives, are being used in various places, mainly in the developing world, and have been shown to be successful and to significantly reduce wastewater facility costs. These “unconventional” systems have only recently been seriously considered (Otis, 1996). They include, for example, settled sewerage and simplified sewerage. Settled sewerage, also known as small bore sewerage, is a sewerage system that is designed to receive only the liquid portion of household wastewater. Solids are removed in as interceptor tank, which is part of the household connection, prior to discharge to the sewer. The clarified effluent flows by gravity into the sewers, which are designed as gravity fluid conduits. The settled sewerage costs are lower than the conventional systems, mainly due to shallow excavation depths, use of small diameter pipe work and simple inspection chambers. The interceptor tank act as a balancing tank which attenuates the flow and thus the system performs equally well regardless to the water-use rate (Bakir, 2001). Simplified sewerage is essentially conventional sewerage without its conservative design requirements. It is a modification of the conventional design standards, including reduction in minimum depth, minimum diameter, minimum slope and change in service connections. Simplified sewers have proven to be substantially less costly than conventional sewers, with cost savings ranging from 20-50 percent (Otis et al, 1996).

The centralized strategy is and has been the conventional wastewater management strategy in the past century. Indeed, it was proven to be very efficient in wastewater treatment and pollution control. However, these conventional systems, and especially the convectional collection system and the intensive treatment technologies, require high skilled labor, large amounts of capital, and steady socio-economic conditions. All these make it difficult and in many cases not beneficial, especially in low population density areas, to apply this strategy for wastewater treatment. A viable alternative in these cases, can be the decentralized management.

3.1.2 *Decentralized wastewater managements*

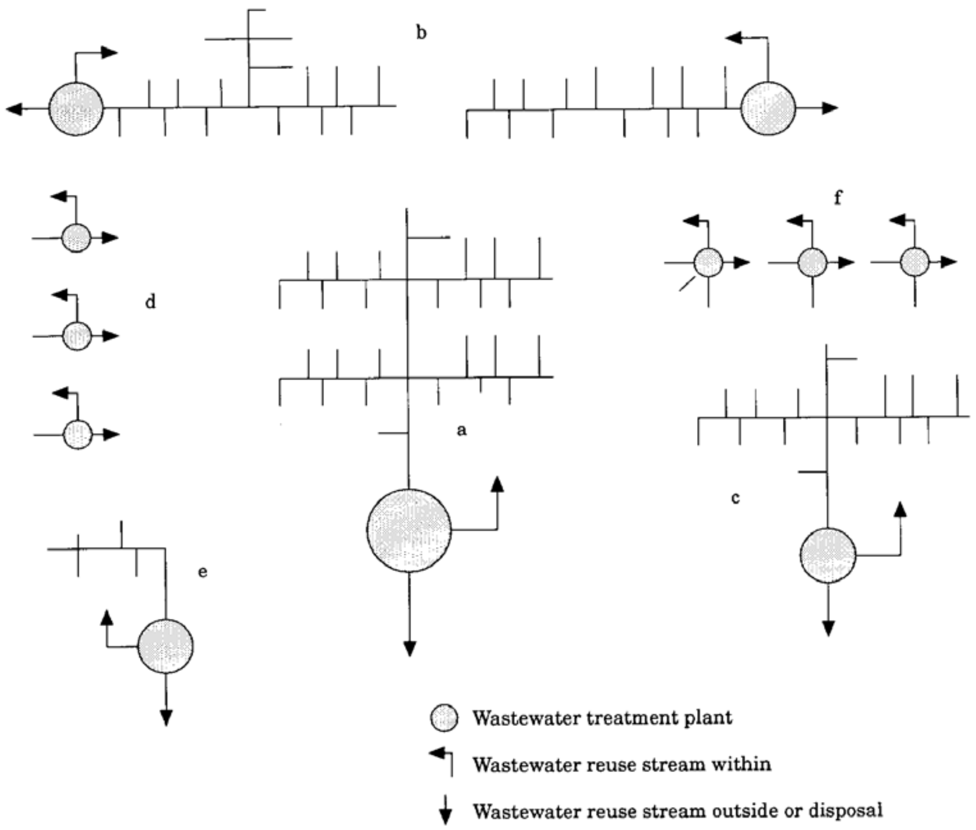
Decentralized wastewater management is a concept in which wastewater is managed: collected, treated and disposed/reused at or near the point of generation (Crites and Tchobanoglous, 1998). Thus, it is also referred to as on-site management. This strategy was, historically, common until the centralized management became the preferred strategy in the end of the nineteenth century. In the USA privy vaults and cesspools were used with the outlet constructed at ground level, usually discharging into the yard, street or an open channel. In Europe and Asia dry sewage systems were more common. In this case containers were placed beneath the seats of privies to collect human excrement and once full – containers were emptied at a disposal location near the residence. This system entailed potential use of the waste as fertilizer on nearby farmland. These systems were gradually replaced by the centralized strategy, as was previously discussed. During the past few decades, however, there is a renewed interest in the previously discarded decentralized management strategy. These newer decentralized technologies introduce significant improvement to the systems of the nineteenth century and they also have the ability to integrate effectively with water-carriage waste removal (Burian et al, 2000). The interest in these technologies was renewed as it became apparent that the centralized strategy is not feasible in many places, or simply not the most cost-effective alternative in some cases. Due to their high costs and complexity of construction, operation and maintenance, or the fact that they require high and reliable water consumption, centralized systems may be less suitable for places such as low-income areas, rural areas with low population density, water-scarce areas, areas with unreliable water supply system, etc. (Bakir, 2001; UNEP/GPA, 2000; Jackson, 1996). Thus, although it is not the preferred strategy of most engineers and decision makers, it has been applied and its use is increasing. It can serve areas of low population densities of industrialized countries as well (Wilderer and Schreff, 2000). In the USA, for example, in the early 1970's, with the passage of the Clean Water Act, it was announced that it was only a matter of time before centralized sewerage facilities would be available to almost all residents. Many years later, it is recognized that complete sewerage of the country may never be possible or desirable for both geographical and economic reasons. Thus, decentralized systems currently serve 25 percent of the US population and approximately 37 percent of new development (Crites and Tchobanoglous, 1998; Burian et al, 2000).

The decentralized systems can be applied on different scales. It can be applied to (1) individual households; (2) a cluster of homes; (3) a neighborhood; (4) public facilities; (5) commercial area; (6) industrial parks; and (7) small portions of large communities (Bakir, 2001; Crites and Tchobanoglous, 1998) (see figure 2).

Available technologies of the decentralized management

Within the framework of the decentralized strategy, few technologies can be applied, wet or dry, basic or more advanced, all with the same principle of treating smaller quantities at or near the source. The common technologies currently in use are basic technologies: septic tanks and pit latrines, although other versions (e.g. composting toilet and pour flush) also exist. A pit latrine is a dry technology. It collects excreta in a pit dug in the ground beneath the toilet structure. During storage in the pit decomposition of the organic substances takes place under anaerobic conditions. Seepage of water into the surrounding soil takes place through the sides and bottom of the pit, further decomposing organic matter by soil bacteria and reducing BOD levels. Bacteria under these conditions do generally not remove nutrients, and pollution of groundwater will occur. Thus, pit latrines pose problems when groundwater is shallow. Control of odor and insects are important with a pit latrine and can be achieved by having a vented pit. When the pit is filled with sludge it needs to be emptied (UNEP, undated). A septic tank is a wet technology. It is a

Figure 2: schematic diagram of decentralized wastewater management (on-site)
(a) subsystem for residential and commercial center; (b) subsystems for residential neighborhoods; (c) subsystems for industrial development; (d) subsystem for individual residence; (e) subsystem for new development; (f) subsystems for establishments or clusters of homes;



Source: Bakir, 2001: 323.

watertight tank that collects wastewater from household utilities via a pipe. The wastewater flows through the tank and the solids will settle to the bottom of the tank. It functions as a storage tank for settled solids and floating materials with storage time of usually 2 to 4 days. About 50% removal of BOD and Suspended Solids is usually achieved in a properly operated septic tank. The clarified effluent flows out of the tank into a drainage field or a drainage system. The solids that accumulate must be removed periodically, as in the case of pit latrine (UNEP/GPA, 2000; UNEP, undated).

These are relatively low-tech, low-cost technologies which allow construction and operation by the local community, and they can reduce public health problems related to wastewater (UNEP/GPA, 2000). However, they provide only partial treatment and do not meet strict environmental standards, and very often are associated with environmental pollution (Wilderer and Schreff, 2000; Bakir, 2001). They are associated with rural areas and unsewered small communities, and are not considered as viable options by many planners and decision makers. Nevertheless, recently, improved technologies are being developed to provide better solutions for decentralized treatment. Combining septic tanks with sand filters can upgrade septic tank’s effluent to advanced secondary and even tertiary levels (Verhuizen, 1997) and various processes for on-site *aerobic* treatment systems have been developed and are available commercially (Bakir, 2001). Further developments include combination of hi-tech components such Membrane Bioreactor (MBR) with the aerobic systems. The advanced aerobic systems, however, require power for aeration and possibly pumping. These improved technologies can meet high environmental standards and can indeed be considered as viable alternatives for wastewater treatment.

In case of decentralized treatment for more than one unit (neighborhoods in small communities; low-density residential and commercial areas; small portions of large communities), non conventional sewerage systems, such as the settled sewerage described above, can be efficient. In this case smaller flows of wastewater will be collected and treated in several small treatment facilities in the community (Bakir, 2001).

Many advantages of the decentralized strategy are described by its advocators: (1) lower costs. The major fiscal advantage of the decentralized systems comes from eliminating a great deal of collection infrastructure. Even in cases when collection system is needed, the use of tanks, retaining the settleable solids, allows the use of small-diameter collection systems. In addition, no large interceptors and few, if any, lift stations, are needed. This results in less costly effluent collection system. Furthermore, in the centralized system the collection and treatment systems are designed for a situation which is anticipated to develop over the upcoming years. Until then, the capacity of the system is far higher than actually needed but the investment costs have to be spent within a relatively short period of time and the burden on the local economy would be higher; (2) environmental advantages. In contrast to the centralized systems, in the decentralized systems the flow volumes are smaller. This implies less environmental damage in case of failure. Furthermore, failure cases themselves are less likely because the systems are less complex. In case of few smaller treatment plants – the probability of simultaneous failure of all of them is significantly lower than that of a failure of one central plant. In addition, because infrastructure costs are reduced more can be invested in appropriate treatment. The treatment and reuse can be tailored to the wastewater stream from each separate sub-system. Industrial wastewater, for example, can be treated separately and not be mixed with the domestic wastewater; (3) increased opportunities for reuse of effluent and solids. Decentralized management increases reuse opportunities. Use of reclaimed water would become more cost-effective as effluent would be available near the potential points of use, thus decreasing the costs of reclaimed water distribution systems. The use of solids can also be improved. The use of solids from centralized plants is often resisted because toxic substances may have concentrated in it. With solids classified by source, material that may contain toxic substances can be isolated from the rest. In addition, because the timing of removal of solids from the tank is not critical, solids can be pumped when they are needed thus eliminating the need for intermediate storage facilities; (4) less water intensive. On-site facilities and the utilization of alternative sewers such as settled sewers reduce the freshwater requirements for waste transportation. The minimum water consumption, required by the centralized systems, is not required and thus the fresh water input in wastewater management – is reduced; (5) can be built gradually. The decentralized system is a modular system. Its different components can be implemented in a stepwise approach. This reduces the need for instantaneous demand for investment, required to build a centralized system. It can also provide good sanitation solutions in places with inhomogeneous sanitation situation, such as municipal areas in developing countries. In these municipalities sanitary systems coexist, differing from no sanitation to highly sophisticated treatment in the different parts of the city (Venhuizen, 1997; Bakir, 2001; Wilderer and Schreff, 2000).

Objections to decentralized management systems, by many water authorities and engineers, are based on two arguments: (1) low performance – this argument is obvious when taking into account the low treatment level achieved by most of the decentralized technologies commonly used, such as septic tanks, and the poor and mostly unprofessional attention on-site facilities usually receive. Usually, household owners and persons in charge of small enterprises are expected to maintain these facilities. They rarely have the knowledge nor are they motivated to efficiently maintain the system; (2) cost – building and operating a great number of small on-site systems is assumed to be far more expensive than one large central system. Also, the operation and maintenance requirements of many small systems will be more than those of one central system (Wilderer and Schreff, 2000; Bakir, 2001). Indeed, Wilderer and Schreff, 2000 note that a decentralized system can only be considered as a viable alternative if it is highly effective and provides advanced treatment; easy to operate; and low in cost. In addition, as decentralized systems require effective operation and maintenance, just as the centralized systems, it must be operated and controlled by highly-qualified people who are trained for the job.

After reviewing the alternative strategies and technologies, decision makers need to be able to choose the suitable strategy for the local circumstances.

3.2 factors influencing the choice of strategy

A sanitation strategy should be environmentally sound, appropriate to local conditions and affordable to those that must pay for the services. Its application dependent on local factors: physical and social. Physical factors include land availability, topography, climate, soil, availability of energy and existing land use. Social factors include population density, community resources (funds, skills), affordability and willingness to pay for the technology and its operation and maintenance, etc. Thus, the strategy and the technology should fit to the local conditions: environmental, economic, cultural and institutional (UNEP, undated; UNEP/GPA, 2000).

Relevant factors and parameters for selection of strategy and technology: on-site (wet or dry), off-side (extensive or intensive), unconventional sewerage, or conventional sewerage, are described in the literature. The main selection parameters are produced wastewater volumes (as dependent on water consumption rates) and population density. Several parameters are described bellow.

1. Minimum water consumption in target community – the first parameter to consider is water consumption rates. This is dependent on the water supply system. If water consumption rate is <50 lcd[7] (water is supplied by wells or hand-pumps), volume of waste generated will be minimal and dry on-site sanitation such as pit latrines should be applied. Wet on-site technologies such as septic tanks will not be suitable as they will operate the same as latrines due to lake of fluid, but are more costly; larger water consumption rate of 50-100 lcd (water is supplied by public stand-posts, for example), dry and wet on-site sanitation may be applied. Settled sewerage may be feasible if population density is higher; if piped water is supplied to households - water consumption rate of >100 lcd, conventional sewerage and off-site treatment may be applied (WHO/UNEP, 1997), as these systems are designed as waste transportation systems in which water is used as the transportation medium. 100 lcd are a basic requirement from problem-free operation of the conventional system. Thus, communities with water consumption lower than that should not be served by conventional sewerage. It is also important to note that conventional sewers can rapidly block if water is shot off for periods. Thus, adequate and reliable water supply system is essential for a reliable performance of the conventional sewerage (Bakir, 2001; Jackson, 1996).
2. Wastewater production volume - >10CM per hectare per day would require off-site transportation of the wastewater. If wastewater production rate is less than that on-site treatment may be applied: <5CM per hectare per day – dry on-site sanitation, 5-10CM per hectare per day – dry and wet on-site sanitation, possibly settled sewerage (UNEP/GPA, 2000; WHO/UNEP, 1997).

[7] liters per capita per day

3. Population density – population density is an important selection parameter. Generally, the higher the population density the lower the unit cost of sewerage and vice versa. For dispersed rural homes, for example, central collection system is not economical due to the high costs of piping wastewater and transporting it to a central treatment plant (Otis, 1996; UNEP, 1998). Conventional sewerage systems are reported to become economically feasible at population densities of 200-300 persons per hectare in developing countries and at 50 persons per hectare in industrialized countries (UNEP/GPA, 2000). However, in developing countries, from a certain level of population density (160 persons per hectare in northeast Brazil, for example) low-cost sewerage such as simplified sewerage is cheaper even than on-site systems (Mara, 1996). On-site sanitation may therefore be feasible for lower density towns, peri-urban areas and rural areas (UNEP/GPA, 2000).
4. Local groundwater contamination risk – On-site sanitation facilities may cause groundwater contamination where there is an inadequate separation between the facility and the groundwater table: if depth of unsaturated zone is less than 2 meters and the hydraulic load exceed 50mm per day, groundwater contamination may occur. This is especially important if shallow wells for potable supplies exist within a distance of 10 times the horizontal groundwater flow velocity. If this is the case, advanced on-site treatment or off-site treatment should be applied. However, if unsaturated zone beneath the facilities is greater than 2 meters, and the hydraulic loading does not exceed 50mm/day, the risk is minimized (WHO/UNEP, 1997).
5. Soil permeability – if soil permeability is low it may not be enough to accommodate the effluent flow rate and effluent will flow to the ground level. In this case off-site sanitation needs to be considered (WHO/UNEP, 1997; UNEP, 1998).
6. Existing infrastructure – existing infrastructure can, of course, affect the selection process. For example, if a community already has septic tanks, and the soil can no longer accept the septic tank effluent – resulting in a need to centrally collect the effluent, than settled sewerage is more likely to be cheaper than simplified

sewerage and conventional sewerage (this needs to be checked on case to case bases) (Mara, 1996).

7. Cost of systems and affordability of the target community – costs per capita of different wastewater systems range according to the systems (on-site/off-site) and the region. The target community's ability to afford the wastewater system is an important factor in selecting a strategy, as any long-term policy to provide a service must be based on a certain assumptions about how much income the provider will receive from its customers. Such income is essential for the proper maintenance and operation and thus efficiency of the system. A community's ability to pay can be assessed by comparing the likely tariff with the minimum income levels of the majority of the community. It is normally accepted that a family should pay no more than 2 percent of its income on sanitation. It should be noted, however, that a community's ability to pay is not the same as its willingness to pay. In communities where sewerage is a high priority, there may be a willingness to contribute a higher percentage of income than 2 percent, and vice versa. It may be advised to address first communities with a known abilities and willingness to pay the tariffs (Reed, 1996).

Other more qualitative factors, such as social considerations and institutional capacity, should also be considered. Social considerations play an important role in selecting a wastewater strategy for a community. In contrast to the conventional sewerage, which does not require routine operational attention, the alternative systems are either more complex or require more maintenance by the community. If the target community is unwilling or unable to accept this responsibility, the conventional system may be more appropriate (UNEP, 1998). Institutional capacity and the availability of skilled labor and management, is another important factor to consider. Wastewater schemes are implemented, operated and maintained by institutions. Often an institution exists before the implementation of a new scheme and it is expected to carry out the task. An institution's ability to cope with the demands of a new scheme will greatly affect the scheme's long-term success, both technically and financially. The availability of skilled labor to operate the scheme should be considered. In many small rural communities, for example, there are no skilled workers to operate an activated sludge process properly, and a simpler process such as lagoons or ponds, may be more suitable. Another prerequisite for effective operation of more complicated schemes is the availability of management infrastructure to collect and process user charges and manage expenses. Also in this case low-maintenance and low-tech solutions should be considered as they are more tolerable to operation and management breakdown (Reed, 1996; UNEP 1998).

4. Conclusions

This paper discusses the issue of wastewater strategies available to decision makers. Whereas the conventional centralized strategy, developed in the middle of the nineteen century and spread out ever since, proved to be very efficient in pollution control and became the preferred strategy on planners and decision makers, it is growingly recognized that this strategy cannot be feasible in many cases. This is mainly due to high costs of transportation systems, especially in low population density areas and in very poor communities. Low capacities of these communities to implement and manage these facilities, is another constraint. As a result, the previously discarded strategy of on-site treatment is growingly becoming popular and accepted.

Indeed, experience shows that the traditional centralized wastewater treatment strategy should be complemented with equally adequate tools that can provide good solutions for areas where this strategy is not feasible. Improved versions of the traditional on-site technologies and development of advanced on-site technologies can provide today a viable alternative for wastewater treatment that can comply with high environmental standards. Thus, in the industrialized countries advanced on-site technologies are being introduced successfully to provide solutions to individual farms, small communities, isolated facilities, etc. On-site technologies should be considered - if they produce high quality effluent in an affordable price, by low and middle income countries as well.

This paper reviews the main challenges facing decision makers in areas that still lack adequate wastewater treatment, such as small communities in middle income countries.

In these cases constraints such as high costs and weak institutions are more sever as local authorities lack the capacity to manage and maintain such facilities. Nevertheless, action must be taken by these communities as solutions complying with high environmental standards, should be introduced. This is especially the case in new EU Member States and countries aspiring to become EU Member States.

The paper also reviews the two main strategies: centralized v. decentralized, available to decision makers, as well as some parameters that can be used when choosing a strategy. The paper does not aim to suggest that one strategy is superior to the other. On the contrary, the paper suggests that both are viable, and thus should be considered on a case-to-case base to choose the most feasible one for local circumstances. Whereas in big densely-populated urban areas the centralized strategy is the most suitable – if can be afforded, in smaller towns and rural communities, both strategies should be considered to select the most feasible one.

5. References

Abd El Gawad, H. A., Butter, J. H. C., (1995), Clustering of Towns and Villages for Centralized Wastewater Treatment, *Water Science and Technology*, **32 (11)**, 85-95.

Bakir, H. A., (2001), Sustainable Wastewater Management for Small Communities in the Middle East and North Africa, *Journal of Environmental Management*, **61**, 319-328.

Bakir, H. A., (undated), Sanitation and Wastewater Management for Small Communities in EMR Countries, *Technical Note on Environmental Health*
http://www.emro.who.int/publications/CEHA-Waster%20Water%20Management.pdf#search=%22Sanitation%20and%20Wastewater%20Management%20for%20Small%20Communities%20in%20EMR%20Countries%22

Burian, S. J., Nix, S. J., Pitt, R. E., Durrans, S. R., (2000), Urban Wastewater Management in the United States: Past, Present, and Future, *Journal of Urban Technology*, **7 (3)**, 33-62.

Crites, R., Tchobanoglous, G., (1998), *Small and Decentralized Wastewater Management Systems*, Boston: McGraw-Hill.

Croatian Ministry of Environmental Protection, Physical Planning and Construction, undated
http://www.mzopu.hr/okolis/html/en/index.aspx

Friedler, E., (2001), Water Reuse – an Integral Part of Water Resources Management: Israel as a Case Study, *Water Policy*, **3**, 29-39.

Hartmann, L., (1999), Historical Development of Wastewater Treatment Processes, In: J. Winter (Ed), *Environmental Processes I, wastewater treatment.* Weinheim: WILEY-VCH.

Hedberg, T., (1999), Attitudes to Traditional and Alternative Sustainable Sanitary Systems, *Water Science and Technology*, **39 (5)**, 9-16.

Jackson, H. B., (1996), Global Needs and Developments in Urban Sanitation, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

Mara, D. D., (1996), Unconventional Sewerage Systems: Their Role in Low-Cost Urban Sanitation, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

Marriott, M. J., (1996), Hydraulic Design of Unconventional Sewerage, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

Otis, R. J., (1996), Small Diameter Gravity Sewers: Experience in the Unites States, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

Otis, R. J., Wright, A., Bakalian, A., (1996), Guidlnies for the Design of Simplified Sewers, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

Reed, R. A., 1996, Selecting Communities for Sewerage, in: D. Mara (Ed.), *Low-Cost Sewerage*, Chichester: John Wiley & Sons.

UN, 2002, Country Profile, Poland
http://www.un.org/esa/agenda21/natlinfo/wssd/poland.pdf

UN, 2004, Hungary – Freshwater country profile
http://www.un.org/esa/agenda21/natlinfo/countr/hungary/Hungarywater04f.pdf

UNECE, 2001, Environmental Performance Review Programme – Romania
http://www.unece.org/env/epr/studies/romania/welcome.htm

UNECE, 2002, Environmental Performance Review Programme – Serbia and Montenegro
http://www.unece.org/env/epr/studies/serbia_and_montenegro/

UNECE, 2004, Environmental Performance Review Programme – Bosnia and Herzegovina
http://www.unece.org/env/epr/studies/bosnia_and_herzegovina/welcome.htm

UNEP, undated, Environmentally Sound Technologies in Wastewater Treatment
http://www.unep.or.jp/ietc/Publications/Freshwater/SB_summary/index.asp

UNEP, 1998, Appropriate Technology for Sewage Pollution Control in the Wider Caribbean Region
http://www.cep.unep.org/publications/Techreports/tr40en/index.html

UNEP/GPA, 2000, Strategy Options for Sewage Management to Protect the Marine Environment, IHE, Delft.

Venhuizen, D., (1997), Paradigm Shift, *Water Environment and Technology*, **9**, 49-54

WHO/UNEP, (1997), Water Pollution Control – A Guide to the use of Water Quality Management Principles
http://www.who.int/water_sanitation_health/resourcesquality/watpolcontrol/en/index.html

WHO/UNIFEC, 2004, Country, Regional and global estimates on Water and Sanitation, the Monitoring Programme for Water Supply and Sanitation
http://www.wssinfo.org/pdf/JMP_04_tables.pdf

Wilderer, P. A., Schreff, D., (2000), Decentralized and Centralized Wastewater Management: a Challenge for Technology Developers, *Water Science and Technology*, **41 (1)**, 1-8.

World Bank, undated, Data, Country Classification http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20420458~menuPK:64133156~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html