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WASTEWATER MANAGEMENT FOR SMALL COMMUNITIES IN PALESTINE

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ABSTRACT

Small Palestinian rural communities, in which about 60% of the total population in Palestine are living, face a variety of environmental infrastructure and public health issues. One of the urgent issues is the provision of safe drinking water and reliable wastewater collection and treatment facilities. The purpose of this paper is to assess the present status of wastewater management in rural Palestinian communities. Great emphases has been made on the historical development, key issues for wastewater management policies and strategies to be implemented. Also lessons and recommendations gained from pilot projects and case studies implemented by non-governmental organizations (NGOs), like the Palestinian Hydrology Group (PHG) are presented. Several rural sanitation projects were assessed and small onsite sewage treatment plants were visited and evaluated, personal contacts to many NGOs and review of published reports of Palestinian institutions, donors and funding agencies, and UNDP and DFID were made. It was found that major sanitation problems are due to the weak economy and low income, low level of technical operating expertise and very limited access to the existing advance wastewater treatment technologies. Overloaded urban old sewage works were implemented to serve Israeli environmental policy and not to preserve the natural resources and for the protection of the aquatic environment and public health. Also the planned and newly erected urban sewage works were donor influenced and initiated. It was found that PHG acts as a catalyst to promote sustainable sanitation facilities in the poor rural Palestine. In many cases, traditional wastewater treatment strategies are inappropriate for the physical and economic characteristics of the small communities. Hence, non-point pollution, caused by direct discharges from rural communities can be significantly reduced by the promotion of onsite low cost treatment systems.

INTRODUCTION

The regional scarcity of water in the Mediterranean and Middle East countries requires endorsement of sustainable wastewater management technologies. The wastewater related problems, which these countries are facing, are yearly increasing owing to the increasing discharge of wastewater as a result of the increasing demand of fresh water for domestic, industrial and agricultural purposes.

The water quality of groundwater wells and some freshwater springs are experiencing gradual nitrate pollution signs (Mukhallalati and Safi, 1995; Alawneh and Al-Sa`ed, 1997). Among the nitrogen pollution sources is untreated municipal sewage from urban areas, domestic discharges and septic tanks from Palestinian rural communities and Israeli colonies, excessive fertilizers usage, leachate from solid waste dumpsites. The newly issued Palestinian

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Environmental Law aiming at the improvement of aquatic environment imposes stringent penalties for polluters. However, regulations for effluent quality standards for sewage works, industrial discharges, and wastewater and biosolids reuses are still missing (PNA, 1999).

At present, about 24% of the total population in Palestine is served by a central public urban sewer system, and less than 5% of the municipal sewage collected is subjected to partial treatment in the existing overloaded municipal sewage works. About 73% of the households in the West Bank have cesspit sanitation and almost 3% without any sanitation system (MOPIC 1998; Abu Madi, 2000). In sparsely populated Palestinian poor rural and semi-urban communities, which form about 60% of the total population in the West Bank, few small sewage treatment plants were installed for the protection of aquatic environment.

Several attempts and reports were made to develop wastewater management strategies for the Palestinian urban areas (Gerheart *et al.,* 1994; Nashashibi, 1995; PWA, 1998), however strategic planning for wastewater management for rural communities are still lacking. Beside applied research studies a number of biological treatment systems for small rural communities were introduced and installed (Mustafa, 1996; PHG, 1999; PARC, 1999; Zimmo *et al.,* 1999). Most of the rural sewage treatment plants, installed to serve less than 1000 inhabitants, use the attached growth (trickling filters) and natural treatment processes preceded by septic tanks. Until now rural small sewage treatment plants showed good removal rates for organic matter and suspended solids but are poor in nitrogen removal (Al-Sa`ed and Zimmo, 2000).

This paper presents and discusses the results of a field study, which is based on review and evaluation of published data, personal interviews, data collection from NGOs and donor agencies, on present status of wastewater management in Palestinian rural communities. Also the experience and problems gained with the existing small sewage treatment plants will be presented and conclusion and recommendations will be made.

PRESENT STATUS OF WASTEWATER MANAGEMENT

URBAN SANITATION

Wastewater management in Palestine has been a neglected issue over the past years. No comprehensive data on wastewater characteristics and amounts discharged are yet available. The effectiveness of the existing urban sewage collection and treatment facilities is usually constrained by limited capacity, poor maintenance, process malfunction, poor maintenance practices, and lack of experienced or properly trained staff. Raw or partially treated wastewater is discharged into the wadis where it is used for irrigation purposes (MOPIC, 1998; Al-Sa`ed, 2000).

The governmental national water institutions are under-funded and have a weak technical staff; hence, the laws and regulations are difficult to enforce. Without permits, illegal connections to the sewer system are made, since municipalities do not have any executive power. The financial and economic analysis form the conceptual plan for urban sanitation in Ramallah District has indicated that about $165 million should be invested to construct the sewerage facilities in the coming 20 years. In the next 10 years all planned 10 sewage works to serve about 550.000 inhabitants, while more than 20% of the rural areas will still lack central sewage treatment facilities (Plancenter Ltd., 1997). However, practical experience gained from recently implemented urban sewage projects, indicated that about 10 years of planning were spent for Albireh sewage works. Main reasons behind are political, economical and lack of technical expertise at municipal and national levels, as well as impact of donor agencies and misconception in the technical design.

The situation of the sewerage system is extremely critical. Approximately, 60% of households in the urban cities are connected to the sewerage system. In some urban and all semi-urban areas as well as all rural communities, collection systems are rarely used and wastewater is discharged into percolating pits or septic tanks. The septic tanks emptied by vacuum trucks and disposed of either in the treatment plant or just in the wades. In villages, no sewage network exists, and wastewater is discharged into percolating pits.

EXISTING URBAN SEWAGE TREATMENT FACILITIES

Urban and Rural Wastewater Characteristics

Water consumption is very low in Palestine due to the lack of adequate and regular water supply and high water rates. Wastewater is mainly of domestic origin. But since water consumption is very low, wastewater is concentrated and its strength, in some locations, is comparable to that of industrial wastewater. Light industries are prevailing in the West Bank, which means that heavy metal contamination is not probable. At present, the situation is changing, but still there is no enforcement of rules and regulations. This leads to a discharge of wastewater that has high pH value, high temperature, high content of chemicals, or high content of inert suspended solids. Table 1 gives the characteristics of wastewater of some cities and rural communities in the West Bank (Nashashibi, 1995; Mustafa, 1996; Tahboub, 2000).

Table 1: Characteristics of raw municipal and rural domestic wastewater in the West Bank

	Municipal Urban Wastewater				**Rural Domestic Wastewater**	
Parameter	**Ramallah**	**Nablus**	**Hebron**	**Al-Bireh**	**Gray**	**Black**
BOD_5	525	11850	1008	522	286	282
COD	1390	2115	2886	1044	630	560
Kj-N	79	120	278	73	17	360
NH_4-N	51	104	113	27	10	370
NO_3-N	0.6	1.7	0.3	-	1	-
SO_4	132	137	267	-	53	36
PO_4	13.1	7.5	20	44	16	34
Cl-	350	-	1155	1099	200	-
TSS	1290	-	1188	554	-	-

* All data in mg/L; - = No data were given

High values of chemical oxygen demand (COD) and biological oxygen demand (BOD) means that wastewater is highly concentrated with organic matter. Hence, the treatment process might be complicated and need advanced technology to reach an effluent that is safe to discharge in the wadis or reuse in agriculture. Another important parameter is the chloride concentration in wastewater. Since the chloride ions are dissolved in the wastewater, the conventional treatment processes do not remove chloride. Thus, in case treated wastewater will be used in agriculture, then salt-tolerant crops should be considered.

Public Owned Wastewater Treatment Plants

The Jenin wastewater treatment plant consists of 3 aerated lagoons that are heavily overloaded and never desludged. In Tulkarem, the municipal sewage is partially pre-treated in two anaerobic ponds, where a nearby Israeli settlement uses the effluent, after further treatment, in irrigating industrial cotton crops. All of the old urban sewage works are almost non-functional due to overloading, misconception in planning, design, construction and operation. The sewage treatment facilities, serving about 50.000 inhabitants, in Albireh City were newly put into operation. The sewage treatment plants, entailing oxidation ditches and sludge management units are working effectively. It is planned to utilize the treated effluent in agricultural purposes. Hence, the sanitation infrastructure has improved effectively since 1993, where the Palestinian National Authority (PNA) has taken over the civil administration.

Privately Owned Wastewater Treatment Plants

There are four privately owned treatment plants. Two of them are located in the district of Bethlehem, one in Jericho and the other at Birzeit University. The effluent is used for onsite irrigation purposes. A pilot treatment plant has been already constructed in Nablus. The technologies that are tested were trickling filters and extended aeration system.

Past and Future Capital Investment on Sewage Treatment Facilities

Through the technical and financial assistance of some donor agencies involved in water and sanitation sector, like USAID/USA and KfW/Germany, the PNA will be investing about $ 200 million and DM 240 million. This will be allocated for large urban municipal wastewater treatment facilities including collection, treatment, disposal and municipal staff training.

To estimate future capital investment costs, taking into account the following assumptions: the present sanitation situation in rural Palestine, a construction economic cost of 100 US$ per inhabitant, a 20 year planning horizon with an average conservative annual future population growth rate of 2% and 50% service coverage. It can be concluded that about 200 million US$ will be sent for rural sewage treatment facilities in the near future, if secondary treatment is envisaged. Since these funds are going to be invested on mainly small communities, proper strategic planning in order to avoid technical and managerial problems encountered in the past in urban sanitation projects is essential. Some of these problems are listed below:

1. Millions of dollars has been wasted in the past as these were miss-invested in the old unsustainable treatment plants, like those implemented during the period of the Israeli occupation. In addition the land occupied by these sewage works can be otherwise used.
2. Millions of dollars has been wasted in the past as these were miss-invested in the erection of WSPs, like those constructed to serve the reluctant Israeli environmental policy during the period of the Israeli occupation. They were never put into operation.
3. Millions of dollars has been wasted in conduction of unreliable water and sanitation studies, detail planning and design and conduction of pilot scale wastewater treatment plants, where another type of large-scale municipal sewage works were constructed.
4. Thousands of dollars are spent or misplaced due to lack of practical experience by the contractors, technical and managerial staff at municipal, official and private sector levels as well as the negative impact of some donor agencies.

Most of this waste in investment is the large municipal sewage treatment facilities. So, careful consideration should be made on proper wastewater management from now on. Palestine can not afford any capital loss from sanitation infrastructures in the future, as financial and technical support of donor countries will decrease with time and is mainly dependent on the peace process progress in the region. It would be of great advantage if the PWA would specify standards for design of various treatment options in order to standardize the requirements for operator's skills and training programs.

RURAL WASTEWATER MANAGEMENT APPROACHES

INTEGRATED RURAL SANITATION PROJECT IN ARTAS VILLAGE

In Palestine, many non-governmental organizations (NGOs) exist to provide technical and financial services to small Palestinian communities as they struggle with their drinking water and wastewater problems. These NGOs are qualified to assist small rural areas in identifying the most cost-effective solutions to their problems. One of such organizations is the Palestinian Hydrology Group (PHG), which traditionally work with many donor agencies to provide valuable technical and financial assistance to small rural communities suffering from various environmental and public health problems.

The selected sanitation case studies discussed in this paper illustrate the best use of cost-effective technologies and available technical and financial assistance. Relevant projects implemented by similar NGOs like the Palestinian Agricultural Relief Committees (PARC) will be also presented.

Description of the proposed sanitation system

The sanitation system that is proposed for implementation in the village of Artas, Palestine is based on the collection of sewage by small-bore gravity sewer system and biological treatment in parallel upflow anaerobic sludge blanket (UASB) rector. During the first phase, the system will serve about 9300 population equivalents (PE) by the year 2005. The effluent of the anaerobic stage is post-treated in agricultural facultative ponds. The effluent is reused for agricultural irrigation. Septage from interceptor tanks near the houses and excess sludge from the anaerobic tanks is treated in a vertical flow wetland system. The system is designed to treat sewage of Artas village, the Salmons Pools Resort, and the village of Al-Khader.

The use of small diameter gravity sewers (SDGS) is one of the introductions, for although the SDS has been suggested for the village of Taffouh in Hebron district. Artas will be the first location in the Middle East to have such a system implemented. This option requires the use interceptor tanks near the houses. The probability of having low sewage flow at least occasionally, due to low water consumption, further justifies the choice for this system. The interceptor tanks bring about certain degree of pre-treatment which is favorable to the process in the anaerobic tank. Small diameter gravity system is developed for flat areas, and so it will be the first time that SDGS system will be constructed in a mountainous environment with very steep slopes. Therefore, the project will contribute to develop and test new standards that can be used else where in similar situations.

Another first step is the use of the upflow anaerobic sludge blanket (UASB) reactor, which will be the first sort in Palestine. A similar pilot treatment plant has been built in Jordan and involved scientists are anxious to exchange performance results and other practical information to enhance the understanding and functioning of this cost effective primary treatment technique for further use in the Middle East. The UASB reactor has been designed a pre-treatment stage and to reduce the strong wastewater to a level were it could be further treated in facultative ponds. Another aspect of this project, the constructed vertical wetlands, will also be new to this region. This project is considered as an urban sanitation one, and only the sewerage systems has been implemented by now. The main treatment system is being modified and still not yet erected. Therefore, no practical experience can be reported.

TREATMENT STRATEGIES FOR UNSEWERED AREAS IN THE WEST BANK

Mustafa (1996) has built a small onsite treatment plant entailing a septic tank-trickling filter pilot plant for the treatment of gray wastewater from one house with 13 persons. The effluent from the plant is used in the garden. It was found that gray and black wastewater have about the same strength with regard to the COD concentration but the ratio of nitrogen in gray to black wastewater is about 1:22 sufficient for biological growth in the trickling filter.

Description of Pilot Plant

The house installation was changed, to separate the gray wastewater from the black wastewater. The black wastewater is discharged into the existing cesspit, while the gray wastewater is treated in the pilot plant. The trickling filter has been designed as a low loaded system. The treatment chain has been newly modified and further developed to serve about 20 people by including an aerobic multi-layer filter. This modification is not reflected in the above diagram (Mustafa, 2000). More details on system design can be seen in the M.Sc. thesis of Mustafa (1996).

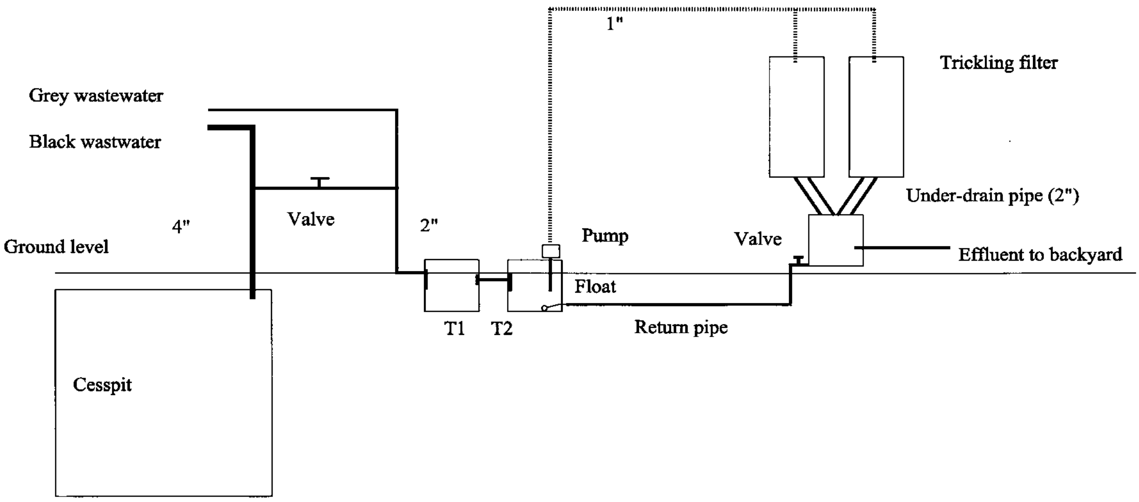

Figure 1: Onsite sewage treatment plant installed by Mustafa (1996)

An advantage experienced during plant operation concerns the emptying of the cesspit; there was no need to empty the cesspit during the past 6 months. The saving in this regard is about $23 per month. About 15 m^3 of the treated gray wastewater per month is used for irrigation three orange trees and some vegetation in the backyard garden. Hence the total amount saved in water consumption and cesspit emptying is about 270$/yr.

Both PHG and PARC implemented onsite wastewater treatment systems of different types and sizes in the range between 5- and 1000 inhabitants over the last 3 years. The systems are listed in Table 2 and illustrated in Fig. 1 and 2. All systems are now under evaluation and monitoring by research personnel in a comparable way to obtain a more objective comparison under field conditions. It is planned that the systems will be evaluated on the functional, economical and environmental aspects.

Table 2: Onsite treatment systems erected by NGOs in rural Palestine

Site	Treatment System	Units	Treatment Objective	Size
Aba	ST + Trickling Filter + Sand Filter	38	Reuse/Treated Gray WW	500 PE
Aba School	ST + TF + Sand Filter	1	Reuse/Treated Gray WW	20 PE
Beit Doggo	Anaerobic Pond + TF + Sand Filter + PP	1	Reuse/Treated Gray WW	200 PE
Jericho	ST + UF Gravel Filter + Sand Filter	1	Reuse/Treated Gray WW	30 PE
Talita Komi	Waste Stabilization Ponds + Sand Filters	1	Reuse/Treated mixed WW	1000 PE
Turmus Ayya School	ST + multilayer Trickling Filter + PP	1	Reuse/Treated mixed WW	50 PE
Al-Samu` School	ST + multilayer TF + Sand Filter + PP	1	Reuse/Treated mixed WW	50 PE
ST = two compartments septic tank; TF = trickling filter; PP = polishing pond; UF = upflow				

Initial results of onsite sewage treatment plants were found to be of the same magnitude as those for large conventional secondary treatment systems. Reported elimination rates were for COD 90 – 95 %; BOD 90 – 95 %; TKN 20 – 79%; and for TSS 90 – 99%. The technical reliability has to be shown mainly affected by the electromechanical parts used in the systems, provided proper operation and maintenance is carried out. Most failure, so far, concerns pumps, where blockage through fouling may cause breakdown of the system.

The technology applied in all these treatment systems revealed a stable one, no possibility of turbid effluent due to suspended solids, no odor complains, and low temperature impact on process stability has been recorded. By waste stabilization ponds, complains and fears were raised concerning odor emission and mosquitoes; transfer of the Blue Nile Fever. However, these problem were solved by covering all ponds and spray of insecticides in the neighborhood of the ponds (Theodory, 2000). However, the environmental impact from all systems is small to negligible.

Beside process efficiency and reliability, sludge disposal and land requirement and environmental impact, capital and operational expenditure, sustainability and process simplicity are considered as critical items in selecting a treatment option for rural areas in Palestine. Investment costs and costs for operation and maintenance were estimated for different sizes of the systems based on current experience in Palestine. As an example, costs for 20 and 200 PE systems might range between 50 and 300 US$ per capita. Annual capital and running costs has been calculated for lifetime of civil and electromechanical parts including rate of interest. The annual capital and running expenditures were estimated in the range between 20 and 35 US$ per person. On the other hand a normal septic tank serving a household of 5 people might have an annual capital and running expenditures as high as $50 per person.

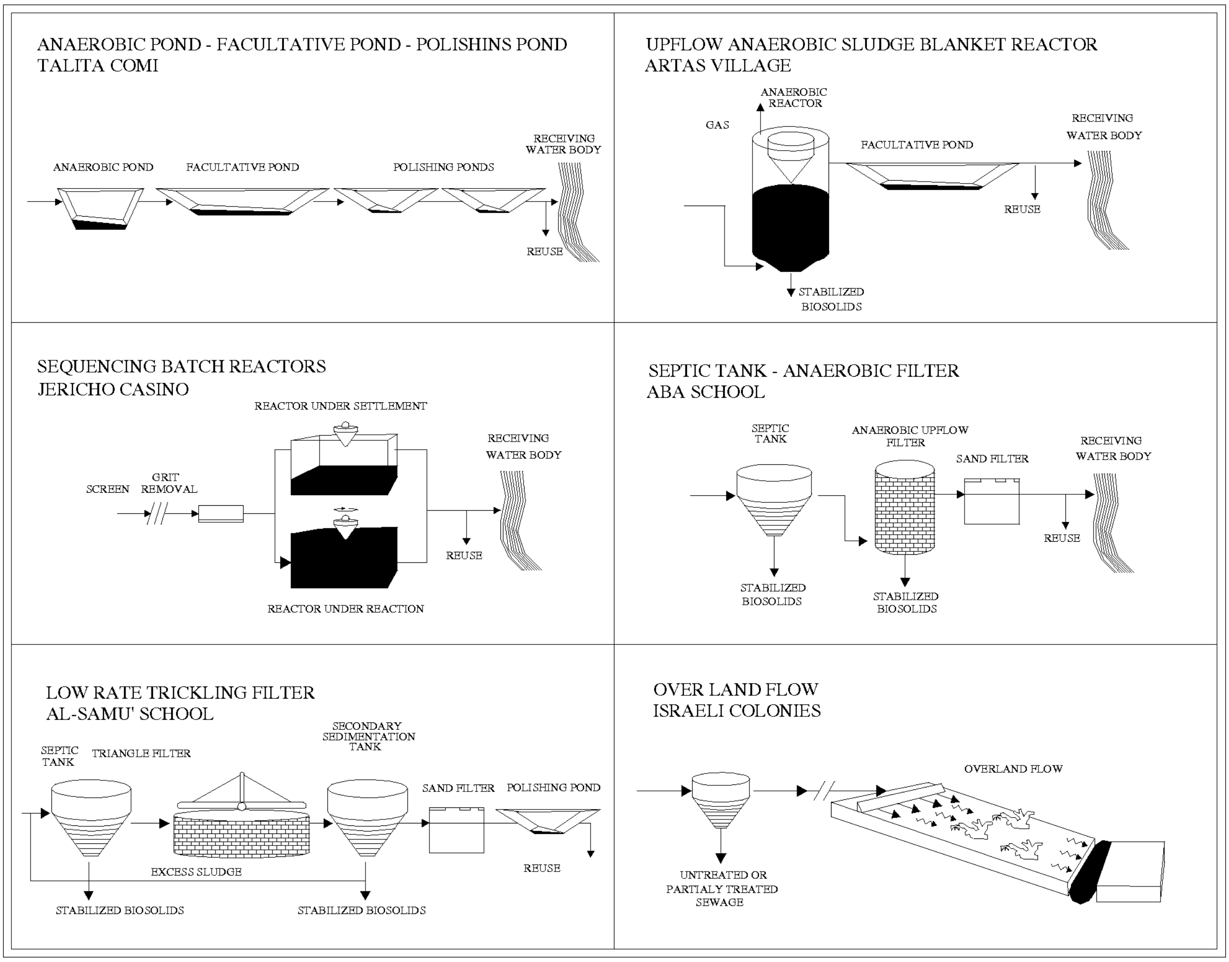

Fig. 2: Flow sheet diagrams of onsite sewage treatment systems in rural Palestine

Reuse of Treated Effluent and Biosolids Management

Palestine is among many countries of the Middle East, where the annual withdrawal of water is already exceeding the renewable amount and water scarcity increases with the rapid population growth and increasingly domestic and agricultural demands. Therefore, reuse of treated effluent and utilization of biosolids (stabilized sludge) is an essential element of an integrated water resources management. It is not the aim of this paper to review and discuss the potential reuse of treated effluent and sludge utilization in Palestine, this issue has been tackled by some authors (Nashashibi, 1995; MOPIC, 1997; Ouda, 2000).

Large urban projects of reuse of treated effluent are still lacking; however, small pilot scale projects have failed. Among the reasons behind are of legal, technical and socio-cultural nature. Nevertheless, it seems clear that hygienic concern related to sanitation and reuses schemes and the need to demonstrate safety of these schemes should be investigated. Small rural onsite projects are successfully implemented where wide public awareness campaigns and environmental education programs were made. Environmental awareness is a key task of most NGOs, like PHG, where lectures, workshops, environmental educational materials and environmental week were organized and conducted (Daoud, 2000). PHG has realized the benefits of reuse of treated wastewater in agricultural irrigation as a resource recovery in terms of offsetting some of the costs of community sanitation. Among the benefits are: conserve limited water resources, expand irrigated areas and produce more food, fodder, or industrial crops, cost savings of expensive fertilizers and increase in soil fertility. It is estimated that, the agricultural component of Beny Zaid regional project will double the total revenue from $4.000/ha to about $8.000/ha through treated wastewater reuse in olive trees irrigation.

Lack of data will make it very difficult to quantify the amount and judge the quality of produced sludge from present rural onsite sewage treatment plants. However, based on the technology applied, it can be said that sludge handling and management as reliable, simple and cost effective concerning the hygienic quality and quantity of biosolids produced.

FUTURE PLANS FOR WASTEWATER MANAGEMENT SERVICES

Strategic Master Plan for Wastewater Management

The Palestinian Water Authority is committed to prevent any harm to the aquatic resources and is doing its utmost efforts to preserve and protect the water resources in Palestine. For this purpose, the PWA has developed a strategic master plan for wastewater management, within the framework of a national strategy for sustainable development (NSSD) to reduce losses of environmental resources on the national, regional and global levels. According to DFID consultation paper on environmental sustainability and eliminating poverty, the Palestinian NSSD should be implemented before 2005, once the Palestinian Water Law is proclaimed by 2003, as indicated by the international development targets, IDTs (DFID, 2000).

The main objective of wastewater strategic plan of the PWA is within 2020, 75% of the population in municipalities and 25% of the population in areas under 5.000 PE, should be connected to treatment plants. The strategy envisaged to construct treatment plants in flexible ways to be able to handle future demands and to produce tools for implementation for treatment plants adjusted to local conditions. Another management tools for regulation of the treatment plants must be developed before 2003. Treatment plants must be secondary or adjusted to reuse, where a strategic plan was assigned to contribute to the education and treating personal in the sector (authorities, operators, municipalities).

Another long-term objective is that about 50% of the population in rural areas must be connected to appropriate treatment within 2020, where the policy to be adopted is that treatment plants should be designed for < 50 person must be of a kind accepted by PWA. The strategy will be making regulations for smaller plants, based on low cost technology. While the action plan is to make regulation for what type of plants and systems that will be accepted for different situations and to decide who should be responsible for regulation.

The policy of PWA on strategic wastewater master plan is based on the concept of "Polluter Pays Principle" and envisaged full cost recovery after the year 2005. Based on affordability basis, also water-tariff models are being developed to assure cost recovery for capital investments and annual running expenditures. These principles are fundamental for success and sustainability of water and sanitation services in both urban and rural communities. However, Palestine relies mainly on external donor funds, this might lead ultimately to degradation of water and sanitation infrastructures, if the envisaged PWA policy is not carefully implemented, and if the beneficiaries are not able or not willing to pay for the services provided.

It is expected that the ability and willingness to pay in rural and semi-urban areas in Palestine are low, due to low-income and high construction costs for centralized sanitation facilities. The results of a survey made by Tiltness (1998) on the willingness to pay for sewerage services in Palestine showed that about 50% of the interviewed (Nablus and Gaza cities) rejected to pay a regular bill and about 20% of un-sewered households can not afford to pay.

Based on this developed strategy, it is obvious that rural sanitation projects will fail to achieve the objectives they are designed to meet as the sanitation sector itself is disorganized. In addition, it does not receive the necessary support from the government. One reason for neglect is the high visibility of projects for major urban areas. Factors behind disorganization are the lack of a comprehensive policy for the rural sanitation sector and lack of knowledge about the low cost technologies appropriate for service levels affordable by the rural poor. Decentralized wastewater management systems should be an integral part of any rural sanitation policy. This will ensure public helth protection, reduction in aqautic environment degradation and save costs of treatment and biosolids. Furthrmore, privatization might play a key role in solving some of the sanitation problems of rural communities. The advantages lay in reduction of capital investments, private sector responsibility of risk for planning, investment and operation, enhance the economical efficiency and project management. However, the experience gained in Europe on privatization of municipal services indicated that privatization was not always the best option for public owned utilities (Nisipeanu, 1998).

Shuval (1999) reported that monopolies of Mekorot and Tahal have ended with the partial and total privatization of these two organizations. The Israeli Water Law (IWL) described by the water law experts as unusual, strongest and leading one in the world, enhanced the process of centralized control of water resources. The IWL was forged in order to meet among others the ideological concepts, resulting in unsustainable water resources management under scarce conditions. In Palestine, suffering under the ideological concepts of IWL "a person's right in land do not provide him with the right in the water source, which is on his land or flows past it", privatization has not been introduced in the national water policy or environmental law. At present it is not a priority, however, it should be investigated case by case and the needed laws and regulations should be developed.

Key factors to success in formulating rural community wastewater management programs should include public acceptance and local political support, funding availability and reasonable costs, visibility and accountability of local leaders. Also capability and skills of local technical and field staff, availability of creative and professional advisors, clear and concise authority, regulations and enforcement mechanisms are key issues (EPA, 1994).

The powers and authorities of the PWA as a legal body for the water and sanitation sectors are still very weak as of political and technical factors. This is quite clear with regard to the power to issue and enforce regulations; the authority to plan and control how and when sanitation services will be provided, the ability to license, train, or certify persons involved in system design, installation, maintenance, and residual disposal. In sum, minimal institutional requirements for the successful implementation of community sanitation projects are; a government policy that support the project, a sectoral agency at the regional level to provide the project with technical support and a community organization, committee to provide link between users and agency.

Moreover, a close cooperation between rural community councils and other national institutions with regard to community planning change in land-use and environmental management will help in a successful development of sanitation management. Most of the housing expansion in many Palestinian rural areas is uncontrolled. This will affect seriously the sustainable water and sanitation management for those areas. To promote a sustainable water and sanitation management in Palestinian rural areas, DFID and PHG are launching a project on Hebron water access and storage of portable water (HWASP) in remote and poor rural areas. This project is being implemented in three phases, where a wider hygien and sanitation education program as well s construction of cisterns and sewage latrines are among the objectives to be achieved.

Rural Domestic Wastewater Treatment Options

Many technical manuals are available to assist in the evaluation and selection of a wastewater management system that is suited to the needs of a particular rural community (EPA, 1992; EPA, 1997; CEP, 1998). Based on a large-scale research carried out by Graaf *et al.,* (1990) on 14 onsite wastewater treatment systems, 8 different types of systems were compared. The comparison involved technological, economical and environmental features.

Low cost anaerobic treatment technologies such as UASB have shown considerable promise recently as advanced pre-treatment option. The UASB technology is feasible in an urban and rural communities in developing world and industrialized counties because of its high organic removal efficiency, simplicity, low cost, low capital and maintenance costs and low land requirements (Lettinga and Halshoff Pol, 1991). These systems are capable of attain high levels of wastewater treatment, produce minimal sludge that is, itself, high in N-P and are capable for producing biogas energy that can be recovered and reused.

Constructed Wetlands

Wetlands designed specifically for treating wastewater are known as "constructed wetlands" and are effective in the removal of BOD, TSS, and N (Brix, 1994). Some of the earliest studies using forested wetlands to treat domestic wastewater demonstrated that nutrients could be removed with a minimum application of expensive and fossil energy consuming technology (Mitsch, 1991).

Wastewater Stabilization Ponds

Waste stabilization ponds (WSPs) are large, man-made basin into which wastewater flows and from which high quality treated effluent can be produced after a retention time of days-as opposed to hours in conventional treatment processes (Mara and Pearson, 1989). They represent an immediate irrigation resource for semi-arid regions and are characterized as simple to operate low-cost, high efficiency and are, therefore, technologies of choice for many developing world situations (WHO, 1987; Mara and Pearson, 1998).

WSPs function through natural forces (sun, wind, gravity, and biological activity) acting on the treatment process, allowing low-cost treatment and providing a much greater removal of pathogens than most conventional treatment processes (Mara and Cairncross, 1989; Bartone, 1991). Dubusk *et al.*, (1989) attribute coliform reduction in WSPs to high wastewater pH and ultraviolet radiation, making them especially attractive for Mediterranean regions where these resources are abundant. WSPs are not energy or capital intensive and allow for a high degree removal of pathogenic organisms.

The disadvantages of the WSPs are that large land areas are required and that their construction may only be feasible when land values are low. WSP lose their comparative cost advantage over mechanized treatment systems when prices are greater than US$ 15-20/m^2 (IBRD, workshop, 1993). However, Mara and Pearson (1998) contend that even at high land costs WSPs are often the cheapest option.

Advanced Treatment

Waste stabilization ponds often have high concentrations of TSS in the effluent, which may not be desirable depending on the irrigation method. Several polishing options are feasible to upgrade pond effluents, thereby increasing the options for effluent reuse. Rock filters, when used in conjunction with WSPs, have been shown to upgrade WSP effluent. Research at a pilot-scale rock filter demonstration conducted at the Assamra WSP in Jordan showed that effluent content reductions could be reduced greatly. TSS and BOD were reduced by 60%, total feacal coliform count by a maximum of 94% and Total-P by 46% at a loading rate of 0.33-0.44 kg TSS/m^3 (Saidam *et al.,* 1995). In a pilot plant study on differences in nitrogen removal in algae-based (ABP) and duckweed-based ponds (DBP), Zimmo *et al.,* (2000) found that both systems were efficient in nitrogen pollution control. However, DBP were efficient in inhibiting algal growth by preventing sunlight from reaching the water column.

CONCLUSIONS AND RECOMMENDATIONS

Palestine is one of the developing countries with limited financial, technical and natural resources. Despite recent capital investments the water and sanitation services in both urban and rural communities are still poor. Policies of industrialized countries are being applied and knowledge and know-how has been implemented to accelerate the development of wastewater infrastructure. However, careful consideration of the local conditions should be made to minimize investment wastage and prevent full utilization of the capital offered. From the results of this study, the following conclusions and recommendations can be made:

1. It is apparent that a variety of treatment technologies are feasible for implementation in Palestine, and even more likely that many low-technology alternatives can be combined and arranged for very high efficiencies. Trickling filters preceded by septic tanks have the best feature for onsite treatment in rural areas. However, utmost care should be taken towards nitrogen pollution control. Monitoring efficiency of existing rural sanitation facilities and experimental verification of the international research findings is suggested.

2. For larger capacities, natural treatment technologies preceded by an advance pre-treatment stage (UASB) are considered feasible. This option has low capital costs, simple maintenance, and resources recovery including wastewater reclamation for irrigation, organic humus for soil improvement and energy source in the form of biogas.

3. There is increasing momentum developing behind the idea that cycling that loops, from point of generation (e.g. household) to point of treatment and reclamation must be differentiated by means of separation of total wastewater into black wastewater and gray wastewater. Reclamation of gray wastewater is more acceptable in rural Palestine as far as the socio-cultural aspects are concerned.

4. More demonstration projects on reuse of treated wastewater and stabilized sludge in/nearby the neighborhood should be introduced. Further epidemiological studies must be undertaken regarding the potential for heavy metals to accumulate in and contaminate food products that are produced from the reclaimed wastewater.

5. To promote best practice in sanitation and environmental health in rural areas, emphasis should be placed on developing sanitation projects that will validate low-technological innovations that are powered by natural processes. These pilots should include a cost benefit analysis component resulting in data that can support decision-making process and educate planners and municipal-level officials regarding the potential benefits of low technology and naturally based treatment and recovery systems.

6. Research should be directed toward the development of methods to mobilize local community groups in self-help sanitation schemes centered on key technologies. Increasing efforts should concentrate on the socio-cultural parts of cleaner production of food products irrigated by reclaimed effluent in target geographical areas.

7. Improved and expanded sanitation services for the poor Palestinian communities require formulating rural community wastewater management programs that should include public acceptance and local political support, funding availability, visibility and accountability of local leaders. Also capability and skills of local technical and field staff, availability of creative and professional advisors, clear and concise authority, regulations and enforcement mechanisms are key issues.

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