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Obstacles and incentives of applying anaerobic technologies for sewage treatment in the Mediterranean Region

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ABSTRACT

According to the World Bank, "The greatest challenge in the water and sanitation sector over the next two decades will be the implementation of low cost sewage treatment that will at the same time permit selective reuse of treated effluents for agricultural and industrial purposes" (Looker, 1998). The main objective of this work is to investigate obstacles and incentives of applying anaerobic technologies for sewage treatment in the Mediterranean Region as a low cost and core of sustainable treatment schemes.

The research methodology was based on distributing two forms of questionnaires, one for wastewater sector professionals and the other for donors, via e mail, fax and web based networks or by personal contact with several academic, technical and managerial people in several Mediterranean countries or countries with Mediterranean climate (Palestine, Jordan, Greece, Italy, Turkey, Spain and Morocco).

The results revealed that the major concern of applying anaerobic wastewater treatment technologies in the Mediterranean Region is not research, design or construction, but rather the experience in operation. Due to the lack of experience and so confidence in the anaerobic systems, practice engineers do not want to take the risk of trying. According to the questionnaire results, the majority of professionals (54.3%) believe that the communities do not play an important role in wastewater treatment technology selection and the majority of professionals (52.9%) and donors (83.3%) said that the academic establishments have no role in the decision making of selecting wastewater treatment technologies and treatment options.

The results revealed that the role of aid agencies and donors in the selection of wastewater treatment technologies can be almost equally described as recommendation (35.3%), imposition (29.4%) and participation (26.5%). This indicates that donors do not all have the same policy. Also, 50% of the interviewed donors said that they choose technologies in which the engineers in their countries are familiar with.

Applying anaerobic wastewater treatment technologies as pre treatment with other aerobic technologies are the most reliable and sustainable wastewater treatment technologies and so from the technical and economical point of view should be included in the wastewater treatment schemes. As a general conclusion, the most important parameter to be taken into account during selection of wastewater treatment technologies is the operational cost, since 100% of both interviewed professionals and donors agreed about this point. Therefore, it is recommended to train physical planners, decision makers, engineers, social scientists, representatives of non-governmental organization and target groups on anaerobic wastewater treatment aspects. In addition, it is recommended to distribute carefully the roles of all of the related stakeholders in technology selection process, all in his/ her position and abilities.

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LIST OF ABBRIVIATIONS

BOD_5	Biochemical oxygen demand
C	Elemental carbon
^oC	Degrees Celsius (centigrade)
CBA	Cost based analysis
CBO	Community based organization
CH_4	Methane gas
CIA	Central Intelligence Agency
COD	Chemical oxygen demand
cm	Centimeter
CO_2	Carbon dioxide
c / yr	Capita / year
DO	Dissolved oxygen
EP	Environmental protection
EPA	Environmental Protection Agency
g	Gram
GLS	Gas/liquid/solids separator in a UASB reactor
GTZ	German Technical Cooperation
H	Hydrogen
HRT	Hydraulic retention time
IASPS	Institute for Advanced Strategic and Political Studies
ICUN	The World Conservation Union
IHE	International Institute for Hydraulic and Environmental Engineering
JICA	Japan International Cooperation Agency
KFW	German development bank
kg	Kilogram
km	Kilometer
kW	Kilowatt
kWh	Kilowatt hour
m	Meter
Mm^3	Million cubic meter
m^2	Square meter
m^3	Cubic meter
MCM	Million cubic meters per year
mg/l	Milligrams per liter
MLD	Million liters per day
mm	Millimeter
ml	Milliliter
MWTP	Municipal wastewater treatment plant
N	Elemental nitrogen
N_2	Nitrogen gas
NGO	Non-governmental organization
NOD	Nitrogenous oxygen demand
ODA	Official Development Assistance
O&M	Operation and maintenance
OM&R	Operation, Maintenance and Equipment Replacement
PE	Person equivalent

RC	Resource conservation
SRT	Solids retention time
UASB reactor	Upflow anaerobic sludge blanket reactor
UN	United Nation
UNEP	United Nations Environmental Program
UNICEF	United Nations International Children's Emergency Fund
UNESCO	United Nations Education, Sciences and Culture Organization
USAID	United States Aid
US$	United State Dollar
WHO	World Health Organization
WSP	Waste Stabilizing Ponds
WWTP	Wastewater Treatment Plant

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Simple, affordable, and efficient treatment systems are urgently needed in developing countries because most of the conventional technologies currently in use in industrialized nations are too expensive and complex (Grau, 1996). Appropriate and sustainable sewage treatment systems will help to preserve biodiversity and maintain healthy (freshwaters) ecosystems, in order to provide clean water, flood control, abundant fisheries and other services of vital interest to human societies. Among the different treatment systems now available worldwide, the anaerobic process is attracting more and more the attention of sanitary engineers and decision makers. It is being used successfully in tropical countries, and there are encouraging results from subtropical and temperate regions (Mahmoud, 2002; Seghezzo, 2004).

Conventional mechanical treatment facilities in developing countries have had a sparse record of success. They frequently do not function as expected because of a variety of technical, financial, and institutional reasons. Alternative treatment technologies emphasize cost reduction, integrated system management, minimal mechanical operations, water reclamation and nutrient conversion wherever feasible. Technologies include simplified, lower cost wastewater collection infrastructure, anaerobic enhanced primary treatment and lagoon-based post-treatment processes that can achieve high effluent quality levels and that can be managed adequately by non-specialists (Journey and Scott, 1996).

The application of these expensive systems does not offer a sustainable solution for sewage treatment in less wealthy countries like Palestine. On the other hand, anaerobic treatment has been proven to be an admirable process and considered by many authors as the core of sustainable waste management (Zeeman and Lettinga, 1999; Hammes *et al.,* 2000; Mahmoud, 2002).

Actually the application of anaerobic technologies for sewage treatment dates back over 100 years. One of the major successes in the development of anaerobic wastewater treatment was the introduction of high-rate reactors due to applying high loading rates, while maintaining long sludge retention time (SRT) at relatively short hydraulic retention time (HRT) due to sludge immobilization (Mahmoud, 2002).

Combined with a proper post-treatment, anaerobic treatment provides a sustainable and appropriate method for providing a good quality effluent from domestic sewage, not only for developing countries but also for advanced countries. It is being used successfully in tropical countries (Goncalves *et al*., 1999), and there are some encouraging results from subtropical and temperate regions (El-Gohary and Naser, 1999).

In developing countries, low maintenance should be preferred over high maintenance technologies, even at the cost of treatment efficiency. Realistic effluent standards must be set that are attainable and enforceable. Introducing too strict effluent standards in developing countries by directly transferring them from developed countries could result in non-sustainable wastewater treatment solutions. It would force the use of technologies beyond the financial, technical and operational means in developing countries, which will ultimately result in process failure (Parr and Horan, 1994).

1.2 PROBLEM DEFINITION

Anaerobic is an attractive process for domestic sewage treatment since it can be characterized by low energy and low cost treatment process. However, this kind of treatment is still applied only at a very limited scale in the Mediterranean Region.

Planners and decision-makers emulate Western sanitation practices to formulate strategies and guidelines for management of wastewater. They consider conventional sewerage for collection and sophisticated technologies for treatment (activated sludge, trickling filter, etc.). These systems do not cope with the financial and operational capabilities of the rural and semi-urban communities and lead to a slow development of sanitation infrastructure.

Excess dependency on the external funds led to humiliation of local funds that could be used to implement alternative and low cost sanitation systems. However, the external funds are limited and time consuming. This phenomenon slows the process of solving the sanitation problems.

1.3 HYPOTHESIS

- The implementation of sustainable anaerobic systems in practice is much more affected by social and psychological matters than the mere technical issues.
- Sanitation systems that have been proven suitable for one country are not necessarily suitable for another and vice versa.
- Technologies without using anaerobic reactors, as pre treatment, are of higher costs than other technologies which include anaerobic reactors.
- There is a lack of knowledge and experience in the anaerobic treatment technologies in the Mediterranean Region.

1.4 RESEARCH OBJECTIVES

This research is aiming at investigating the obstacles and incentives of applying anaerobic technologies of sewage treatment in the Mediterranean countries (Palestine, Jordan, Greece, Italy, Turkey, Spain and Morocco). The idea of this work is to investigate why UP TILL THIS MOMENT ANAEROBIC WASTEWATER TREATMENT IS NOT integrated in many recent wastewater treatment projects, e.g. still extended aeration treatment plants are constructed despite of the great benefits of applying anaerobic treatment, like the cases in Al-Bireh, Amman and Cairo cities.

The sub-objectives of this research are to:

1. Evaluate the published research results of anaerobic treatment of sewage in the whole Mediterranean Region,
2. Assess the current status of applying anaerobic technologies in the Mediterranean Region,
3. Investigate and compare the methodologies and role of both private and public sector in addition to the role of aid agencies and donors in technology selection and implementation,
4. Assess, through case studies, the role and impact of citizens involvement in technology selection,

5. Define several scenarios from previous studies with and without anaerobic reactors and compare them in terms of technical and financial aspects.

1.5 METHODOLOGY

The objectives of the study were attained by the following methodology:

1- Literature search.

2- Collecting detailed information on different wastewater treatment technologies of the wastewater treatment and comparing them.

3- A cost and technical comparison methodologies from previous studies (local and international) between conventional wastewater treatment technologies without using anaerobic reactors as pre treatment and other technologies which include anaerobic reactors are investigated.

4- Surveying by the means of distributing questionnaires, via e mail and fax, among many academic, technical and managerial people in the whole Mediterranean countries on which basis they choose the treatment technologies, and why anaerobic treatment technologies are chosen or not chosen!,

5- Investigating the roles of both private and public sectors in addition to academic establishments and development assistance agencies (USAID, KFW, UNDP, GTZ and PECDAR)

CHAPTER 2

LETERATURE REVIEW

2.1 INTRODUCTION

Wastewater, the water discarded after it has been used for domestic, commercial or industrial purposes, usually requires treatment before discharge, in order to protect receiving environment. The main objective of wastewater treatment is to separate undesirable impurities from the product water. The choice of treatment processes for any particular application depends on the quality of the raw water, the required quality of the treated water, and the economic resources available to pay for both the capital and operating costs of the treatment plant (Barnes *et al.,* 1981). The systematic treatment of wastewater followed in the late 1800s and early 1900s. Before that time, the relationship of pollution to disease had been only faintly understood, and the science of bacteriology, then in its infancy, had not been applied to the subject of wastewater treatment.

At the present time, most of the unit operations and processes used for wastewater treatment are undergoing continual and intensive investigation from the standpoint of implementation and application. As a result, many modifications and new operations and processes have been developed (Metcalf and Eddy, 2003).

The increasing scarcity of clean water in the Mediterranean Region sets the need for appropriate management of available water resources. Particularly regions suffering from a lack of water urgently need integrated environmental protection and resources conservation (EP and RC) technologies in order to enable effective management of the available water resources. EP and RC concepts focus on a minimum of consumptive use of energy, chemicals, and water and a maximum of reuse of treated wastewater and of residues product from the pollutants present in the wastewater. Consequently, by implementing these concepts, instead of social threat wastewaters like sewage and industrial effluents become an important resource for water, fertilizers, soil conditioners and to some extent also energy. In addition, a bridge is made between environmental protection and agriculture practice, stimulating agriculture in the neighborhood of large cities (Lier *et al.,* 1998)

Anaerobic treatment of wastewater has been a viable technology used around the world for centuries. Better understanding of both the engineering and the biology involved in these natural enhanced processes has led to technological advances that have made anaerobic reactors a viable treatment technology. These systems are modular, compact, low cost, and effective and are operating in many countries. It is a technology on the verge of commercialization.

2.2 WASTEWATER TREATMENT

The objective for applying wastewater treatment system is preventing pollution of the environment. In solving environmental problems, such as sanitation and treatment, a number of solutions can be formulated. However, only some of them can be considered as sustainable, complying with the general sustainability criteria as proposed by Lettinga *et al.* (1997). Important criteria to be set for such appropriate environmental protection technologies and methodologies are summarized in Table (2.1). The classically applied centralized sanitation concepts completely clashes with the first criterion listed in this table. A part from its benefits, a large sewage network in fact is nothing more than a transportation system for human excreta to a central discharge point and/or treatment system, with valuable drinking water as the transport medium. The water demand for such sewer system is extremely high and in fact absurd in those conditions. Also from the environmental engineering point of view, the general applied centralized sanitation concept can be questioned. Concentrated wastes are relatively easy to manage while management of diluted human excreta requires large civil investments and/or high-tech technologies.

Treatment of municipal wastewater depends on natural processes, such as gravity to clarify an effluent and bacterial action to stabilize the biodegradable organic fraction. Pathogenic organisms are removed through natural die-off, deprivation of appropriate hosts and competition from other organisms in a generally hostile environment. Adequate detention time and temperature are the two most important variables affecting pathogen mortality (Alaerts *et al.*, 1990).

Table (2.1): Criteria for selection appropriate environmental protection technologies and methodologies (Lettinga *et al.,* 1997)

- No dilution of high strength residues (wastes) with (clean) water, e.g. for conveying them from the site where they are produced (e.g. installation of expensive sewerage).
- Maximum of recovery and reuse of treated water and by-products obtained from the polluting substances, e.g. for irrigation, fertilization etc.
- Application of efficient, robust and reliable treatment/conversion technologies, which are low-cost (in construction, operation and maintenance), which have a long life-time and are plain in operation and maintenance.
- Applicable at any scale, very small and very big as well.
- Leading to a high self-sufficiency in all respects.
- Applicable at very small as well as very big scale,
- Acceptable for the local population.

Complete wastewater treatment consists of a series of steps, defined by Jeremy *et al.,* (1999) as follows:

- **Preliminary treatment** this includes simple processes such as screening (usually by bar screens) and grit removal (through constant velocity channels) to remove the gross solid pollution.
- **Primary treatment** usually plain sedimentation; simple settlement of the solid material in sewage can reduce the polluting load by significant amounts
- **Secondary treatment** for further treatment and removal of common pollutants, usually by a biological process.
- **Advanced or tertiary treatment** usually for removal of specific pollutants, e.g. nitrogen or phosphorous, or specific industrial pollutants.

Municipal wastewater treatment often combines anaerobic and aerobic treatment steps in order to achieve the best possible purification results. Under "real life" conditions in developing countries, typical full scale process combinations are however rarely entirely realized. Instead, often only the main treatment steps (aerobic wastewater treatment without a sludge digestion or anaerobic UASB treatment of sludge and wastewater without a post- treatment of the wastewater) are put in place in order to reduce the most severe environmental effects. Accordingly, post-treatment steps are often not realized in developing countries as yet. Future considerations do however have to be based on more stringent decomposition values, environmental, hygiene and nutrient standards (GTZ, 2001).

Complete treatment, or treatment to the advanced stage, is typically not undertaken except to protect economically important receiving bodies of water against eutrophication, or to meet specific criteria for a particular reuse application. The reason is the high cost: infrastructure and operating costs escalate dramatically to achieve an advanced quality final treated effluent. In addition, operators with specialist knowledge are needed to manage the historically prevalent treatment processes (GTZ, 2001).

2.3 ANAEROBIC VERSUS AEROBIC TREATMENT

Until the beginning of the 20^{th} Century, common sewage treatment was land spreading. From this, trickling filter treatment was developed. Due to the increasing amount of concentrated sewage, scientists looked for intensive treatment without the aid of filters. Since 1890, both in the U.K. and the U.S., trials were made to relieve obnoxious conditions arising from wastewater, by blowing air through the water phase. It was around 1912 that a big advance was made, not discharging the flocculent biological solids, but using them over and over again. The principle of "activated sludge" was first described by Ardern and Lockett (1914) and later by Sawyer (1965). Hence, all together, aerobic treatment is about 100 years old. Only in recent years the emphasis of aerobic wastewater treatment truly shifted from the technological hardware to the biotechnological software.

At the end of the 19^{th} Century, the important advance towards anaerobic treatment of the suspended solids of wastewater was made. The industrial approach of sludge digestion was realized at the turn of the century in the U.K. The first heated tank was installed in 1927 in Germany (McCarty, 1981). In contrast to aerobic treatment, the recognition of the biological phenomena occurring in the digestion process started at the same time as this technology came to existence. Now that both aerobic and anaerobic wastewater treatment can be considered as having been upgraded to the level of scientific recognition, it is worthwhile to evaluate to what extent both technologies are currently evolving, either as complementary to one another, as it tended to be in the past, or as direct competitors.

Conventional mechanical treatment facilities in developing countries have had a sparse record of success. They frequently do not function as expected because of a variety of technical, financial and institutional reasons. Alternative treatment technologies emphasize cost reduction, integrated system management, minimal mechanical operations, water reclamation and nutrient conversion wherever feasible. Conventional wastewater (secondary) treatment systems use various types of mechanical equipment to supply air to aerobic bacteria that stabilize organic material and to mix the substrate with the bulk liquid. Aerobic treatment systems may be designed to support nitrification and denitrification to remove nitrogen and to remove phosphorus through biological action. Mechanically aerated wastewater treatment systems are more compact than naturally aerated systems and are capable of providing an effluent low in BOD_5 (<10 mg/l). Conventional treatment systems are in large, medium and small-scale applications for domestic and municipal wastewater effluents. Conventional treatment systems that have been used in developing countries include the activated sludge process and more recent variants, including sequencing batch reactors, extended aeration and the oxidation ditch (Alaerts *et al.*, 1990).

Anaerobic treatment not only removes solids, but includes active biological stabilization of the majority of oxygen consuming substances. Anaerobic treatment processes can achieve an effluent quality intermediate between the primary and secondary that can be classified as an enhanced primary treated effluent. Anaerobic treatment removes the major part of the carbonaceous oxygen demand from raw wastewater, but typically the residual nitrogenous oxygen demand in the effluent requires further treatment to be competitive with a conventional secondary treatment process. Depending on the composition of the raw wastewater, anaerobic reactors can achieve 65-85 percent removal of oxygen consuming substances and 60-80 percent removal of suspended solids. A schematic diagram for both anaerobic wastewater and aerobic treatment technologies is shown below in Figure (2.1).

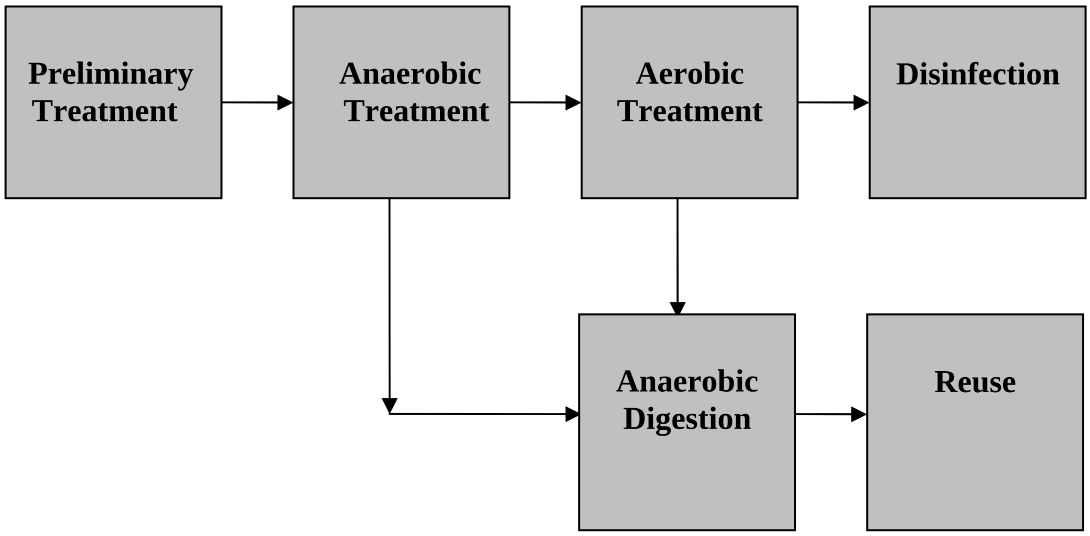

Figure (2.1): Schematic diagram for a treatment plant using both anaerobic as Pre-treatment and aerobic treatment technologies (CH2MHILL, 2004)

2.3.1 CONVENTIONAL WASTEWATER TREATMENT

The equipment which is used to supply air to aerobic bacteria that stabilize organic material includes pumps for liquids, compressors or blowers for air, rotating devices and auxiliary electrical equipment and control systems. High-rate aerobic treatment systems rely either on suspended bacterial growth, in which the aerobic bacteria are mixed with the wastewater by mechanical stirring or injecting air into the reactor, or attached growth where the wastewater is exposed to bacterial films that grow on a fixed medium in the reactor. A few types of systems combine both suspended and attached growth. Aerobic treatment systems may be designed to support nitrification and denitrification to remove nitrogen and to remove phosphorus through biological action (Engelmann, 1993).

Table (2.2) compares the average performance and sludge production of some of the most common aerobic treatment technologies. Performance varies with the quality of the effluent, temperature, process modifications and the constituents of the wastewater.

Table (2.2): Average performance and sludge production of the most common aerobic treatment technologies (Engelmann, 1993)

Treatment Technology	Removal Efficiency (%)				Effluent TSS (mg/l)	Sludge production (dry weight) kg/kgBOD removal
	BOD_5	TKN	N_{total}	P		
Primary sedimentation	20-30	15-20	0	-	-	-
Activated sludge						
High load	90	25	30	30	25	0.9-1.0
Low load	95	75	55	45	10	0.5-0.7
Oxidation ditch	95-98	80-90	50-70	10-20	10-15	0.3
Trickling filter						
High load	80	20-35	25	-	45	0.6
Low load	90	60-80	35	-	25	0.4
Rotating biological contactor	90-95	50-75	-	-	-	0.6
Aerated lagoon	70-80	-	-	-	-	0.03-0.08m^3/c/yr
Waste stabilization ponds	80-90	-	-	-	50-75% removal	0.03-0.08m^3/c/yr

2.3.2 ANAEROBIC WASTEWATER TREATMENT

Anaerobic digestion has been rediscovered in the last two decades, mainly as a result of the energy crisis. Major developments have been made with regard to anaerobic metabolism, physiological interactions among different microbial species, effects of toxic compounds and biomass and biomass accumulation. A number of advantages of anaerobic digestion over aerobic purification has been recognized, anaerobic treatment is more suited to wastewater high in BOD. It is used to treat the sludge from an activated sludge treatment or biological filtration process. In households where there is cottage industry (such as food processing to supply restaurants or food market) the wastewater may be high in BOD. Wastewater high in BOD may also be generated when water conservation measures result in less water being used. A simple method to treat blackwater and kitchen waste is shown in Figure (2.2) the biogas produced can be combusted for use in cooking (UNEP, 2003).

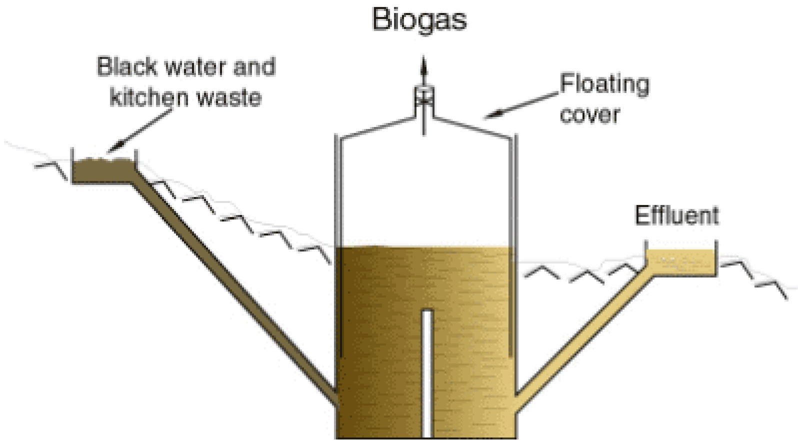

Figure (2.2): A simple anaerobic treatment of blackwater and kitchen waste (UNEP, 2003)

In the Upflow Anaerobic Sludge Blanket (UASB) process wastewater is passed upward through a sludge blanket. The sludge blanket consists of anaerobic bacteria, which have developed into flocs or granules. Because of the high settling velocity of the granules, the granules are not carried over in the upflowing wastewater. A high concentration of bacteria is therefore retained in the tank. The tank itself has no internal moving parts. If wastewater is distributed evenly at the base of the tank, mixing between the wastewater and the granules of bacteria is promoted by the carbon dioxide and methane gases produced by the anaerobic treatment process and the upward moving flow of the wastewater (UNEP, 2003)

Although the reactor itself has a simple configuration with no moving parts, pumping of the feed is still required. Methane gas is produced which needs special handling procedures to prevent leakage and explosion. Wastewater treated anaerobically requires further aerobic treatment to reduce its BOD and odor. The mixture of methane and carbon dioxide (termed 'biogas') can be combusted and used for heating the content of the anaerobic reactor or for other purposes(UNEP, 2003). COD balance and energy comparison between aerobic and anaerobic treatment processes is shown below in Figure (2.3) (Jewell, 1994).

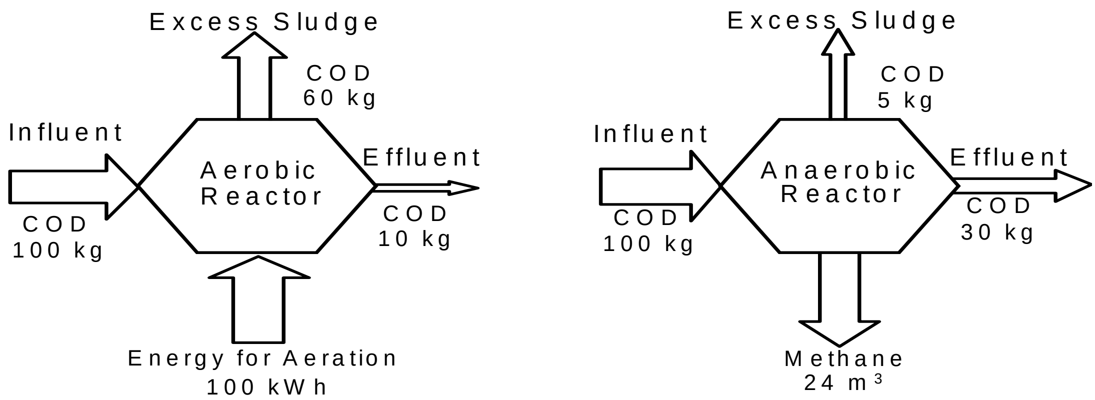

Figure (2.3): COD Balance and Energy Comparison between Aerobic and Anaerobic Treatment Processes (Jewell, 1994)

Removal efficiencies depend on water temperature, hydraulic loading, reactor design, and the quality of the works and the maintenance status of the reactor (Journey and Scott, 1996). Depending on the composition of the wastewater, the removal efficiency of the UASB process may vary between 60-70 percent for COD and 75-85 percent for BOD_5 at influent temperatures between 20-35 ^oC. At 24 ^oC a properly designed and built reactor treating a typical municipal wastewater, when operated within the design parameters, may be expected to average removal efficiencies of 75 percent of BOD, 70 percent of COD and 80 percent of TSS. Only negligible amounts of nitrogen and phosphorus are removed; 75-90 percent of N will be converted to ammonium ion (NH_4^+). Sulfur compounds are almost completely converted to hydrogen sulfide (H_2S). Removal of low concentrations of helminthes ova is almost complete. In endemic regions with high concentrations, 80-90 percent removal may be expected. Removal of pathogenic bacteria and viruses is about 50 percent The composition of biogas generated in the reactor depends on the characteristics of the wastewater and on the loadings applied. Gas production is typically 220-250 l/kg of influent COD, excluding gas dissolved in the effluent. For an influent COD concentration of 300 mg/l, gas production will be about 60-75 l/m^3 of treated wastewater. The measured gas production is the primary control parameter of the reactor, e.g., the parameter that indicates whether the reactor is functioning properly. Lower production indicates inhibition of the biological process, sludge loss or some other problem. Sludge production depends mainly on the concentration and organic content of suspended solids in the wastewater and the SRT and is adversely affected by sludge washout (Journey and Scott, 1996).

2.4 ADVANTAGES, DRAWBACKS AND PROSPECTS OF ANAEROBIC TREATMENT SYSTEMS

Anaerobic treatment of wastewater is an effective enhanced primary treatment option for developing countries. Advantages of anaerobic treatment over aerobic treatment processes with the drawbacks and prospects of the anaerobic treatment are listed below in Table (2.3) (Lettinga *et al.,* 1993; Foresti (2001); Gijzen (2001); Mahmoud (2002))**:**

Table (2.3): Advantages and drawbacks of anaerobic sewage treatment

Advantages:-

- ❖ A substantial saving in operational costs as no energy is required for aeration; on the contrary energy is produced in the form of methane gas, which can be utilized for heating or electricity production. Hence, it couples the degradation of organic materials from waste to the production of energy.
- ❖ The process can handle high hydraulic and organic loading rates. Thus, the applied technologies are rather compact and reduce the volume of post treatment stages.
- ❖ The technologies are simple in construction and operation; consequently they are low cost technologies.
- ❖ The systems can be applied everywhere and at any scale as little if any energy is required, enabling a decentralized application. This unique privilege reflects the systems flexibility, besides the fact that the decentralized mode leads to very significant savings in the investment costs of sewerage systems.
- ❖ The excess sludge production is low. In addition the sludge is well stabilized and easily dewatered due to high solids retention time (SRT). Thus, the sludge does not require extensive costly post treatment.
- ❖ The valuable nutrients (N and P) are conserved which give high potential for crop irrigation and aquaculture.

Drawbacks:-

- ❖ Need for post treatment, depending on the requirements for effluent standards.
- ❖ No experience with full-scale application at low/moderate temperatures.
- ❖ Considering amount of produced biogas i.e., CH_4 and H_2S remains in the effluent especially for low strength wastewater (sewage).

- Produced CH_4 during anaerobic sewage treatment is often not utilized for energy production.

Anaerobic sewage treatment in countries with a low or moderate temperature climate is a real challenge for researchers in the field of environmental technology. However the investigations, which have been carried out by several researchers, represented a commendable move towards the understanding of the involved complex processes and the development of a series of novel technologies. The results of several researchers on bench scale and pilot scale systems operated at low temperatures have opened new perspectives but no full-scale application has so far been realized. Nevertheless, experience with the application of one stage up flow anaerobic sludge blanket (UASB) reactor system at low temperature and high influent suspended solids concentration as found in many Middle East countries is still to be developed (Mahmoud, 2002).

2.5 ANAEROBIC REACTORS IN SERIES WITH MECHANICALLY AERATED TREATMENT SYSTEMS

Where skilled manpower and a reliable electric power supply are available, but not enough affordable land for pond systems, the investment and operating costs of conventional mechanically aerated treatment plants may be reduced by using anaerobic reactors as the initial major treatment process. Research in Brazil demonstrated that using an anaerobic reactor in series with a mechanically aerated post-treatment process has several important advantages (Haandel and Adiranus, 1995):

The volume of the anaerobic/aerobic treatment plant will be about half the volume of a conventional activated sludge plant, reducing the capital cost correspondingly. The demand for electric power for mechanical aeration is reduced by more than 50 percent, reducing operating costs. The anaerobic reactor replaces both the primary clarifier and the sludge digester of a conventional system (Journey and Scott, 1996).

2.5.1 Oxidation ditch

The oxidation ditch is an option for post-treatment of an anaerobic effluent. It is a secondary treatment process that is less difficult to manage than the activated sludge process. It uses an oval channel with a rotor placed across it to provide aeration and circulation. The screened wastewater in the ditch is aerated by the rotor and circulated at the rate of 0.3-0.6 m/second (Alaerts *et al.,* 1990). The size and power consumption of an oxidation ditch used for post-treatment of an anaerobic effluent will be smaller than one that treats the raw wastewater.

2.5.2 Trickling Filter

The trickling filter is an aerobic attached growth process that distributes settled wastewater or an anaerobic effluent over solid media, such as rock, broken brick or plastic. Attached films of aerobic biomass grow on the media and digest the organic material in the wastewater. Periodically, excess biomass sloughs off the media and is collected for disposal in a secondary clarifier. Part of the clarified effluent is re-circulated over the filter to increase hydraulic scour to keep the fast growing biomass in check. The aerobic sludge byproduct of the trickling filter may be combined with the raw wastewater influent and digested in the anaerobic reactor that is used as the initial treatment step, increasing the organic loading to the reactor and improving its removal efficiency.

The trickling filter process is a simple and robust process that can operate at high or low loads. With recirculation, it can remove 80-90 percent of BOD_5 and 25-35 percent of total nitrogen. In warm climates the trickling filter may become infested with flies, and may be the source of odors (Journey and Scott, 1996).

2.5.3 Low Energy Post Treatment Technologies

Since anaerobic treatment needs little electric power, other than small amounts for pumping within the treatment plant, it would be reasonable in a developing country to select a post-treatment process that can also operate with little or no power supply. Pond technologies meet that requirement, receiving the energy needed for the biological treatment processes directly from sunlight and oxygen from natural reaeration from the atmosphere through the surface of the pond. Similarly, subsurface flow wetlands rely on attached films of aerobic bacteria that receive oxygen from the vascular system of the plants through the roots. Stabilization ponds may be used to treat wastewater effluents typically to secondary quality, beginning with raw wastewater, or they may be designed to treat effluents at any stage of treatment. A pond system can polish an anaerobic enhanced primary treated effluent and, with appropriate retention time, can remove pathogens to an acceptable level before discharge into a receiving stream or before reuse for irrigation or groundwater recharge.

Brazilian researchers have developed design criteria for pond systems that provide effective post-treatment of anaerobic reactor effluents in a warm climate (Catunda *et al.*, 1995). These design criteria are described below:

The substantially reduced oxygen demand and solids content of an anaerobic reactor effluent makes it possible to reduce the pond area by half or more compared with a conventional pond system that receives raw wastewater. It has been established empirically that initial anaerobic treatment facilitates the removal of nitrogen and phosphorus by means of physical-chemical processes (volatilization and precipitation) that develop in the pond. An anaerobic reactor substitutes for the initial cells in a conventional pond series that are designed to stabilize organic material. The effect is to reduce the overall pond area, and the post-treatment ponds are optimized to destroy pathogens and to remove residual oxygen demand and nutrients.

Application of a *plug flow* hydraulic regime for post-treatment ponds reduces the pond space needed by 50-65 percent compared with a pond series that would normally be designed for polishing. The size reduction is more than 80 percent compared with a conventional series of 4-5 ponds designed to receive raw wastewater. A plug flow pond system for post-treatment can be designed to maximize algae growth, so that photosynthesis by algae predominates over bacterial growth. Light can penetrate almost the entire water column in a shallow pond (0.3-0.65 m depth) because of the relatively low turbidity of the reactor effluent (Journey and Scott, 1996).

2.5.4 Constructed Wetlands

Wetlands can be the site for most biological and physical treatment processes, such as microbial degradation of organic material, sedimentation of suspended solids and removal of pathogens. They also function as sinks where mineralized nutrients are fixed in plant biomass or removed through the processes of adsorption, precipitation, nitrification and denitrification (Reed *et al*., 1995).

The soil in wetlands is saturated with water for all or most of the year and colonized by aquatic vegetation, including macrophytes (higher plants) and bacteria. Natural wetlands differ in the dominant types of vegetation native to each: swamps have mostly trees), bogs have primarily mosses and peat, and marshes that are characterized by grasses, other emergent macrophytes and floating macrophytes. Marshes are the most common type of wetland used for wastewater treatment.

Constructed wetlands have a controlled hydraulic regime, a graded bottom and provision for management of vegetation and other system components. There are two main types of constructed wetland, according to the position of the water surface with respect to ground level: free water surface and subsurface flow.

The water surface in a free water surface wetland is exposed to the atmosphere, where reaeration occurs, and the emergent vegetation is rooted in the soil at the bottom of the excavated basin. Operating depths range from 0.3-0.8 m and retention times up to several days.

A subsurface flow wetland has porous media, such as gravel, filling the excavated basin to a depth of 0.3-0.6 m, and the surface of the water is maintained below the surface of the media. The same types of emergent plants as in the free water surface wetland are rooted in the gravel.

Microbial films grow on the surfaces of roots and media in constructed wetlands and are the sites of active biological treatment, mediated by temperature, oxygen availability and by the surface area of the attached growth. Oxygen is transported by the vascular system of the plants, from the leaves to the roots to the microbial films that colonize the roots and media (van Haandel and Adiranus, 1995).

Constructed wetlands can remove large amounts of BOD_5, nutrients and suspended solids. Maintaining high nutrient removal efficiencies through the mechanism of plant uptake ultimately depends on periodic harvesting to provide space for additional plant growth and to prevent recycling of BOD_5 and nutrients within the system.

2.6 CHARACTERISTICS OF THE MEDITERRANEAN REGION

The peoples around the Mediterranean all share the same ecosystem. However belonging to four important religions and speaking over 15 different languages (and throughout more than 30 centuries of historical conflicts and not always peaceful exchanges), all these peoples have developed common techniques to relate to their environment. A so-called "Mediterranean culture" has been shaped: from architecture to cuisine, from agriculture to water management or fishing techniques. A large array of common adaptations to a common environment is shared by peoples now integrated in over 20 different countries (IUCN Mediterranean Office, 2002).

Mediterranean Sea is surrounded by European, African, and Asian Cotenants. It is 3,700 km long, covers an area of 2.5 million km^2 and has contact with 16 countries with a total area of 6.7 million km^2. In the coming decades, most of the Mediterranean basin countries in North Africa, Middle East and Southern Europe will face the growing need for wastewater reuse. This is to sustain population and economic growth for the basin's inhabitants (200 million approximately) sustaining one of the highest growth rates as well as for the growing number of tourists in the region (Shelef and Azov, 1996).

With respect to wastewater reuse and reclamation, Mediterranean countries share the following features and characteristics (Alcalde, 2004):

- Warm, sunny and mostly rainless climatic conditions during a relatively long summer and a rather long rainy season during autumn/winter and early spring.
- A general shortage of water, at least in certain regions of the respective countries.
- A threat of pollution to groundwater and surface water due to the lack of dilution, dispersion and flushing out- a consequence of the general shortage of water.
- Advantages in intensive agriculture (due to relatively warm and sunny climatic conditions) aimed at exporting of agricultural products to colder agriculture during the dry summer, while in some countries, irrigation is needed climate countries. There is a need in most regions for irrigation to sustain such intensive almost all year.

- Droughts, ranging from frequent to occasional, depending on the region. Multiyear droughts have been experienced in the Middle East and Southern Europe in the past two decades.
- Rapid population growth and significant consumptive demands, especially as a result of shifts from rural to urban areas.
- Trans-frontiers water dependencies, and challenging questions of overlapping political and administrative boundaries affecting shared water bodies.
- Tourism is one of the most important economical branches, and hard currency earner (in certain countries the entire economy virtually relies on tourism). Indeed, the number of tourists and visitors to Mediterranean countries is close to 200 million per year. Intensive high-level tourism requires a high standard of sanitation, safe drinking water, safe food (vegetables, fruits and seafood) and unpolluted bathing beaches.
- Relative susceptibility to sanitation-oriented disease outbreaks and even epidemics) due to the warm climate, relatively high proportion of disease carriers and in certain areas the persistence of endemic diseases.
- Relative shortage of funds for both capital investments and operating costs in the public municipal sector.

The above features dictate that intensive and safe wastewater treatment and reuse schemes should be practiced on a large scale in the Mediterranean countries. The management of water resources has the basic scope of balancing water availability (quantitatively and qualitatively) and water demand in space and time, at a reasonable cost and with acceptable environmental impacts. The mismatch of water availability and water need has a strong impact on all aspects of water use in Mediterranean region. Such impacts are: a) the necessity to build reservoirs to store water in the wet season; (b) the need for diverting water from one basin to another; (c) the over exploitation of groundwater and increasing risk of sea water intrusion in coastal areas; and (d) finally, very strong effects on water quality and on water treatment requirements (Correia, 1991).

A unique feature of this area is that water is one of the limiting factors for sustainable development, increased quality of life, and peace.

In the Mediterranean basin, wastewater recycling and reuse are practiced since the Ancient Greek and Roman civilizations (Angelakis and Spyridakis, 1996). Land application of recycled water is an old common practice, which has gone through different development stages with time, knowledge of the pressures, treatment technology, and regulation evolution. Wastewater has also been used by the Mediterranean civilizations (wastewater was reused in the 14th and 15th centuries in the Milanese Marcites and in the Valencian huertas and the Europeans (Great Britain, Germany, France, Poland, etc), respectively (Soulie and Tremea, 1992).

In the Mediterranean region, the volume of wastewater is increasing. Large areas may be supplied with recycled water which may also be used for different other purposes depending on the demand, the water characteristics, its suitability, etc. Consequently, there is a major potential use of recycled water in the region. It is, however, essential that the development of water reuse in agriculture and other sectors be based on scientific evidences of its effects on environment and public health. Although several studies have been conducted on wastewater quality and for different purposes, at this time, there are no regulations of water reuse at Mediterranean level. With the development of tourism and Mediterranean food market, there is a need for sharing a common rationale for developing water reuse criteria on both sides of the Mediterranean.

The Mediterranean region is characterized by common issues related to environmental and development problems, in particular, concerning water resources management, their development and pollution control. However the two shores (North/East and South) of the basin are strongly contrasted and face differently the arising issues. Hot and dry summers and mild winters receiving the major part of the annual precipitation characterize the "Mediterranean" climate. Rainfall is unevenly distributed (in space and time). Moreover, the whole basin or parts of it are experiencing drought episodes in a more or less regular pattern with unpredictable successions of dry years which may seriously worsen the situation.

According to the Blue Plan (Margeta and Vallee, 2000), renewable water resources are very unequally shared across the Mediterranean basin with around 72% located in

North (Spain, France and Monaco, Italy, Malta, Bosnia-Herzegovina, Croatia, Slovenia, R.F. of Yugoslavia, Albania, and Greece), 23% in the East (Turkey, Cyprus, Syria, Lebanon, Israel, Palestinian Territories of Gaza and the West Bank, and Jordan), and 5% in the South (Egypt, Libya, Tunisia, Algeria, and Morocco).

Natural and renewable water resources are unequally distributed between Mediterranean countries with the rich North and the poor to extremely poor South and East. But within each country water resources are also unequally distributed. In Spain, 81% of resources are located in the Northern half of the country; in Tunisia, the North provides the 80% of the country's water resources; in Algeria, 75% of renewable resources are concentrated in 6% of the land in the Mediterranean coastal border. The hydrographic basins are broken up and also several basins are crossed by national borders, making the resource common to several countries. Furthermore, some considerable water volumes stored in large deep aquifers in Libya, Tunisia, Egypt, and Algeria are non-renewable resources and their use is consequently not sustainable (Kayamanidou, 1998). Several characteristics of the Mediterranean countries are shown in Table (2.4) for the years 2005 and 2025. In terms of population, the annual availability of water resources per capita is very imbalanced.

Table (2.4): Several characteristics of the Mediterranean countries

Country	**Surface area (km^2)**	**Total Pop-ulation (x1000) 2005 2025**	**Population growth rate (annual %) 2005 2025**	**Urban Pop-ulation (%) 2005 2025**	**Rural Population (%) 2005 2025**	**Urban ** water supply cover-age (%) 2005**	**Rural ** water supply cover-age (%) 2005**	**Urban ** sanitation coverage (%) 2005**	**Rural ** sanitation coverage (%) 2005**
Algeria	2.4 million	32 877 42 429	1.56 0.94	(60.0) (70.3)	(40.1) (29.7)	98	88	90	74
Cyprus	9,250.0	813 892	0.61 0.28	(69.5) (74.7)	(30.5) (25.3)	100	100	100	100
Egypt	1.0 million	74 878 103 165	1.96 1.26	(42.3) (50.7)	(57.7) (49.3	96	94	98	91
France	551.5 thousand	60 711 64 165	0.38 0.18	(76.7) (81.7)	(23.3) (18.3)	-	-	-	-
Greece	132.0 thousand	10 978 10 707	0.03	(61.4) (70.1)	(38.6) (29.9)	-	-	-	-

Israel	21,060.0	6 685 8 598		(91.7) (93.1)	(8.3) (6.9)	-	-	-	-
Italy	301.3 thousand	57 253 52 939		(67.5) (72.3)	(32,5) (27.7)	-	-	-	-
Jordan	89,210.0	5 750 8 116		(79.3) (83.4)	(20.7) (16.6)	100	84	100	98
Lebanon	10,400.0	3 761 4 554		(88.0) (91.4)	(12.0) (8.6)	100	100	100	100
Libya	1.8 million	5 768 7 785		(86.9) (90.5)	(13.1) (9.5)	72	68	97	96
Malta	320.0	397 418		(92.1) (94.6)	(7.9) (5.4)	100	100	100	100
Morocco	446.6 thousand	31 564 40 721		(58.8) (70.1)	(41.2) (29.9)	100	58	100	42
Occupied Palestinian territories*	6,620.0	3 635 (2003)	3.6	-	-	-	-	-	-
Portugal	91,980.0	10 080 9 83		(55.6) (66.1)	(44.4) (33.9)	-	-	-	-
Spain	506.0 thousand	41 184 40 369		(76.7) (80.4)	(23.3) (19.6)	-	-	-	-
Syria	185.2 thousand	18 650 26 979		(50.3) (56.8)	(49.7) (43.2)	94	64	98	81
Tunisia	163.6 thousand	10 042 12 037		(64.4) (72.4)	(35.6) (27.6)	-	-	-	-
Turkey	774.8 thousand	73 302 88 995		(67.3) (75.9)	(32.7) (24.1)	82	84	98	70

Source: *World Population Prospects: The 2002 Revision* (United Nations, Population Division) and World Development Indicators database, World Bank, April 2004,

*Source: CIA World Fact book, December 2003 and The Palestinian Central Bureau of Statistics, September 2003

**Source: *World population prospects: 1998 revision.* New York, United Nations, Department of Economic and Social Affairs, Population Division, 1999.Global Water Supply and Sanitation Assessment 2000 Report, World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF).

2.7 EXISTING WASTEWATER TREATMENT TECHNOLOGIES IN THE MEDITERRANEAN REGION

Generally speaking most of the countries in the region do not have specific national standards for wastewater treatment technologies (UNEP, 2000). The following conventional methods are used:

- Activated sludge plants
- Trickling filters
- Aerated lagoons
- Oxidization ponds or waste stabilization ponds

In Egypt, the number of treatment plants are increasing; from 22 treatment plants in 1992 treating about 650 million cubic meter per year to a potential of 123 plants treating about 4.9 billion cubic meters per year in 2005. Two major treatment plants (one is oxidation pond and the other is activated sludge) are completed for Cairo West and Cairo East. They are operating at very good efficiencies. Alexandria, being the second largest city, has a new activated sludge treatment plant with a capacity of 1.3 million cubic meters per day. Most of major cities will have wastewater treatment plants with priority given to coastal and tourist cities like Matrouh, Luxur and the new town in the Red Sea. Other cities in the new developed land (Sina and New Valley) do not have treatment facilities since they rely on septic tanks. The treatment plants of the industrial cities (10^{th} of Ramadan and 6^{th} of October) are oxidation ponds designed to meet domestic wastewater plus the effluent of the industrial plant (of acceptable standards). In Egypt, although the use of waste stabilization ponds is increasing, activated sludge method is still the most common method (UNEP, 2003).

In Jordan, since 1930, waste-water collection in Jordan had been restricted to the town of Salt, where primitive physical devices such as septic tanks and cesspits were in use. Effluent from these was often discharged to gardens, resulting in environmental problems such as groundwater pollution. As population increased, modern technology was introduced to collect and treat wastewater. Currently, there are nearly 20 treatment plants around the country, including two that are scheduled to be put into service in the near future. Table (2.5) shows some characteristics of the existing wastewater treatment plants in the country (UN, 2003)

Table (2.5): Wastewater treatment plants in Jordan (1999) (UN, 2003)

No.	WWTP	Year of operation	Treatment system	Design capacity (m^3/d)	Inflow av. In 2000 (m^3/d)
1	Abu Nuseir	1986	OD+ RBC	4,000	1,411
2	Al-Samra	1985	L	68,000	166,844
3	Aqaba	1987	L	9,000	8,774
4	Baqʾa	1988	TF	6,000	10,284
5	Central Irbid	1987	TF + AS	11,023	4,612
6	Fuheis	1997	AS	2,400	1,019
7	Jerash	1983	EA	3,500	1,603
8	Karak	1988	TF	786	1,146
9	Kufranja	1989	TF	1,900	1,734
10	Maʾan	1989	L	1,590	1,738
11	Madaba	1989	L	2,000	3,609
12	Mafraq	1988	L	1,800	1,1,933
13	Ramtha	1987	L	1,920	2,174
14	Salt	1981	EA	7,600	3,166
15	Tafila	1988	TF	800	851
16	Wadi Seer	1997	L+aeration	4,000	5,993
17	Wadi Arab	1999	AS	22,000	914

AS: activated sludge; OD: oxidation ditch; EA: extended aeration; AL: aerated lagoon; RBC: rotating biological contactor; TF: trickling filter.

Furthermore, 56 per cent of the population of Jordan, i.e. some 2.5 million people, is connected to the wastewater collection network, including 50 per cent of the country's urban population (UN, 2003)

The largest one is serving Greater Amman and Zarqa district with a population of 1.5 million inhabitants. Al Samra waste stabilization ponds (WSP) were designed for a capacity of 68,000m^3/day. Al Samra WSP were receiving influent and organic loading far in excess (2.5 times) of the designed capacity. The plant consists of three trains; each has two anaerobic ponds, four facultative ponds and four maturation ponds. In spite of the excessive loading with respect to the design parameters, the removal efficiency of BOD and TSS at the facilities has declined only slightly. This situation is attributed to the fact that facultative (and probably maturation ponds) are acting anaerobically, producing offensive odors and impacting several kilometers of the area around the facility. Al Samra effluent BOD, COD, and TSS do not meet the Jordanian standard for the discharge of effluent to wadis. The government has completed a study (Herza 1997) for the rehabilitation, expansion and development of existing wastewater system in Amman- Zarqa basin area to treat about 600 m^3/d by the year

2020. For the rest of the country, Table (2.5) illustrates some information on the different operating wastewater treatment plants. By comparing the design inflow to the actual inflow it is clear that 7 out 14 plants are operating under hydraulic and organic overloading (UNEP, 2003). A partial view of Al Samra wastewater treatment plant is shown below in Figure (2.4).

Figure (2.4): Partial view of the Al Samra WSP, Amman. In the foreground are some of the olive trees, the harvest from which pays towards the O&M costs of the pond system

In Lebanon, Domestic wastewater management is one of the greatest headaches of Lebanese municipalities and concerned ministries. On population pressures, Lebanon generates an estimated 249 Mm^3 of wastewater per year, with a total BOD load of 99,960 tones. In addition, industries generate an estimated 43 Mm^3 of wastewater per year. During the reconstruction period following the 15 year civil war, the government has completed a preliminary treatment plant in Beirut with a design capacity of 170,000m^3/day. Beirut treatment facilities employ screening, grit removal and settling. However, the infrastructure in sewer pipeline system has not been completed to connect all the city households to the treatment plant (UNEP, 2003)

Wastewater management is expensive! It requires adequate collection and treatment of wastewater, and disposal of treated effluent and sludge. To date, while significant improvements are being made to the sewer network, little has been achieved in terms of wastewater treatment. Nevertheless, several wastewater treatment plants are expected to become operational over the coming years.

Thirty-five wastewater treatment plants (WWTPs) are planned for the near future; the government of Lebanon (GOL) initiated the construction of seven wastewater treatment plants in 2001: Saida, Chekka, Batroun, Jbeil, Chouf coastal area, Baalbeck and Nabatiyeh; 18 for which funding has been approved and are in the preparatory stage; and 10 for which no funding has yet been secured (see Table (2.6). The only large-scale WWTP that is operational at the present time is the Ghadir plant, south of Beirut, which provides only preliminary treatment, namely grit and scum removal. An exploratory study is being conducted on the economic feasibility of upgrading the Ghadir WWTP to provide secondary treatment before discharge into the sea (Ministry of Environment of Lebanon, 2001).

Table (2.6): Implementation Status of Wastewater treatment Plants in Lebanon

Location/name	Implementation status		
	Under Execution	Under Preparation	No Funding Secured
Jebrayal			X
Abdeh			X
Michmich		X	
Bakhoun		X	
Tripoli		X	
Becharre			X
Hasroun			X
Amioun			X
Chekka X	X		
Batroun	X		
Jbeil X	X		
Kartaba		X	
Khanchara			X
Haraje		X	
Kesrouane/Tabarja			X
Dora			X
Ghadir			X
Chouf coastal area	X		
Mazraat el Chouf		X	
Saida	X		
Sour			X
Hermel		X	

Laboue		X	
Yammouneh		X	
Baalbeck	X		
Zahle		X	
Aanjar		X	
Jib Jinnine/Deir Tahnich		X	
Karoun		X	
Sohmor/Yohmor		X	
Hasbaya		X	
Jbaa		X	
Nabatiyeh	X		
Shakra		X	
Bint Jbeil		X	

Source: Ministry of Environment, State of the Environment Report 2001.

In the absence of operational wastewater treatment plants, effluent from coastal communities is discharged into the sea, while effluent from inland communities is disposed of in rivers, streams, dry river beds, on open land or underground through dry wells. There are approximately 53 outfalls along the coast. Most outfalls extend only a couple of meters or terminate at the surface of the water; thus, there is no submersed outfall and thus no effective dilution of waste-water. The Ghadir outfall, however, is a submersed pipeline 1,200 millimeters in diameter which extends 2.6 kilometers out into the Mediterranean Sea. The outlet point is approximately 60 meters deep, and consequently the wastewater is adequately diluted. Delays in the construction of waste-water works in various parts of the country have prompted a number of municipalities and local communities to make their own arrangements with the technical and financial support of non-governmental organizations (NGOs) that secure funding through international donors such as the United States Agency for International Development (USAID). Thirteen small community-level wastewater treatment plants became operational in this way in 2001. Most of these provide secondary treatment, producing water that is suitable for irrigation (Ministry of Environment of Lebanon, 2001).

In the West Asia region (Jordan, Lebanon, Egypt, Syria and Palestine), a diverse range of technologies are used in various countries ranging from conventional wastewater treatment methods and wastewater stabilization ponds in large communities to small-scale treatment technologies in small communities. Most of these treatment plants are overloaded due to uncontrolled population growth coupled with the slow development of new treatment facilities, available technologies that are used in the region are grouped under two categories; (i) large scale technologies and (ii) community scale technologies. (UNEP, 2003)

In Tunisia, sanitation coverage in the sewered cities is about 78%, which is 61% of the urban population (5.8 million). Like in Jordan and Palestine, the unsewered households rely on cesspits and public tanks (Abu Madi, 2004). In 1988, about 78 million m^3 of wastewater was treated in 26 WWTPs. In 2000, this amount has increased to 148 million m^3, produced at 61 WWTPs (representing 77.1% of sewered wastewater and 46.8% of total wastewater production). Five treatment plants are located in the Tunis area, producing about 62 million m^3 / year. Several of the plants are located along the coast to protect coastal resorts and minimize sea pollution; currently they discharge around 88% of the treated effluent. The commonly used systems for wastewater treatment include activated sludge, trickling filters, and lagoons. The Characteristics of wastewater treatment plants in Tunisia (2000) are shown in Table (.27).

Table (2.7): Characteristics of wastewater treatment plants in Tunisia (2000) (Abu Madi, 2004)

No.	WWTP	Year of operation	Treatment system	Design capacity (m^3/d)	Inflow av. In 2000 (m^3/d)
1	Cherguia	1985	AS	60,000	40,540
2	Cotiere Nord	1981	L	15,750	16,673
3	Choutrana	1986	AS	111,000	111,720
4	Kalaat El Andalos	1994	AL	1,500	379
5	Sud Meliane	1982	OD	37,500	41,780
6	Rades	1976	L	700	1,233
7	SE1 Hammamet	1980	AS	4,208	3,606
8	SE2 Hammamet	1980	AS	5,146	2,110
9	Hammamet Sud	1995	EA	11,386	5,076
10	SE3 Nabeul	1981	OD	3,500	2,301
11	SE4 Nabeul	1979	AS	9,585	8,731
12	Kelibia	1976	AS	7,742	3,424
13	Soliman	1983	OD	2,547	2,432
14	Grombalia	1993	OD	2,445	2,165
15	Menzel Bozelfa	1993	OD	1,395	2,791
16	Beja	1994	EA	14,000	7,262

17	Mejdez El Bab	1994	EA	4,500	933
18	Teboursouk	2000	OD	1,280	1,125
19	Siliana	2000	EA	4,530	2,263
20	Bizerte	1997	EA	26,600	4,360
21	Menzel Borguiba	1997	EA	11,065	3,980
22	Jendouba	1994	EA	8,000	4,044
23	Kef	1998	EA	8,500	3,896
24	Tabarka	1993	EA	5,500	2,110
25	Sousse Nord	1978	AS	17,400	18,079
26	Sousse Sud	1980	AS	18,700	19,058
27	Sidi Bou Ali	1996	L+Duckweed	644	385
28	Msaken	1996	EA	7,844	3,430
29	Kalaa Sghira	1993	OD	1,450	739
30	Monastir El Ghadir	1962	TF	2,600	2,576
31	Dkhila	1979	AS	3,100	2,773
32	Moknine	1986	L	6,400	5,011
33	Jemmel	2000	EA	6,700	2,163
34	Wardanin	1993	OD	1,500	1,051
35	Sahline	1993	OD	2,560	3,001
36	Sayada	1993	OD	1,660	1,626
37	Ksour Essef	1994	OD	1,500	669
38	El Jem	1994	L	4,840	1,027
39	Mahdia	1995	AL	10,220	3,550
40	Monastir Frina	1995	EA	13,500	4,577
41	Kairouan	1979	EA	12,000	12,154
42	Kasserine	1994	AL	15,000	3,500
43	Sidi Bou Zid	1994	L	3,125	1,756
44	Sfax	1983	AL	24,000	23,915
45	Mahres	1994	OD	780	601
46	Gafsa	1985	L	3,500	6,592
47	Nefta	1992	OD	1,335	1,114
48	Tozeur	2000	EA	5,324	1,689
49	Houmt Essouk	1991	AL	3,500	1,724
50	Dar Jebra	1972	AS	1,600	4,186
51	Dar Jebra Modulaire	1995	EA	420	537
52	Sidi Mehrez	1981	AL	4,000	3,991
53	Sidi Slim	1971	AS	1,800	4,891
54	Tanit	1971	TF	260	111
55	Zarzis Souihel	1980	AS	1,108	118
56	Lella Meriam	1982	AL	1,726	797
57	Zarzis Ville	1992	OD	1,335	569
58	Medenine	2000	EA	8,870	748
59	Tatouine	1999	EA	5,430	1,171
60	Gabes	1995	EA	17,300	12,055

AS: activated sludge; OD: oxidation ditch; EA: extended aeration; AL: aerated lagoon; RBC: rotating biological contactor; TF: trickling filter.

In Turkey, the wastewater treatment technologies available in the large cities are shown in the Table (2.8):

Table (2.8): Treatment technologies for Turkish UWWTP, (Source: Turkish Ministry of Health, 2002)

Province	**District**	**Stages of the Treatment Plant**
Adana, TR - 01		
	Seyhan	S+C+GC+PST+AT+SST+OP
	Yuregir	S+PST+AT+SST+SD
	Kozan	S+PST+SST+OP
	Yumurtalik	S+PST+AT+SST+CL
Ankara, TR - 06		
	Merkez	S+GC+PST+AT+SST+STh+AnSDi+BFP
Antalya, TR - 07		
	Antalya	S+GC+AT+SST+AL+D
	Alanya	S+GC+AT+SST+CL+OTHER
	Kemer-Beldibi	S+GC+AT+SST+OP+CL+OTHER
	Kemer-Camyuva	S+GC+AT+SST+OP+CL+OTHER
	Kemer-Goynuk	S+GC+AT+SST+OP+CL+OTHER
	Kemer-Kemer	S+GC+AT+SST+OP+CL+OTHER
	Kemer-Tekirova	S+GC+AT+SST+OP+CL+OTHER
	Gazipasa	S+PST+AT+SST
	Manavgat-Colakli	S+PST+AT+SST
	Manavgat-Side(1)-Kumkoy	S+GC+AT+DT
	Manavgat-Side(2)-Titreyengol	S+GC+MC
	Serik-Bogazkent	S+AT+SST
	Serik-Serik	S+PST+AT+SST
Bursa, TR-16		
	Bursa- Dogu	S+PST
	Bursa-Bati	S+PST
	Inegol	S+EAT+SST+FBP
	Karacabey	AL+FT+ST+SDB
	Inegol-Yenicekoy	S+PST+AT+SST

	Merkez	S+PST+AT+SST
Gaziantep, TR-27		
	Gaziantep	S+GC+PST+AT+SST
	Merkez-Nizip	S+GC+PST+AT+SST
Istanbul, TR-34		
	Istanbul-Baltalimani	S+GC
	Istanbul-Buyukcekmece	S
	Istanbul-Uskudar	S
	Istanbul-Terkos	S+AT+SST+BFT
	Istanbul-Pasakoy	S+GC+PRT+NT+DT+SST+DAF+SDe
	Istanbul-Tuzla	S+GC+PST+AT+SST+STh+DAF+SDe
	Istanbul-Atakoy	S+GC+PST+TF+SST+SD+BFP
	Istanbul-Yenikapi	S
	Istanbul-Kadıkoy	S+GC
	Istanbul-Kucukcekmece	S+GC
	Istanbul-Kucuksu	S+GC
	Silivri-Canta	S+PST+AT+SST
	Silivri-Silivri	S+EAT+SST+CL
Izmir, TR-35		
	Izmir-Merkez	S+GC+PST+PRT+AT+SST
	Izmir-Guneybati	S+GC+ANT+AT+SST
	Selcuk	S+2PST
	Urla	S+GC
	Karaburun-Iskele	S+ET+AT+SST+CL+STh
	Karaburun-Efes	S+ET+AT+SST+CL+STh
Samsun, TR-55		
	Bafra	S+PST+AT+SST+BFP
	Terme	PST
	Ondokuz Mayis	S+GC+PST+NT+DT+AT+SST+CL

Stages of Treatment, S: Screen, GC: Grit Chamber, PST: Primary Settling Tank, AT: Aeration Tank, SST: Secondary Settling Tank, TF: Trickling Filter, OP: Oxidation Pond, ET: Equalization Tank, PRT: Phosphorus Removal Tank, Tank, SF: Sand Filter, DAF: Dissolved Air Flotation, CL: Chlorination, SP: Stabilization Pond, NT: Nitrification Tank, DT: Denitrification Tank, AAT:

Anaerobic-Anoxic Tank, EAT: Extended Aeration Tank, AL: Aerated Lagoon, OT: Oil Trap, ASDi: Aerobic Sludge Digestion, AnSDi: Anaerobic Sludge Digestion, BFP: Belt Filter Pres, STh: Sludge Thickener, SDB: Sludge Drying Beds, FT; Facultative Tank, SD: Sludge Digestion, SDe: Sludge Dewatering, MC: Mixing Chamber, ANT: Anaerobic Tank

In Palestine, the Palestinian Territories are in a water-scarce region. Since 1967 Israel has controlled Palestinian water resources and takes major amounts for itself. Sustainable management of Palestinian water resources is thus very difficult. Israel recognized Palestinian water rights in the 1993 Oslo accords but this made no difference on the ground. Wastewater services for the Palestinian population vary regionally and are generally inadequate. Before the latest Intifada from 2001, daily water consumption was 50-80 liters per capita, low by international standards. There are few wastewater collection and treatment systems. Since 2001 there has been huge damage to the Palestinian infrastructure and economy. Many water and sanitation facilities have been damaged. Consumers find it hard to pay for basic services including water and sanitation. Service providers are faced with sharply reduced revenues due to the current political situation (e.g. curfew, closures) and sever economic problems. The legal and institutional framework of the water and sanitation sector is still in formation (GTZ, 2005).

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). 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).

Table (2.9) gives the characteristics of wastewater of some cities and rural communities in the West Bank (Tahboub, 2000).

Table (2.9): Characteristics of raw municipal and rural domestic wastewater in the West Bank (Tahboub, 2000)

	Municipal Urban Wastewater				**Rural Domestic Wastewater**	
Parameter	**Ramallah**	**Nablus**	**Hebron**	**Al-Bireh**	**Gray**	**Black**
BOD_5	525	1850	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

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 (Al-Sa`ed, 2000).

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 (Al-Sa`ed, 2000). The difficulties in Nablus City caused by curfews, restrictions and incursions by the Israeli forces are still continuing. Also, construction of wastewater treatment plants has been on hold for the last two years because of difficult working conditions (GTZ, 2005). Except for one detergents factory in Ramallah, wastewater of slaughterhouses, chemical factories, hospitals, etc. is disposed of in the sewerage system without previous treatment.

In Israel, in the past few years, water consumption in Israel has been approximately 490 million cubic meters (hereafter: mm^3) for households, 120 mm^3 for industry, and 950 mm^3 for agriculture. The country has three sources of water: freshwater, treated effluent, and brackish water, freshwater accounts for the largest share, with a pumping potential of approximately 1,500 mm^3 per year. Approximately 70 percent of freshwater comes from three principal sources: the Jordan River basin, the Yarkon-Taninim aquifer (also known as the mountain aquifer), and the coastal aquifer. Small aquifers and flood runoff provide the remaining 30 percent (IASPS, 1996).

The wastewater treatment is aimed at preventing environmental hazards, as well as adding an important water source to the country's water balance (Shuval, 1987; Shelef, 1990, 1991). It should be admitted that the sever water crisis in Israel is the main driving force to the relatively high percentage of treated wastewater in Israel, rather than pure environmental considerations. The number of various types of treatment plants in Israel is given in Table (2.10)

Table (2.10): Wastewater treatment plants in Israel, (Shuval, 1987; Shelef, 1990, 1991)

Type of plant	**Number of plants**	**%**	**Raw sewage (mcmy)**	**%**
Oxidation ponds	375	65	70	24
Mechanical biological	71	12	146	50
Primary	50	9	16	5
Central septic tanks	81	14	18	6
No treatment	0	0	43	15
Total	**577**	**100**	**293**	**100**

About 92% of the wastewater in Israel is collected by municipal sewers. The water crisis in Israel and the relatively low cost of treated wastewater, rather than pure environmental considerations, are the main driving forces behind the high percentage of reuse (Angelakis, 2002).

WSP have been regarded as the wastewater treatment technology of first choice in Israel, given the need for the use of treated wastewater for irrigation. Early WSP built in the 1950s, comprised two alternately used anaerobic ponds in parallel (1-2 day's retention time), and followed by a “minimal” facultative pond with a retention time of only 5-7 days (compared with the then more usual 20-30 days).

In Greece, Historically, Greece is considered as a pioneer in the development of sophisticated sewerage systems, as suggested by findings in ancient palaces and cities of the Minoan civilization (Angelakis and Spyridakis, 1996). Greece has a population of 10.6 million people living in an area of about 132,000 km^2, with a coastline of 15,000 km. The country is located in the south-eastern most part of the European Union, bound by the Ionan, Aegean, and Libean open seas of the Mediterranean region. The economy of the country is increasingly dependent on the tourism industry. Thus, sustainability, conservation of natural resources and the prevention of coastal pollution are of special significance.

Greece is an ideal country where developments in wastewater technology can be tested and established. In Greece, most MWTP have been constructed close to the sea. The large number of extended aeration systems (180 out of a total 241 MWTP); (Tsagarakis *et al*., 1998a) suggests that **engineers and other decision-makers tend to choose tried and tested technologies, which is not altogether surprising.**

In 1980 a paper in Water and Sewage Works (Anon., 1980) described the status of Greece’s wastewater treatment sector. The paper started like this: "There’s no old time adage that when in Greece you do as Greeks do. That’s good because until recently, if you were in the wastewater field and in Greece, you did almost nothing. There’s some movement now, and recently, the first municipal wastewater treatment plant was built in the central part of the country". On pollution control the paper said: “Greece, a Johnny-come-lately in the pollution control field in general, has been spurred into some action by several developments: The all- too heavy direct disposal of untreated wastes into offshore waters has been hurting its fishing industry, and the country depends a lot on that industry. Also, Greece is on the first leg of a multiyear journey into the ranks of the common market and there will have to be some conformance with EEC pollution-control standards before it enjoys that membership.

So, antipollution efforts just now getting underway are due to accelerate during the next few years. By the end of 1997, 241 MWTP had been constructed across the country, of which 127 were in operation and were serving 47% of the total permanent population (Tsagarakis *et al.*, 1998a). Greece has an estimated population of 10.6 million and 270 MWTP in operation or under construction, which could serve about60% of the country's permanent population with at least secondary treatment. It is estimated that a further 2000 MWTP, each serving a population equivalent (p.e.) of more than 500, would be needed for the next 26% of the population, while the remaining 14% live in villages of fewer than 500 (p.e.), for which on-site sanitation technologies should be used.

2.8 SUMMARY OF LITERATURE REVIEW

Anaerobic treatment of wastewater is an effective enhanced primary treatment option for developing countries, which can be used in series with mechanically aerated treatment systems such as oxidation ditch, trickling filter and constructed wetland. With respect to wastewater reuse and reclamation, Mediterranean countries share the same features and characteristics. The most common characteristics of these countries are water shortage and relative shortage of fund, and due to the shortage of water and fund it becomes very important to be careful in selecting wastewater treatment technologies.

The following wastewater treatment technologies are in general used in the Mediterranean Region:

- Activated sludge plants
- Trickling filters
- Aerated lagoons
- Oxidization ponds or waste stabilization ponds

Those technologies are too much expensive centralized schemes; they do not cope with the situation in these countries.

CHAPTER 3
RESEARCH METHODOLOGY

The methodology of this research was done according to the following steps:

-Search and collecting of all available relevant recent information and data, including literature review, description the topography and climate of the Mediterranean Region, all of these are shown in chapter two.

-Collecting detailed technical and financial information on different technologies of the wastewater treatment and comparing them.

- Estimating investment costs of the different technologies and conducting of economical analysis, since cost is an important consideration in the selection of technology, decision makers need to know about the relative costs of technologies, so that a decision to select a particular technology can be based on sound financial and economical consideration. A cost and technical comparison methodologies from previous studies (local and international) between conventional wastewater treatment technologies without using anaerobic reactors as pre or post treatment and other technologies which include anaerobic reactors are shown in chapter four.

- Investigating roles in wastewater treatment technology selection of the community, private sector, academic establishments and development assistance agencies:
    1. USAID,
    2. KFW,
    3. UNDP,
    4. GTZ and
    5. PECDAR, which are discussed in chapter three.

- In addition to what was mentioned above, two questionnaires were prepared:
    1. One for professionals and
    2. The other for donors.

The reason for preparing two questionnaires is to understand the standpoints of both professionals and donors since they compose technical and financial aspects of the related projects, and they complete each other in the project evaluation and implementation.

The contacted persons were selected from a checklist of professionals by giving the priority to the professionals who are used to be in touch with donors during all stages of such projects related to wastewater subject, such as NGOs and municipalities engineers who are responsible for water and wastewater sections.

The professionals' questionnaire was divided into five sections;
- Water resources,
- Social criteria,
- Wastewater treatment,
- Anaerobic wastewater treatment technologies and
- Sludge produced by anaerobic treatment.

The professionals' questionnaire forms were sent to the technical and managerial people in the Mediterranean countries by e-mails, fax or by personnel contact. This operation, sending forms, lasted for about 9 months and approximately 700 forms were sent to the professionals, and those professionals were reminded from time to time.

The donors' questionnaire forms were sent in the same way to the development assistance agencies. Also, two regional web based networks were used to distribute both, the questionnaire for professionals and for donors.

34 answers had been received from professionals, 6 answers were received from the above mentioned donor agencies representatives in Palestine, mostly the data were gathered from the donors by holding personal interview. The data gathered were analyzed qualitatively and quantitatively. Table (3.1) shows target groups and sample sizes of the research professionals and donors questionnaires.

Table (3.1): Sample size and target groups of each country of the interviewed professionals and donors

No.	Country	Sample size	Target groups
1.	Palestine	24	Public sector, Private sector, Universities, Donors
2.	Jordan	6	Public sector, Private sector, Universities
3.	Greece	3	Universities
4.	Italy	2	Universities
5.	Turkey	1	Universities
6.	Spain	1	Universities
7.	Morocco	2	Universities
8.	Germany	2	Donors

Information about the concerned professionals and donors names are given in appendix C.

CHAPTER 4

TECHNOLGY SELECTION OF WASTEWATER TREATMENT

4.1 INTRODUCTION

The selection of technology is an essential step in any strategy for wastewater management. The technology should be environmentally sound, appropriate to local conditions, and affordable to those who must pay for the services. The selection process should be combined with awareness and behavior changes, regulations, and enforcement, and should be applicable and efficient within the context of the whole system. The average performance of a technology, its reliability (under variable wastewater flows and compositions and operational problems), its institutional manageability (planning, designing, construction, operation and maintaining capacity, including the local availability of skilled human resources), and required investment, operation, and maintenance costs are other aspects to be considered (UNEP, 2003)

In the past, many sanitation projects were developed according to a conventional, technical approach, where the intervention and technology were determined by the implementing agency. Demand for sanitation was not assessed and there was little communication between the project planners and future users. Consequently, social, gender, cultural and religious aspects were not sufficiently considered when designing the project (WHO, 2003).

Technology, particularly in terms of performance and available wastewater treatment options, has developed in parallel with economic growth. However, technology cannot be expected to solve each pollution problem. Typically, a wastewater treatment plant transfers 1 m^3 of wastewater into 1-2 liters of concentrated sludge. Wastewater treatment systems are generally capital-intensive and require expensive, specialized operators. Therefore, before selecting and investing in wastewater treatment technology it is always preferable to investigate whether pollution can be minimized or prevented. For any pollution control initiative an analysis of cost-effectiveness needs to be made and compared with all conceivable alternatives, (Veenstra *et al.,* 1997).

In the countries where capital is scarce and poorly-skilled workers are abundant, solutions to wastewater treatment should preferably be low-technology orientated. This commonly means that the technology chosen is less mechanized and has a lower degree of automatic process control, and that construction, operation and maintenance aim to involve locally available personnel rather than imported mechanized components (Veenstra *et al.,* 1997).

The technology selection process results from a multi-criteria optimization considering technological, logistic, environmental, financial and institutional factors within a planning horizon of 10-20 years (Veenstra *et al.,* 1997). Key factors are:

- The size of the community to be served (including the industrial equivalents).
- The characteristics of the sewer system (combined, separate, small-bore).
- The sources of wastewater (domestic, industrial, stormwater, infiltration).
- The future opportunities to minimize pollution loads.
- The discharge standards for treated effluent.
- The availability of local skills for design, construction and O&M.
- Environmental conditions such as land availability, geography and climate.

4.2 REWARDS AND RISKS IN ENVIRONMENTAL TECHNOLOGY

Environmental technology can be defined as the branch of technology dealing with the detection, study, and solution of real or potential problems affecting the natural equilibrium. Experience in some industrialized nations has proven that, in many cases, the use of specific environmental technologies offers both environmental and economic advantages (Weale, 1992; Skea, 2000).

The introduction of new technologies can transform socio-cultural systems and therefore, a certain process usually, needs to take place between the invention or development of a certain technology and its affective adoption by end-users (Freeman, 1974). The diffusion of new or improved technologies in society is a complex process, facilitated or hindered by a large number of factors (Ray, 1984). The evolution and adoption of a new technology has been explained with the invention-innovation (introduction)-diffusion-decline model (Rosenberg, 1976; Schot, 1991).

Technology transfer allows developing countries to use technologies developed elsewhere, without being involved in the long and costly process of technology creation. The importer is supposed to save time and money although certain aspects of technology transfer have other social, economical and technological aspects that have to be considered (Wei, 1995). Technology transfer should not only be a transfer of capital goods and operating skills and tools, but should also represent a base for developing the technological capability of a country. Building technological capability means the development of human resources necessary to select, assimilate, adapt, improve, and create new technology (Menghitsu, 1988; Putranto *et al., 2003*).
Technological progress, while fostering an improvement in the quality of life, exposes us to previously unknown and sometimes catastrophic risks (Sinclair-Desgagne and Vachone, 2000). Any technology transfer will also entail the adoption of the risks associated with a particular technology, and an integrated assessment of innovation and risk is a prerequisite for a responsible form of technological innovation (Hellstrom, 2003). The amount of risks associated with new technologies (like vulnerability related to increased dependency on worldwide information networks) is usually related to the fact that most technological innovations tend to increase the amount of complexity, interdependence, and centralization in the world, relying more and more on a small number of corporate actors, and large economies of scale. Therefore, it can be argued that technological changes in the direction of simplicity, independence, self-sufficiency, and decentralization would entail an associated reduction in these global risks.

Obstacles to Adoption of Advanced Technologies: 1) lack of internal expertise needed to verify which new technologies are most relevant to operations. New technologies are continually being developed. Understanding which ones offer the greatest competitive advantage is difficult and often requires extensive technical understanding of the technology and its application, 2) these technologies also often require applied research to enable their successful implementation by specific companies. Most smaller companies do not have internal research and development capabilities needed and must rely on either resources of companies that are selling the new technologies or independent third party organizations, 3) the risk to smaller companies associated with adopting new technologies is significant, due to the scale of their operations. Larger firms can more easily implement and test new technologies without significantly affecting their productive capacity. Also, the financial risk of failure of new technologies to generate the necessary benefits to recover investments is less for larger companies that have greater internal capital resources. Smaller firms typically lack access to capital required for "early stage" technology applications. For these and many other reasons, the risk of being involved in the diffusion of new technologies for smaller companies is significant (Weinstein, 2003).

The speed at which a new technology will become adopted is affected by many technical, social institutional and even geographic factors (Schot, 1991). The adoption of (environmental) technology may also clash against established technological traditions, patterns, standards, archetypes, or models (in general called "paradigm") which are rooted in society and scientific and technological research. A technological paradigm defines the needs that are meant to be fulfilled, the scientific principles utilized for the search task, and the technology to be used (Kemb, 1993). The path of technical change that develops from a technological paradigm is called "technological trajectory" (Dosi, 1998, according to Kemb, 1993). In addition, reluctant attitudes among established groups working in conventional technologies frequently make the adoption significantly slower. In this respect, Mackenzie and Wajcman (1999) describe (and criticize) two contrasting visions: the deterministic vision (also called neoclassical), which basically states that the best technology (in terms of intrinsic technical efficiency) will eventually prevail, and the paranoid vision that sees all unsuccessful technologies as victims of a monopolistic complot against them. According to them, both sides "underestimate the complexity and uncertainty of knowledge of the characteristics of technologies, even the most technical characteristics". In real cases it might be necessary to "weight up the relative importance of differing characteristics" before selecting the best technological option for a particular situation.

4.3 ASSESSMENT OF THE SUSTAINABILITY OF SEWAGE TREATMENT SYSTEMS

The problem with the current treatment technologies is that they lack sustainability. Many treatment systems in developing countries are not successful and therefore unsustainable because they were simply copied from Western treatment systems without considering the appropriateness of the technology for the culture, land, and climate. Often local engineers educated in the Western development programs supported the choice for the inappropriate systems. Many of the implemented installations were abandoned due to the high cost of running the system and repairs (Lier, 1998).

On the other hand, conventional systems may even be technologically inadequate to handle the locally produced sewage. For example, in comparison to the US and Europe, domestic wastewater in arid areas like the Middle East are up to five times more concentrated in the amount of oxygen demand per volume of sewage. This is extremely high and may cause a large amount of sludge production (Lier, 1998).

Based on experience from past mistakes in sewage treatment technology, the definition of what is sustainable is clearer. Developers should base the selection of technology upon specific site conditions and financial resources of individual communities. Although site-specific properties must be taken into account, there are core parts of sustainable treatment that should be met in each case.

There are several research and development projects on wastewater treatment, some have been successful and sustainable and some have not. The reasons for success or failure most often depend on the appropriateness of the implemented technology. The following description is a perfect example of the inappropriateness of adapting Western technology without making adjustments for the local environment. In the 1970s, a foreign country donated a conventional activated sludge plant to the city of Amman, Jordan. Due to the arid climate, however, sewage in Jordan has extremely high concentrations of organic matter. This caused several problems in the plant such as: high-energy consumption for aeration, high volume of sludge production, operational problems in the operational plant, and high consumption of polymers and clean water for drying the sludge after digestion. Next, they implemented another unsustainable technology by constructing one of the world's largest stabilization ponds. Soon after the pond was installed, the plant was operating at loading rates double that of the design load causing very poor effluent quality. Recently, another Western program installed off-gas treatment to prevent odor by placing surface aerators in the maturation ponds. However, operation costs of the aerators were too high and the system stopped after two months. Not only was it expensive, but it also didn't fix the odor problems since the odorous gases were coming off the anaerobic ponds and there was little improvement in effluent quality. Unfortunately, all of the reasons for not installing a stabilization pond, mentioned in Table (4.1), were present in this situation (Lier, 1998). One alternative treatment technology that would have supported the high COD quality of the influent would have been anaerobic digestion. As explained previously, anaerobic digesters are generally low-tech, have low energy usage, and are less expensive to maintain.

Table (4.1): Disadvantages of Lagoon systems in arid climates (Lier, 1998)

1. High demand for large area of arable, flat land.
2. Often characterized by significant odor problems in anaerobic and facultative ponds.
3. Loss of valuable greenhouse gas (methane) to the atmosphere.
4. Evaporation of huge quantities of valuable water.
5. Increase of inorganic salt content due to evaporation.
6. The system is non-flexible towards an increase in the population.

Technologies were compared according to 4 basic criteria subdivided into 20 operational indicators adapted from Alaerts *et al.* (1990), Dalal-Clayton (1993), Boshier (1993), Wicklein (1998), Balkema *et al.* (2002), Lindholm and Nordeide (2000), Lettinga *et al.* (2001), Dunmade (2002), and Sanders *et al.* (2003). To make water supply and sanitation sustainable for low-income communities, a better appreciation of the complex interrelationships between technical, environmental, social, and economic issues is vital:

-Technical aspects

This criterion refers to the performance of the wastewater treatment system itself.

- Effectiveness. Indicates whether the system can comply with local, national or international discharge standards, generally expressed in terms of biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), pathogenic microorganisms, and nitrogen compounds, among others, under normal working conditions. Storm water, accidents in the network, natural disasters, sabotages, illegal discharges, and other unpredictable events will fall out of this definition. Daily and seasonal variations in the influent characteristics have to be considered in the design of any treatment system. As pointed out by Alaerts *et al*. (1990), it is important to realize that fluctuations in effluent quality are normal in all types of treatment plants. However, yearly average effluent values conceal the fact that, due to these variations, several days per year the discharge standards might be violated. To minimize these variations, plant designers must use lower mean effluent values in their calculations, which implies that the design removal efficiency needs to be higher and, consequently, so will be the hydraulic retention time (HRT) and/or the plant size. Effluent quality from two or more biological steps in series will tend to be better than from a single-step system because subsequent steps can reduce significantly the effluent variability.

- Removal efficiency. The removal efficiency of all relevant pollutants was considered separately from the ability of the system to comply with discharge standards. In fact, two systems can comply with the standards, but can provide higher removal efficiency for a certain component at the same cost, even if this component was not included in the standards (but may be included in the future). High efficiency guarantees consistent compliance with discharge standards.
- Reliability. This indicator refers to the robustness of the system, defined as the capacity to assimilate (ordinary) variations in sewage flow rate and composition, the reaction to shocks, and the time needed to restart the system after breakdowns or maintenance operations. Vulnerability of the system, or potential risks associated with human errors (i.e. spillage of chemicals), equipment failures, natural catastrophes, power outages, vandalism, sabotages, etc., were also included in this indicator.
- System manageability. Includes relative complicity of operation and maintenance, and dependency on (complex) infra structural services like power and/or water supply. Availability of spare parts, existence of know-how, and time between repairs can play a capital role in the feasibility of the technology (Dunmade, 2002). The number and type of personnel (skilled and/or unskilled) required by the system was also included in the indicator.

- Environmental aspects

This criterion aims at assessing the environmental impact of the different technologies.

- Conservation. Environmental issues like the potential degradation of critical ecosystems and the conservation of the biodiversity were grouped within this indicator. The fragility of some ecosystems may require treatment technologies that are especially safe and not prone to fail.
- External inputs. This indicator takes into account the need of construction materials, basic and sophisticated equipment, and chemicals (alkalis, chlorine, etc.). The extent of self sufficiency in construction, operation and maintenance must be considered here.
- Land use and impact. Land used for wastewater treatment is a hidden subsidy and a cost to the community even if the land was given for free to the project (the government could have rented the land) (Alaerts *et al.*, 1990). The land requirements and landscape spoiling were included in this indicator.
- Emissions. Wastewater treatment plants produce emissions to the air, the water, and the soil. Anaerobic systems produce methane that must be flared or otherwise used to avoid its release into the atmosphere, where its greenhouse effect is much more important than that of carbon dioxide. However, when methane used as a fuel, not only its emission is prevented, but also the use of fossil fuels and the concomitant emission of carbon dioxide are avoided. Having said that, it is also important to take into account the presence of dissolved methane in the effluent, especially at low temperatures. If not recovered, this methane will be released into the air when the effluent is discharged. On the other hand, systems that require electricity to operate are indirectly generating emissions at the generation point. Odor nuisance can be a problem of some importance either in aerobic or anaerobic treatment systems (Alaerts *et al.*, 1990). Activated sludge plants can produce aerosols (fine water spray) which can carry pathogens for considerable distances. Noise nuisance can be an

issue for some aerobic treatment systems requiring heavy pumping. Emissions to surface water are mainly produced in the form of effluent. The intensity of this emission will very much depend on the treatment system. Even assuming that all systems comply with discharge standards, the higher the removal efficiency, the lower the emission of pollutants and the environmental impact of the discharge. Soil pollution can raise from inadequate disposal of reuse of treated sewage and biological sludge. Leakage from the bottom of extensive ponds can affect both the soil and the groundwater table. Significant acute pollution can result at the point of discharge when a treatment plant needs to be stopped for reparation and maintenance, or due to equipment failure or breakdown. Back up systems, storage ponds, or other mitigation measures (i.e. the setting of an early alert system) may have to be considered when the system is designed. Complex technologies will be more likely to fail and produce acute pollution events, especially in developing countries, where the time between breakdown and reparation can be very long. Within this indicator, it is important to assess the options in terms of their role in the potential prevention of environmental pollution problems.

- Reduce, Reuse, And Recycle. The production of well-stabilized biological sludge that can be used as a soil amendment or fertilizer would be a positive feature of any wastewater treatment system. However, sludge handling should be safe, simple, and relatively inexpensive compared to the overall running costs. The use of the biogas produced by anaerobic systems can mean significant savings. The treated wastewater is also a by-product, as it can be used for irrigation. In this sense, the removal of nutrients like nitrogen and phosphorus is detrimental. The potential persistence of enteric parasites must be taken into account in reuse schemes, as pointed out by Boncz (2002). Sanitation technologies should aim at the "complete utilization of all possible waste resources" (Lettinga et al., 2001). A proper final destination must be found for all types of residues that can not be reused.

- Social aspects

This criterion takes into account social, political, and cultural aspects related to the potential acceptability of the new technology in the local context, and the possibility that it might be definitely incorporated as a current practice by the new users.

- Institutions and politics: Basic institutions are needed to promote and manage adequate sanitation systems. Awareness and commitment in individuals working in those institutions are very important factors for the successful implementation and maintenance of sanitation networks. The public in general, and policy-makers in particular, also need to aware of the fact that appropriate means have to be allocated to plan, construct, maintain, and improve sanitation infrastructure. These considerations are valid for all types of treatment technologies, although new technologies may be more negatively affected (Alaerts *et al.,* 1990). Some technologies are preferred over others based on their local availability, previous successes, and many other (sometimes very subjective) reasons.
- Management capacity: There must be a minimum management capacity both at governmental and private level for the successful development of any wastewater treatment technology. Private firms need this capacity to participate in buildings for the construction of sewerage networks and treatment plants, and governments should be able to set adequate technical standards, evaluate bids, and enforce compliance of contract conditions.
- Management scale: This indicator refers to the potentiality of the systems to be applied at different scales (off-site, on-site, community on-site), in different areas (urban, peri-urban, rural and by different actors (governments, private companies, end-users), and the potential of the systems to be applied in decentralized way. The systems need to be flexible (not scale-specific) in order to adapt to the infinite variations that can be found in real cases. Inflexible systems will tend to force the development of land use and housing according to a pattern that best fit their needs (for example, centralized sewage treatment systems would force the construction of an extensive collection network even in places where it may be avoided).
- Change of routine: Refers to changes needed in the current practices of environmental engineers and experts to adapt (new) sanitation technologies.

The more change needed, the more difficult the adoption. Special attention should be paid to the possible existence of a new technology because they protect preexisting commercial interests related to already establish technologies.

- Social acceptability: Acceptability of a certain sanitation technology will be a function of society's judgment of its importance (Dunmade, 2002). The importance of certain goods or services can sometimes be associated to the people's willingness to pay for them. The community should financially contribute on a regular basis to a central governmental, a semi-governmental authority, or to a private company for the service of sanitation. In most cases, when this service is centrally provided, paying for its compulsory. Special attention should be devoted to the presence of cultural aspects that may promote or hinder the spread of a certain technology (attitude towards centralized sewerage versus decentralized on-site sewage management, reluctance to contribute to maintenance operations, sensitivity to odors, willingness to live close to a treatment plant, health aspects, religious principles, current practices and standards of cleanliness and comfort, among others) (Boshier, 1993; van Vliet and Stein, 2003). The existence of active environmental and social non-governmental organizations (NGOs) can be important to facilitate the process of social acceptance by all social actors. Minorities should always be taken into consideration and should participate in the decisions, especially when they could be potentially affected (George, 1999). Public participation of all stakeholders in the decision-making process is essential (including the planning, design, implementation, and monitoring process). The potential contribution to the alleviation of poverty and the improvement of public health, specially those fractions of the population who are less privileged, must also be an issue for the potential acceptance and adoption of a given technology.
- Regulatory framework: The use of some technologies may require previous adaptation of the local legislation in order to be applied. Others may be already embodied in technical standards and norms. Although the existence of a favorable regulatory framework is not a direct indication of the sustainability

of a technology, it may certainly promote or hinder its swift adoption dissemination.

- Economic aspects

This criterion assesses the total costs and benefits of the new technology, taking into account its entire lifecycle and hidden costs that are not included in traditional assessments. These aspects may also be integrated in a cost-benefit framework using CBA as a decision-support technique.

- Investment costs: This is a comparative analysis between construction costs of different alternatives for the same site and economic conditions. Centralized sanitation, with conventional sewerage followed by off-site treatment and disposal requires a high initial investment, in principle the highest of all sanitation options (Alaerts *et al.,* 1990).
- Running costs: Also a comparative analysis between possible alternatives. Operation and maintenance costs represent an important item in the overall feasibility of the system, and can determine its success or failure altogether. In fact, the lack of operation and maintenance seems to be one of the most widespread causes of technology failure in developing countries investment costs are covered by international loans, but operation and maintenance costs, including reparations and spare parts, must be afforded by local authorities. Correct allocation of tax money is then mandatory for a proper operation. A minimum of governmental management capacity and organization is required for that purpose. In the context, systems with low running costs will have more chances of being operated correctly over prolonged periods of time, and may be preferred (Boshier, 1993). Low cost, locally produced, high-quality spare parts and the immediate and permanent availability of skilled technical experts can be crucial in case of equipment failure or breakdown.
- Lifetime: As investment money may not be available again once a wastewater treatment system is built, the longer the lifetime of equipment and construction items, the more attractive a system will

become, especially for developing countries. Electro-mechanical equipment and parts are more prone to breakdown and therefore, a sustainable system should avoid them as much as possible. In traditional test CBA test, benefits and costs from different projects are discounted in time to calculate monetary gains or losses occurring at points in time. However, lifetime is considered to be an indicator on its own because it depends strongly on incidental situations like the availability of international loans.

- Externalities: Activities in one part of the social system often generate unwanted (environmental) effects called "externalities" on other parts (Freeman, 1974; Löfregen, 2000). An externality can also be defined as a cost or project input that was not included in the project expenditure and is eventually afforded by the community at large. Externalities can be, in principle, positive or negative, but they mostly associated to negative environmental effects of economic activities (like pollution). Potential sources of externalities are land excavation, induced ecological change, loss of "natural capital" and any kind of social disruption during the construction of the project (resettlements, destruction of property or cultural heritage, traffic diversion, etc.) (Alaerts *et al.,* 1999; George, 1999).

Some indicators could, if necessary, be further divided into more specific factors (i.e. the indicator effectiveness could be divided into factors *BOD, COD, SS, pathogens, and nitrogen compounds*, among others). However, the advantage of such subdivision must be justified for each specific case and the costs and difficulties of data gathering must be taken into account. Otherwise, a more general and simple approach seems comprehensive enough to perform an appropriate assessment in most cases.

Short description of the criteria and indicators used to assess the sustainability of sewage treatment technologies is shown below in Table (4.2) and Figure (4.1):

Table (4.2): Criteria and indicators used to assess the sustainability of sewage treatment technologies, Seghezzo (2004)

Criteria	Indicators	Short Description
Technical Aspects	Effectiveness	Compliance with discharge standards
	Removal Efficiency	Removal of pollutants (when not in standards, or beyond them)
	Reliability	Robustness; vulnerability and risks associated with errors, disasters
	System manageability	Operation and maintenance; reparations; personnel requirements
Environmental Aspects	Conservation	Protection of (fragile) ecosystems and conservations of biodiversity
	External inputs	Need of materials, equipment, electricity, fossil fuels; self-sufficiency
	Land use and impact	Footprint (area occupied); impact on the landscape
	Emissions	Substances released into the environment; pollution prevention
	Reduce, reuse, recycle	Sludge; biogas; treated water of irrigation; nutrients
Social Aspects	Institutions and politics	Basic institutions; awareness in policy-makers/public about sanitations
	Management capacity	Governmental and private proficiency to manage sanitation systems
	Management scale	Operation at different scales and by different actors; decentralization
	Change of routines	Changes by practitioners to adopt sanitation technologies; lobbies
	Social acceptability	Cultural aspects; users adaptation; alleviation of poverty; minorities
	Scientific support	The role of universities and research centers (monitoring, innovation)
	Regulatory framework	Local legislation that promotes or hinders the use of different options
Economic Aspects	Investment costs	Construction costs; equipment required costs of the land
	Running costs	Operation and maintenance; reparations; availability of spare parts
	Life time	Lifetime of construction items and electromechanical equipment
	Externalities	Change in natural capital; excavations; social disruptions

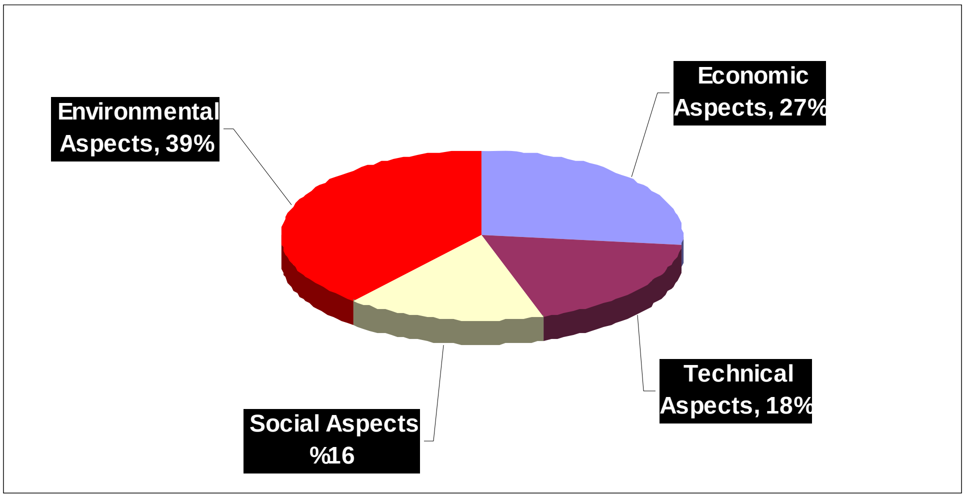

Figure (4.1): Relative Importance of the Criteria of Sustainability (Seghezzo, 2004)

4.4 ASSESSING O&M NEEDS

The description of each technology includes: the O&M activities required, and their frequency; the human resource needs; and the materials, spare parts, tools and equipment needed. This shows the importance of O&M in terms of human and technical requirements. For example, activities and repairs are part of O&M and the frequency with which they need to be carried out depends largely on elements such as the quality of materials, the quality of workmanship during the construction phase, and the level of corrective and preventive maintenance carried out by the actors concerned (WHO, 2003).

The lack of spare parts may be a major constraint in the sustainability of sanitation systems. A lack of spare parts can result from policies pursued by the donors, such as when hardware has to be purchased from the donor countries. Many donors, however, are only involved in the construction phase of the project and make no provision for continuing the supply of spare parts after handing over the project to the community. Some donors have attempted to overcome the problem by supplying a stock of spares at the time of installation. But this is only a short-term remedy, because the absence of a supply system and the lack of foreign exchange mean that stocks do not get replenished.

Even when donors have bought and installed equipment already used within a country, there has often been no consistent government or water-agency policy on standardization. The outcome is a wide range of equipment, for which no water agency in a developing country can afford to stock a comprehensive range of spare parts. Spare parts availability and supply are therefore major considerations if water supplies are to be sustainable and suitable for community management. The availability of spare parts should be one of the main factors that determine the suitability of a particular technology. Before opting for a technology, the mechanism for supplying spare parts must be investigated, established and assured. Often, however, the issue of spare parts arises only after the technology has been selected and installed, which puts its sustainability at risk.

The community will need to know the cost of running their water-supply and sanitation systems and this will be determined partly by the demand for spare parts. Estimates may be based on previous experience, or on guidance from the manufacturers. Care must be exercised when using manufacturers' figures for spare parts, since the need for spares will vary according to local circumstances. For example, the air filter for a diesel generator will require more frequent changes in a very dusty environment, compared to "standard" conditions. The extent of use, the care with which the equipment is used, and the effectiveness of preventive maintenance will all have an impact on the need for spare parts (WHO, 2003).

Spare parts can be divided into three categories:

1. frequently needed spare parts, for which the accessibility should be as close as possible to the village (shop, mechanic);
2. occasionally needed spare parts (every six months or every year), for which accessibility can be at a nearby major centre;
3. major rehabilitation or replacement spare parts, for which accessibility can be at the local or regional level, or at the state capital.

Several countries have chosen to standardize the choice of technology; this choice has positive as well as negative aspects, which should be carefully considered before applying such a policy, these positive and negative aspects are shown below in Table (4.3).

Table (4.3): Pros and Cons of Standardizing Technology

For standardization	against standardization
— Common use of the same item of equipment encourages agencies and shopkeepers to store and supply spare parts, because there is a" guaranteed demand"; — Standardization avoids the proliferation of brands and technologies, which would make it easier to stock and supply spare parts; — The prices and market for spare parts can be more easily determined; — Users become familiar with one type of technology; — Personnel training can be standardized.	— the chosen technology does not fully respond to the needs and preferences of users; — the market is closed to new, innovative and cheaper technologies; — there is little incentive for the private and research sectors to become involved; — standardization limits price competition between different brands and impedes optimization; — limiting technology choice may conflict with donor policies.

Source: (WHO, 2003)

Output should satisfy demand, but as demand may be irregular, a stock of parts can act as a buffer. However, this requires that capital be available at the beginning of production for materials, labor, overhead costs and storage. A government subsidy or donor grant can provide the initial kick-start. To ensure the compatibility and reliability of parts, it may be necessary for the government to institute standards and an inspection procedure (WHO, 2003).

4.5 DISTRIBUTION OF ROLES IN TECHNOLOGY SELECTION POCESS

4.5.1 Community Participation

Success or failure of a system primarily depends on one factor; whether the system is sustainable or not. And for the sustainability of a system, the use and maintenance has to be done by the community. This can only come when the community participates at all stages of the project (Chattopadhyay, 2005)

Currently, the World Bank and other bilateral donors are adopting a demand-responsive approach. It is recognized that for sustainability of a project, widespread stakeholder consultation is necessary. The questions of eligibility, choice of technology, cost sharing, and involvement of community, for operation and maintenance, have assumed significance. It is felt that the technology chosen should give the community the highest service level that it is willing to pay for, will benefit from, and has the institutional capacity to sustain (Chattopadhyay, 2005).

The community should select the technology, with support from the aid agency. This will contribute to the sustainability of the technology and increase the number of community members who will use it. The improvement of sanitation facilities should be accompanied by Information, Education, Communication (IEC) activities to promote safe sanitation behavior and proper hygiene. These activities have a longer time horizon than the physical improvement of structures. Schools, institutions, and religious and social community groups should play a prominent role in promoting proper hygiene and sanitation behavior. Special attention must also be paid to the technology design and its sitting, to prevent the sanitation facilities from polluting the environment, particularly water resources and the immediate living environment. Control measures must be carried out to minimize these risks.

The aspiration of most urban households, including the urban poor, is to have access to cost-effective and affordable sanitation services via public or private utilities. Consequently, they would be willing to participate, as responsible users, by paying the appropriate service charges. In the cities of many developing countries, however, such services are not yet universally accessible and poor communities must, themselves, get involved in the planning and delivery of sanitation and sewerage options (WHO/UNEP, 1997)

A productive partnership can be formed between community groups and the municipal government or the utility. Often, such a system involves public provision of the external or trunk infrastructure, which may be operated by either the public or private sector, and the community providing and managing the internal or feeder infrastructure. The link between feeder and trunk infrastructure is essential for the evacuation and disposal of human waste collected by the community, but it is too easily overlooked. Many forms of community participation are possible for the provision of sanitation and sewerage services, such as:

· Information gathering on community conditions needs and impact assessments.
· Articulation of, and advocacy for, local preferences and priorities, consultations concerning programs, projects and policies.
· Involvement in the selection and design of interventions.
· Contribution of "sweat equity" or management of project implementation.
· Information dissemination.
· Monitoring and evaluation of interventions.

Promoting and enabling community participation can take many forms. Where political will exists, governments may promote participation and create the conditions under which communities and households, as well as NGOs and the private sector, can play their appropriate roles. When such government support is absent, alternative approaches have commonly been used to stimulate community involvement and to build the necessary political will. First, NGOs or community-based organizations (CBOs) often play a catalytic role in mobilizing communities and forming partnerships. Consultations and town meetings are increasingly used as a forum to discuss and agree on environmental priorities, and to propose participatory solutions

(Bartone *et al.,* 1994). Finally, communities may engage in public protests or legal actions as a means of building a constituency of the urban poor and applying pressure on local governments and utilities for dialogue and action (WHO/UNEP, 1997).

4.5.2 Role of the Private Sector

For the implementation and promotion of a new technology, strategies must include local participation as well as municipal. The importance of local participation is a positive growing trend in governmental projects. The participation must fit with the local population to meet particular local needs. Local communities can contribute indigenous, valid ideas for cost savings in the project. Agreement on key issues between design engineers and the local residents is necessary early in the project, and if local participation is extensive, capital costs can ultimately be reduced. According to the Inter-American Development Bank, "Citizen participation, properly channeled, generates savings, mobilizes financial and human resources, promotes equity and makes a decisive contribution to the strengthening of society and the democratic system" (Looker, 1998).

There is a strong sense of ownership by members of the community in their projects. This pride in the new development helps to ensure the sustainability of the water supply and sanitation systems. Once the project is implemented, local participation contributes to the community's confidence in the new technology and allows them to take on other challenges such as accessing financial aid for other infrastructure projects (Looker, 1998).

Financial resources can also be mobilized through the private sector; poor service provision by the public sector often suggests a need for increasing partnerships with the private sector. Private sector participation, however, is only one possible opportunity; it is not a panacea. In situations in which existing sanitation service delivery is either too costly or inadequate, private sector participation should be examined as a means of enhancing efficiency and lowering costs, and of expanding the resources available for service delivery.

In deciding whether to involve the private sector, it is important to assess several key factors which have been summarized by the Infrastructure for Development*:* World

Development Report, 1994 (World Bank, 1994a). Introducing competition is the most important step in creating conditions for greater efficiency by both private and public operators; some services can be split into separate operations to help create contestable markets. The principle of accountability to the public should be maintained through transparent contractual agreements that are open to public scrutiny and should help to minimize risks to public welfare, create real competition, ensure efficiency, and promote self-financing. Paradoxically, public sector capacity may have to be strengthened in order to achieve effective private sector participation which requires public sector agencies with sufficient capacity to prepare bidding documents and performance indicators, assess proposed outputs and costs, administer the contracting process, and regulate contract performance.

An important point to remember is that the private sector performs the necessary function of mobilizing financing for needed investments, but the investments made together with operations, maintenance and depreciation costs will all have to be recovered through tariffs charged to domestic and industrial customers.

4.5.3 Role of the Universities

It is very important for the state to be able to control the design, construction and operational efficiency of all wastewater treatment plants. There is no point in imposing any kind of effluent requirement or adopting the most advanced technology for wastewater treatment if there is no mechanism to ensure maximum efficiency. It is therefore important to predict whether a proposed technology can be supported by the institutions. Appropriate legislation needs not only to be developed, but also implemented. This will require adequate funding. Political interference has been reported regarding site selection and other aspects of MWTP construction and operation. Those MWTP that are supervised by specialized agencies generally operate well. Putting MWTP in the hands of non-technical and non-specialized agencies has led to problems and poor performance. Most of the time, the causes of poor performance are non-technical and the majority of them could have been avoided by better administration of the plants, construction and operation (Tsagarakis *et al.*, 2000b).

The role of universities and other research institutes may be important in raising the issue of sanitation and assessing possible technological solutions for particular problems and locations. Universities and research centers could also play a role in the continuous assessment (and improvement) of the technology once it is adopted. On the other hand, universities may be a hindrance for the diffusion of new technologies if teachers and staff are not aware of developments in the field of sanitation. Engineers teaching at universities many times work also as consultants or contractors, and may belong to the commercial establishment that oppose new technologies due to sheer ignorance, fear of change, or vested interests (Seghezzo, 2004).

Actually, the academic establishments, especially in developing countries, do not have any role in decision making in the selection of wastewater treatment technology, a case study in this subject was observed in West Bank while meeting one of the donor countries.

Case Study

While recently (2005) selecting the type and location of a treatment plant to serve a certain region in the West Bank, which will be constructed to treat wastewater in one of the most famous wadis coming from a major city in the West Bank and the villages surrounded by the Wadi, local expertise were not involved in the subject but imported expertise with no knowledge or experience in the area and the subject of sanitation were involved. This was because the aid agency selected the expertise from their countries in spite of the availability of several local institutional and consultant expertise with a long experience in the subject of sanitation and a non restricted knowledge in the nature of the area. This gives an indication how the donors ignore the local expertise and bring expertise from their countries with multi double salaries (personal contact with the aid agency, 2005).

4.5.4 Role of Donors and Aid Agencies

Substantial funds are required to establish environmental management systems, institute legal systems or regulations for environmental protection, and strengthen related organizations and enforcement. However, there are recipient countries that are not capable of raising sufficient funds for environmental protection measures. In these cases the central and local governments are not able to secure the necessary funds due to fiscal problems, and most of the budget is allocated to personnel costs. In such a situation, it is difficult to promote the self-help efforts of the recipient country for environmental protection, and in the short term specific outcomes cannot be expected even with the support provided by donor countries (JICA, 2004).

Such inefficiency, however, should not preclude assistance to developing countries with financial difficulties. Assistance to these countries should be provided as preparatory work from a long-term viewpoint, on the assumption that sufficient financial resources will be gained for environmental conservation in the coming years. In these circumstances, technical cooperation to strengthen environmental management is not very likely to produce significant results in the immediate future. Since strengthening and consolidating environment management systems takes at least several years, the recipient agencies and their technical personnel are required to have the potential capacity to benefit from technical cooperation. As technical cooperation is provided, this capacity is gradually enhanced. Therefore, for cooperation in the environmental field, it is essential to assess the stage of economic development and the system of environmental management of the recipient countries and introduce policies or technologies that meet their prior needs and that are appropriate for their conditions. Since there are a wide range of environmental problems and various sectors are involved, donor country's support alone is insufficient to solve such diverse problems in the recipient countries. This has led to the view that links should be established with UN agencies, international development banks, other developed donor countries, as well as NGOs in order to implement such broad-ranging activities that cater to the needs of recipient countries (JICA, 2004).

CHAPTER 5

FINANCIAL AND ECONOMICAL ISSUES

5.1 INTRODUCTION

The selection and design of wastewater treatment facilities is greatly dependent on the costs associated with treatment processes, including capital investment, operation and maintenance, land requirements, sludge handling and disposal, and monitoring costs (UN, 2003).

This chapter presents cost and technical comparison methodologies from previous studies (local and international) between conventional wastewater treatment technologies without using anaerobic reactors as pre treatment, and other technologies which include anaerobic reactors provides illustrative examples of cost estimates as reported in the literature.

The process of evaluating and selecting appropriate wastewater treatment technology usually begins with a technical feasibility study that depends on the nature of the application (UN, 2003). Cost effectiveness evaluation is undertaken only after existing and future conditions have been estimated, wastewater volume and characteristics forecast, and process alternatives for wastewater treatment, effluent and sludge management identified and compared in terms of their effectiveness. According to Qasim (1999) "a cost-effective (wastewater treatment) solution is one that will minimize total costs of the resources over the life of the treatment facility". Resources are the capital, operation and maintenance costs, but also social and environmental costs. Benefits from sludge and effluent reuse must also be included in the feasibility study. Wastewater treatment cost estimation requires a thorough knowledge of the mechanical elements involved. In addition, experience and sound judgment are necessary, since there are a number of parameters that cannot easily be quantified. When the costs associated with two or more processes appears to be equal, sensitivity analysis with respect to estimate inaccuracies must be performed to break the tie (UN, 2003).

5.2 EXISTING SOURCES OF FINANCING

There are three main sources of finance for water sector investments, including wastewater. These are:

- International Transfers (Official Development Assistance (ODA) and international lending from development banks and commercial banks)
- Private Sector Investments (International and domestic)
- Other Domestic Sources (budgetary allocations, domestic lending and user finances) it should be noted that private financing and borrowing can only provide a limited breathing space in providing financial resources. The medium and long term sustainable financing will have to be financed by either the users, general budgetary allocations, ODA-grants, or other grants (UNEP, 2004).

5.3 IDENTIFICATION OF ALTERNATIVES

The primary objective of facility planning is to identify and evaluate various potential solutions to address wastewater management needs. For new facilities or major upgrades, the alternatives analysis should consider the establishment of the sewer service area and possible connections to existing sewerage systems (regionalization). Facility plans must conform to approved sewer service areas contained in area wide water quality management plans. If a revision to a sewer service area is being proposed, the first step of the planning process will be to seek an amendment to the sewer service area (Wisconsin, 2003).

Any proposal for a new or upgraded treatment plant may include consideration of different treatment technologies, facility sites, and discharge locations. Discharge may be to surface waters or to groundwater via land application systems such as spray irrigation or rapid infiltration basins. Consideration of innovative as well as conventional technologies is encouraged. If new or innovative methods of treatment are proposed, supplemental performance data may be required to support performance claims for the technology.

The alternatives analysis should include consideration of improving plant performance by improved operation and maintenance measures. In some cases, this may be addressed separately by an "Operation and Needs" study. Phased construction of upgrades may be considered, but all alternatives must still be compared on the basis of a planning period. When it is proposed to significantly upgrade any portion of an existing facility and to increase plant capacity, the facility planning analysis should also examine the condition of the other processes at the facility. If the other existing processes are not code compliance, or do not perform adequately, the facility plan should examine whether it is necessary, and cost-effective to improve them (Wisconsin, 2003).

All alternatives must be feasible in terms of being implemental from legal, institutional, financial and management standpoints. In some circumstances, local annexation requirements may be associated with a regionalization alternative. Annexation requirements would be evaluated along with project costs and non-monetary factors. In general, the Annexation is not accepted, by itself, as a factor that would necessarily prevent implementation of a project.

After identifying feasible alternatives, they may be systematically compared and screened to identify the principal alternatives to be subjected to the detailed cost analysis. The level of detail in the analysis will depend upon the size and complexity of the project, and the range of cost differences among alternatives.

5.4 COST-EFFECTIVE ANALYSIS METHODOLOGY

To provide valid monetary cost comparisons, all opportunity costs associated with an alternative over the planning period should be identified and presented on a total present worth or equivalent uniform annual cost basis. Sunk costs should not be included in the cost-effectiveness analysis because these costs have already been committed regardless of the alternative selected. Sunk costs include investments in existing wastewater facilities and associated lands, outstanding indebtedness and costs for preparing the facilities plan.

Costs should be based on market prices prevailing at the time of the study. Except for energy and land costs, the inflation of costs over the planning period is not allowed. The analysis should account for initial capital costs, future capital costs, annual operation and maintenance costs, and salvage values. Salvage values are determined by assigning a design service life to various components and then calculating the remaining service life and associated value of the component at the end of the planning period. Present worth factors should be based on the current discount rate as established by the U. S. Environmental Protection Agency.

Connection fees or other charges should not be included in a cost-effective analysis if they are a method of cost recovery for a sunk cost, or if they only reflect a transfer of payments from one entity to another (Wisconsin, 2003). Costs for treatment capacity acquisition from an existing treatment plant may, or may not, be included in the cost-effectiveness analysis depending on specific circumstances. If an existing facility has planned (or excess) capacity to service an area, then no capacity acquisition cost should be included in a cost-effectiveness analysis conducted for connecting that area (the capacity is already available and cost is sunk). But if an existing treatment facility does not have planned (or excess) capacity to service a certain area, then serving that new area would reduce the plant's reserve capacity intended for its remaining service area, and thus shorten its design service life. As a result, the plant would need to be upgraded sooner than what would otherwise be necessary. This represents an actual future cost that should be accounted for in the cost-effective analysis if the plant upgrading would be expected to occur within the planning period.

Alternatives should be compared on the basis of total present worth or equivalent uniform annual costs. Alternative costs are considered within 10% of each other to be essentially equal in monetary value due to normal cost estimating variability. In some situations, the provision of a sensitivity analysis may be required to assess how project costs would vary based on a range of planning assumptions or circumstances.
The facility plan report should contain both a cost-effectiveness analysis and a fiscal impact cost analysis. The fiscal cost analysis will consider grant or loan assistance, financing arrangements, and provide estimates of expected user charges or fees (which should include any existing indebtedness).

The final determination on cost-effectiveness is made with consideration of monetary costs, fiscal impacts, environmental impacts, and possibly other non-monetary considerations (Wisconsin, 2003).

Several studies for the purpose of comparing several alternatives of treatment technologies were carried out, and most of them approved the sustainability of anaerobic treatment technology. Four previous studies, one locally and the others international, are mentioned below:

5.4.1 Evaluation of Wastewater Treatment Alternatives for Hebron City (Palestine)

A study made by Tahboub (2000) to evaluate the following different eight treatment methods and techniques to choose the best alternative and its technology:

- Conventional Activated Sludge
- Trickling Filter
- Extended Aeration
- Oxidation Ditches
- Aerated Lagoon
- Stabilization bonds with Anaerobic Treatment
- Stabilization bonds without Anaerobic Treatment
- Upflow Anaerobic Sludge Blanket (UASB) followed by Oxidation Ditches as a post treatment

After a preliminary assessment Tahboub found that from technical and financial point of view there are two feasible options for the purpose of the study, Oxidation Ditches and UASB followed by Oxidation Ditch. Oxidation Ditches have been adopted widely as a treatment technology in many treatment plants all over Palestine like in Al-Bireh, Nablus, Rafah and Gaza. Tables (5.1) and (5.2) summarize the efficiency predications of the each treatment plant unit operations for the respective design treatment options. The anticipated effluent qualities of the treatment plants depending on influent characteristics are also shown. The removal efficiencies are estimated based on design criteria of each unit operation.

Table (5.1): Efficiency predications for Oxidation Ditch system (Alaerts *et al.*, 1994)

Parameter	Influent (mg/L)	Oxidation Ditch System		Needed Effluent Criteria (mg/L)
		Efficiency (%)	Effluent (mg/L)	
BOD	571.3	95-98	11-29	30
COD	1142.6	95	57	75
TSS	685.6	95	34	50
TKN	113.9	80-90	11-23	25
Total P	10.9	10-20	9-10	15

Table (5.2): Efficiency predications for UASB followed by Oxidation Ditch (Alaerts *et al.*, 1994)

Parameter	**Influent mg/L)**	**UASB**		**Oxidation Ditch System**		**Needed Effluent Criteria (mg/L)**
		Efficiency (%)	**Effluent (mg/L)**	**Efficiency (%)**	**Effluent (mg/L)**	
BOD	571.3	60-85	85-229	95-98	2-12	30
COD	1142.6	60-80	229-457	95	12-23	75
TSS	685.6	65-86	103-240	95	5-12	50
TKN	113.9	5 of BOD/N	102-110	80-90	10-22	25
Total P	10.9	3 of BOD/P	4-8	10-20	4-6	15

The financial evaluation based on estimating the initial investment cost needed for each alternative and the initial running cost was done also. A summary of annual running costs are shown below in Table (5.3).

Table (5.3): Summary of annual running costs (Tahboub, 2000)

Item	**Conventional Activated Sludge Percentage %**		**UASB + Extended Aeration Percentage %**	
Annual Capital Costs	1,836,806	27.47	2,547,396	48.94
Energy Consumption	3,722,415	55.66	1,432,156	27.51
Salaries, Wages and Loans	271,200	4.06	321,600	6.19
Maintenance and Repair Costs	362,218	5.42	516,981	9.94
Misc. Chemicals and Supplies Costs	18,368	0.27	24,474	0.47
Residues and Sludge Disposal	476,800	7.12	361,760	6.95
Total Annual Running Costs	6,687,523	100	5,205,367	100
Spec. Annual Costs (US$/PE. Yr)	19.8		15.4	
Spec. Wastewater Treatment Costs (US$/m^3)	0.52		0.40	

Finally, Tahboub (2000) found that the recommended treatment alternative according to the design results, from environmental, social and institutional point of view, was

UASB followed by Oxidation Ditches whether there is intention to gas utilization or not from the UASB process.

5.4.2 Assessment of the Sustainability of Anaerobic Sewage Treatment in Salta (Argentina)

Another study was made by Seghezzo (2004) for the purpose of measuring the sustainability of Anaerobic Sewage Treatment in Salta. The sustainability assessment was confined to the comparison of three different technological options, as follows:

- Option A: Aerobic high-rate treatment system. This option consisted of the following units: (a) primary sedimentation tanks; (b) trickling filters (secondary treatment; (c) secondary sedimentation tanks; (d) sludge digestion; (e) chlorination.
- Option B: Waste stabilization ponds (WSP): A series of three ponds was considered: (a) anaerobic pond; (b) facultative pond; (c) maturation pond.
- Option C: UASB reactor with post-treatment in polishing ponds. A single-stage UASB reactor followed by a series of small WSP called "polishing ponds" designed for pathogen removal.

The selection of these options was based on their immediate availability in the region. Different assessment can be made with the inclusion of other technological options. However, it was believed that the three options reflected the most realistic alternatives in the local context. Overall sustainability was medium to low for option A, medium to high for option B, and high for option C (Figure 5.1)

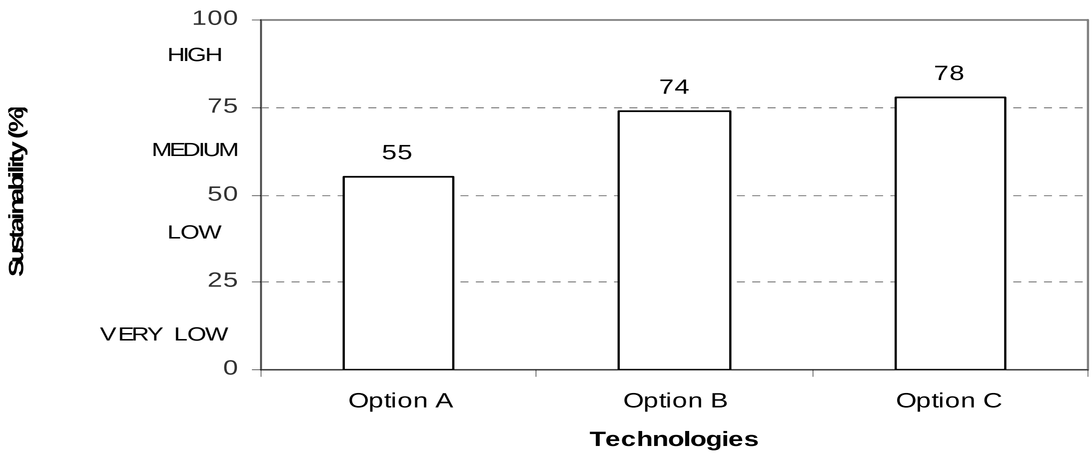

Figure (5.1): Sustainability indexes of the different options (Seghezzo, 2004)

A simple list of strengths and weaknesses, together with the sustainability index, can be a very useful way of communicating the results. Strengths and weaknesses (see Table (5.4)) are a confirmation of the advantages and disadvantages generally reported for these types of treatment systems (van Haandel and Lettinga, 1994; von Sperling, 1996).

Table (5.4): Main strengths and weaknesses of the options (Seghezzo, 2004)

Option	Strengths	Weaknesses
A	- The system is scientific - Land requirements are very low - social acceptability is high	- High investment and running costs - Operation is relatively complex - Generates a lot of biological sludge
B	- The system is very efficient and reliable -Construction is relatively cheap - Operation is cheap and simple	- Required a lot of land - The risk of emissions to the air and the soil is higher - People may reject it due to the potential productions of bad odors and vectors
C	- The system is very efficient - It is environmentally sound -Generates useful by-products and energy	- There is a little experience with anaerobic reactors in the region - Investment costs can be high - Companies may resist the adoption of this technology

As a conclusion of this study of Seghezzo (2004), it is recommended that UASB reactor followed by adequate post-treatment, e.g. polishing ponds is the most sustainable alternative for sewage treatment in the region.

5.4.3 Indicative Economic Analysis of Wastewater Treatment in Developing Countries

A study done by Journey and Scott (1996) although based on rough estimates, the analyses presented in Table (5.5) indicates some interesting generalizations. The costs of both construction and operation are far higher in Jordan than in Latin America or South Asia. This may be because there is a continuing dependence on imported expertise and equipment. However, because the economy is relatively strong and water is so scarce, treating wastewater in Jordan can pay handsomely. In fact, the potential economic value of recycled water is so high, especially for industrial reuse that on-site uses will have to be tested very carefully before they can be broadly recommended. This is particularly true for on on-site uses which are highly water consumptive, such as fish ponds.

In more humid climates the greater general availability of water reduces the demand for, and the value of treated effluent for irrigation and the incentive for industries to accept water reclaimed from wastewater. In this situation the profitability of effluent reuse on the site of the treatment facility may be considerably higher (Journey and Scott, 1996).

Table (5.5): Comparisons of Results of Indicative Analysis for Activated Sludge Treatment Plants and Resource Recovery Treatment and Production Systems

		Arid e.g., Jordan		**Humid e.g., Colombia**		**Very Humid Bangladesh**	
Scenario		***1A***	***1B***	***2A***	***2B***	***3A***	***3B***
COSTS							
Capital Cost	US$ m	9.54	4.50	4.50	2.25	3.60	1.50
OM&R Cost	US$ m/year	0.48	0.11	0.27	0.06	0.27	0.25
EFFLUENT ALLOCATION							
On-site use	%	5	35	5	30	5	30
Industry	%	15	15	30	30	22	22
Agriculture	%	70	40	30	30	50	10
ECONOMIC VALUES							
Treatment	$\$/m^3$	0.25	0.25	0.20	0.20	0.15	0.15
On-site use	$\$/m^3$	0.88	0.95	0.33	0.33	0.11	0.19
Industry	$\$/m^3$	1.50	1.50	0.50	0.50	0.25	0.25
Agriculture	$\$/m^3$	0.75	0.75	0.15	0.15	0.05	0.05
RESULTS OF ANALYSIS							
Economic internal rate of return	%	26.6	36.0	17.4	36.6	9.7	43.2

Source: (Journey and Scott, 1996)

5.4.4 Cost Comparison of Wastewater Treatment Technologies for Tropical Conditions

Oomen and Schellinkhout (1993) made a cost comparison (investment plus operation & maintenance) of 9 sewage treatment systems for tropical conditions (lowest water temperature $\geq 15^oC$). Among these were conventional aerobic systems, aerated ponds, stabilization ponds and anaerobic treatment (UASB reactor system), having either a trickling filter or facultative ponds as a post-treatment stage. They showed that the annual costs of the latter systems were the lowest under a wide range of conditions. In the neighborhood of (big) cities the anaerobic wastewater reactor system is far cheaper than the "low-cost" stabilization pond systems owing to the generally high land prices. The annual costs (investment depreciation and running costs) of a UASB-pond system were found to be half the value of an activated sludge system. The total investment costs in the city of Bucaramanga (Colombia) amounted 16 USD per capita, while the operating costs are 0.7 USD per capita per year. The power consumption never exceeded 5 % of the operation costs.

CHAPTER 6
RESEARCH RESULTS AND DISCUSSION

6.1 PROFESSIONALS' QUESTIONNAIRE

6.1.1 WATER RESOURCES

In the Mediterranean Region, there is water shortage and it becomes very important to protect water resources, and this is obvious from the analyzed data, also there are less people served by municipal water distribution system in rural areas of the region, and of course, the specific daily water consumption is lower with less quality of water, especially in the eastern and southern parts of the region (Palestine, Jordan and Morocco), and this in turn will reflect the situation of the overall economy. Actually, one of the most important reasons of getting an improved style of life is to have easily and available good quality of water which is considered to be a fundamental human right.

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 (Al-Sa'ed, 2000). Table (6.1) shows water situation in the region.

Table (6.1): Water situation in the Mediterranean Region (Q1 +Q2 +Q3+Q4)[1]

No.	Country	Sample size	Is there water shortage	Water quality	Municipal water distribution services %		Water consumption Liter/capita/day
					Urban	Rural	
1.	Palestine	20	Yes	Fair	93.12	67.71	66
2.	Jordan	6	Yes	Good-Fair	98.4	92.8	110.6
3.	Greece	3	Yes	Fair	98.3	70	206.7
4.	Italy*	2	Yes	Good	95	60	270
5.	Turkey*	1	No	Fair	80	20	100
6.	Spain*	1	Yes	Fair	100	100	300
7.	Morocco*	1	Yes	Good	95	10	90
Note: few people had responded from Italy, Turkey, Spain and Morocco and this will give limitations to the results							

[1]Q: Question number in the professionals' questionnaire section 1.

6.1.2 SOCIAL CRITERIA

Results of this study in table (6.2) show that the overall economy of most of the Mediterranean countries ranges between fair and bad, especially in the eastern and southern parts of the region (Palestine, Jordan and Morocco); this leads to poor water supply and sanitation systems especially in the rural areas.

The shortages of finance for investment and the inability to recover costs from users still characterize the financial management of the water and sanitation sector in developing counties of the region (Abu Madi, 2000).

The amount of BOD of the domestic sewage influent mostly gives an indication to the type of food consumed by the people. The amount of BOD in the eastern and southern parts of the region (Palestine, Jordan and Morocco) ranges between 600-800 mg/l, while it ranges between 200-400-600 mg/l in the western (European) countries (Greece, Italy, Turkey and Spain). Also the amount of BOD plays an important role in wastewater treatment technology selection. As it is mentioned in the literature review, in comparison to the US and Europe, domestic wastewaters in arid areas are up to five times more concentrated in the amount of oxygen demand per volume of sewage. This is extremely high and may cause a large amount of sludge production, and will cost too much if cost affective technologies are not selected like anaerobic wastewater treatment technologies.

The results also show that the public awareness to the pollution problem, which plays an important role in minimizing the size of this pollution, is low in Palestine and Morocco but high in the other countries of the region. This gives an indication to the need for training the public engineers and technicians, since the wastewater treatment is a priority in protecting public or environmental health in the region. Table (6.2) shows some of the social criteria related to the region. Figures (6.1) and (6.2) show overall economy and range of the BOD of domestic sewage influent in the region.

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 (Al-Sa’ed, 2000).

Table (6.2): Social criteria of the Mediterranean Region (Q1+Q2 +Q3 +Q4 +Q5)

No.	Country	Situation of Overall economy	Wastewater coverage (%) of population		Range of BOD(Mg/l)	Public awareness	Is wastewater a priority
			Urban	Rural			
1.	Palestine	Bad	53	7	600-800	Low	Yes
2.	Jordan	Fair	55	20	600-800	High	Yes
3.	Greece	Good	80	30	400-600	High	Yes
4.	Italy*	Good/Fair	83	45	200-400	High/Low	Yes/No
5.	Turkey*	Fair	-	-	200-400	High	No
6.	Spain*	Good	100	75	400-600	High	No
7.	Morocco*	Good/Fair	8.3		-	Low	Yes
*: few people had responded to us from Italy, Turkey, Spain and Morocco and this will give limitations to the results.							

Q: Question number in the professionals' questionnaire section 2.

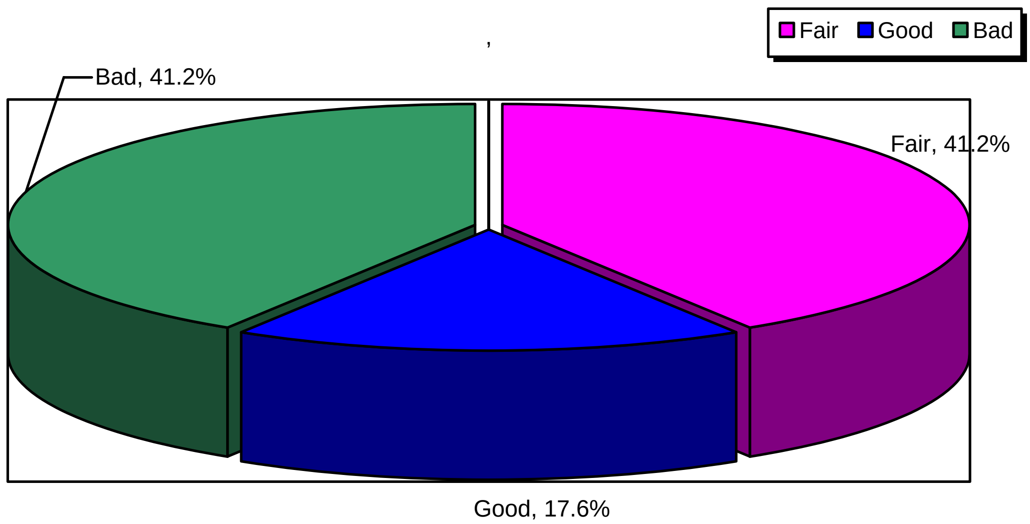

Figure 6.1: Overall economy of the Mediterranean Region

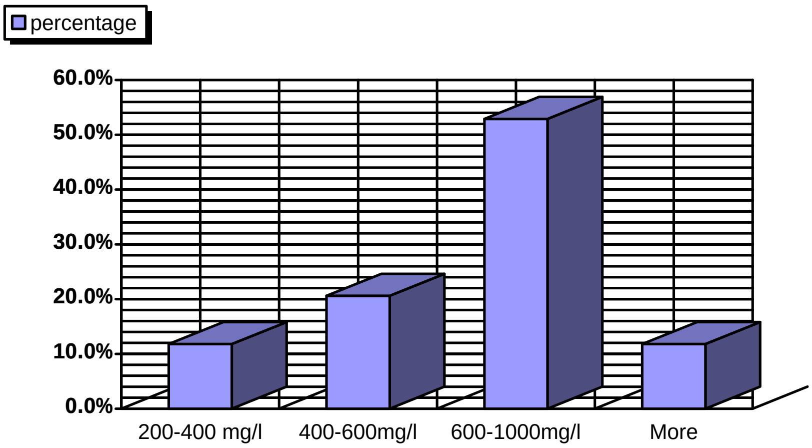

Figure 6.2: Range of BOD of the domestic sewage influent in the Mediterranean Region

6.1.3 WASTEWATER TREATMENT

As it is mentioned in the previous section, poor wastewater treatment is mainly resulted from the bad situation of the overall economy. Table (6.3) shows the situation of wastewater treatment technology in the Mediterranean Region.

Table (6.3): The situation of wastewater treatment technology in the Mediterranean Region

Q.1Based on your experience, how can you describe the situation of wastewater treatment technology in your country?(N=34)	Poor		Fair		Good	
	Count	%	Count	%	Count	%
	19	54.3	13	37.1	2	5.7

Since the most important parameters to be taken into account during selection of wastewater treatment technology, according to the analyzed data in Table (6.4), are operational cost and capital cost, therefore, the selected technologies should be with less operational cost, and later with less capital cost. But unfortunately in many cases, especially in eastern and southern parts of the Mediterranean Region, are not taken into considerations. This is obvious from the kinds of treatment plants available in the Mediterranean Region, according to the analyzed data, which shows that mostly big centralized with high operational cost schemes are used. The available high costly conventional wastewater treatment technologies, for a long time, are not successful for the developing countries and most of them ceased to function due to the lack of maintenance. Also comparing the results obtained in Tables (6.5) and (6.6) it is obvious that the governments are concerning much more in land availability than operation and maintenance. This will make it difficult for the project to sustain since it may stop to work as soon as handing it to the community. Table (6.4) shows the parameters of wastewater that should be taken into account during selection of wastewater treatment technology and their consideration in the region; Table (6.5) shows the weights (1-10) of priority of wastewater treatment technology selection of parameters according to the believe of professionals in the region and Table (6.6) shows the weights according to their consideration in the governments.

Table (6.4): The parameters that should be taken into account during selection of wastewater treatment technology

Q.2 The parameters that should be taken into account during selection of wastewater treatment technology:	Yes		No		Missing
	Count	%	Count	%	
Availability of expertise	**30**	**88.2**	**4**	**11.8**	
Capital cost	**32**	**94.1**	**2**	**5.9**	
Operational cost	**34**	**100**	**0**	**00**	
Land availability	**28**	**82.4**	**6**	**17.6**	
Existence of the same part of technology in operation	**22**	**64.7**	**7**	**20.6**	**5**
Energy consumption	**32**	**94.1**	**1**	**2.9**	**1**
Odor emission	**30**	**88.2**	**2**	**5.9**	**2**
Confidence in the technology performance	**31**	**91.2**	**2**	**5.9**	**1**
Standards	**30**	**88.2**	**3**	**8.8**	**1**

Others like

NO	
1	**Surrounding land uses e.g., in the cases of effluent recirculation**
2	**Type of pollution existing**
3	**Availability of spare parts**
4	**All above parameters**
5	**End use & environment**
6	**Qualified staff in charge of operation , production of sludge**
7	**Appropriateness to sewage character**
8	**Acceptance to reuse water**
9	**Climate**
10	**Environmental implications**
11	**Awareness, reuse, decentralization, on-site and collective treatments**
12	**Political restrictions**
13	**Water quality & reuse**

Q.3 Are the above mentioned parameters taken into account in your country?	Yes		No	
	Count	%	Count	%
	16	**47.1**	**18**	**52.9**

Table (6.5): Weights (1-10) of priority of wastewater treatment technology selection parameters in the region according to the believe of professionals

Q.4 Please give these parameters weights (1-10) according to their priority as you think it should be (1 for very low, 10 for very high)?	Mean	Std. Deviation
Availability of expertise	**7.06**	**2.67002**
Capital cost	**7.58**	**2.57907**
Operational cost	**8.23**	**1.99516**
Land availability	**6.80**	**2.59176**
Existence of the same part of technology in operation	**5.41**	**2.80964**
Energy consumption	**6.97**	**2.18302**
Odor emission	**6.47**	**1.83328**
Confidence in the technology performance	**6.16**	**2.50462**
Standards	**7.29**	**2.39713**
Others like	**7.54**	**2.53691**

Table (6.6): Weights (1-10) of priority of wastewater treatment technology selection parameters in the region according to the consideration in the governments

Q.5 Please give these parameters weights (1-10) according to their consideration in your country (1 for very low, 10 for very high)?	Mean	Std. Deviation
Availability of expertise	**5.13**	**2.83331**
Capital cost	**6.73**	**2.51058**
Operational cost	**7.00**	**2.37045**
Land availability	**7.45**	**2.50195**
Existence of the same part of technology in operation	**4.67**	**2.76285**
Energy consumption	**5.77**	**2.75909**
Odor emission	**5.95**	**2.78563**
Confidence in the technology performance	**6.05**	**2.83645**
Standards	**5.81**	**3.05972**
Others like	**5.13**	**2.83331**

The role of the aid agencies and donors in wastewater treatment technology selection in the region ranges between recommendation, imposition and participation. This gives an indication that donors do not all have the same policy. Some will try to impose their understanding of the best technology; others will conduct a participatory approach with local NGOs and other organizations and local communities. However, the general belief is that most try to recommend what donors think is the appropriate solution/technology. Table (6.7) shows percentages of types of roles played by aid agencies and donors in the selection of wastewater treatment technology in the region.

For the technology to be successful the community should be given a suitable role in decision making, since the community will pay for the operation and maintenance of the project. Unfortunately, the results in table (6.8) show that in most of the cases the community does not take an important role in treatment technology selection, this in turn will affect the sustainability of the project during operation and maintenance stages.

Table 6.7: Percentages of types of roles played by aid agencies and donors in the selection of the wastewater treatment technology in the Mediterranean Region

Q.9 You can describe the role of the aid agencies and donors in the selection of the wastewater treatment technology in your country as:	Professionals N=34	
	Count	%
Recommendation	**12**	**35.3**
Imposition	**10**	**29.4**
Participation	**9**	**26.5**
Missing	**3**	

Although it is very important to involve the academic establishments in the technology selection, because they follow up the new and last technologies over the world, the results in table (6.8) show that the academic establishments, mostly, do not have any role in decision making in technology selection, and this may lead to a wrong selection and may slower implementation stages of the project, also it may make the operation and maintenance period difficult to follow up. Table (6.8) shows percentages of professionals having an idea about difference between aerobic and anaerobic wastewater treatment in the region and roles of communities and universities.

Table (6.8): knowledge about difference between aerobic and anaerobic wastewater treatment in the Mediterranean Region and roles of communities and universities

Question	Yes		No		Missing
Q.7 Do you have an idea about the difference between aerobic and anaerobic wastewater treatment?	Count	%	Count	%	
	33	**94.3**	**1**	**2.9**	-
Q.8 Do you believe that the community takes an important role in treatment technology selection?	Yes		No		
	Count	%	Count	%	
	15	**42.9**	**19**	**54.3**	-
Q.11 Do you think that the academic establishments in your country have a role in decision making in the wastewater treatment technology selection?	Yes		No		
	Count	%	Count	%	
	15	**44.1**	**18**	**52.9**	**1**
Q.12 Do you think that it is important to involve the academic establishments in the technology selection?	Yes		No		
	Count	%	Count	%	
	33	**97.1**	**1**	**2.9**	-

6.1.4 ANAEROBIC WASTEWATER TREATMENT TECHNOLOGIES

Although applying anaerobic wastewater treatment is encouraged and considered as a reliable alternative with little odor problems, can be applied instead of other alternatives completely in some cases, recommended to be applied without any post treatment as first phase till enough fund is made available, is believed to be well developed and giving the needed level, from the technical and economical point of view should be included in the wastewater treatment scheme and it is believed that high rate anaerobic treatment technologies like UASB reactors remove more than 60% of the BOD and so reduce the volume/area of the subsequent treatment steps at almost the same ratio, however, anaerobic technologies are not enjoying the popularity they deserve in practice, the following item, which is considered according to its weight in the results in Figure (6.3), the main reason for that:

-Practice engineers lack experience and confidence in the system, and so they do not want to take the risk of trying.

Obstacles to adoption of new advanced technologies include lack of information, lack of expertise, lack of funds, and risk-averse attitudes (Weinstein, 2003). Practical experience gained from recently implemented urban sewage projects, indicated that about 10 years of planning were spent for Albireh sewage works (Al-Sa’ed, 2000). 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. As it is obvious from Table (6.11), there is a lack of experience in the operation of such systems which makes it difficult to start the job even after preparing all project documents. This assures what is mentioned in literature review according to the advantages and drawbacks of anaerobic over aerobic wastewater treatment systems, one of the most important drawbacks is: no experience with full-scale application at low/moderate temperatures.

Table (6.9) shows percentages of professionals encouraging applying anaerobic wastewater treatment and the reliability of those systems, Table (6.10) shows the percentages of availability of odors in anaerobic treatment systems, Table (6.11) shows the percentage of availability of experience in those systems, Table (6.12) shows some other incentives of applying anaerobic systems in the wastewater treatment scheme and Figure (6.3) explains the reasons behind unpopularity of anaerobic wastewater treatment systems in practice.

Table (6.9): Percentages of professionals Encouraging applying anaerobic wastewater treatment and the reliability of those systems in the Mediterranean Region

Q.1 Do you encourage applying anaerobic wastewater treatment?	Yes		No		Cannot decide		Missing
	Count	%	Count	%	Count	%	
	21	**61.8**	**1**	**2.9**	**10**	**29.4**	**2**
Q.2Can the anaerobic treatment be considered as a reliable alternative?	Yes		No		Cannot decide		Missing
	Count	%	Count	%	Count	%	
	29	**85.3**	**5**	**14.7**	**-**	**-**	**-**

Table (6.10): Odor problems in the anaerobic treatment

Q.3 Does the anaerobic treatment have any odor problems?	No odor problems		Little odor problem		Too much odor problems		Missing
	Count	%	Count	%	Count	%	
	3	**8.8**	**21**	**61.8**	**8**	**23.5**	**2**

Table (6.11): Availability of enough experience in anaerobic treatment in the Mediterranean Region

Q.4 Experience in anaerobic treatment?	Yes		No		No idea		Missing
	Count	%	Count	%	Count	%	
Research	**20**	**58.8**	**9**	**26.5**	**3**	**8.8**	**2**
Design	**17**	**50.0**	**12**	**35.3**	**3**	**8.8**	**2**
Operation	**9**	**26.5**	**18**	**52.9**	**5**	**14.7**	**2**
Construction	**15**	**44.1**	**12**	**35.3**	**6**	**17.6**	**1**

Table (6.12): Some incentives of applying anaerobic systems in the wastewater treatment scheme

Q.5 Can the anaerobic treatment be used, in some cases, instead of other alternatives completely (not as pre-treatment)?	**Yes**		**No**		**No idea**		**Missing**
	Count	%	Count	%	Count	%	
	21	**61.8**	**9**	**26.5**	**2**	**5.9**	**2**
Q.6 In case the coverage of wastewater treatment services in your country is poor, do you recommend to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	14	**41.2**	**11**	**32.4**	**6**	**17.6**	**3**
Q.7 Do you believe that the anaerobic treatment technology is well developed and giving the needed level or still needs progress?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	20	**58.8**	**9**	**26.5**	**4**	**11.8**	**1**
Q.8 Do you believe that the anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	27	**79.4**	**00**	**00**	**6**	**17.6**	**1**

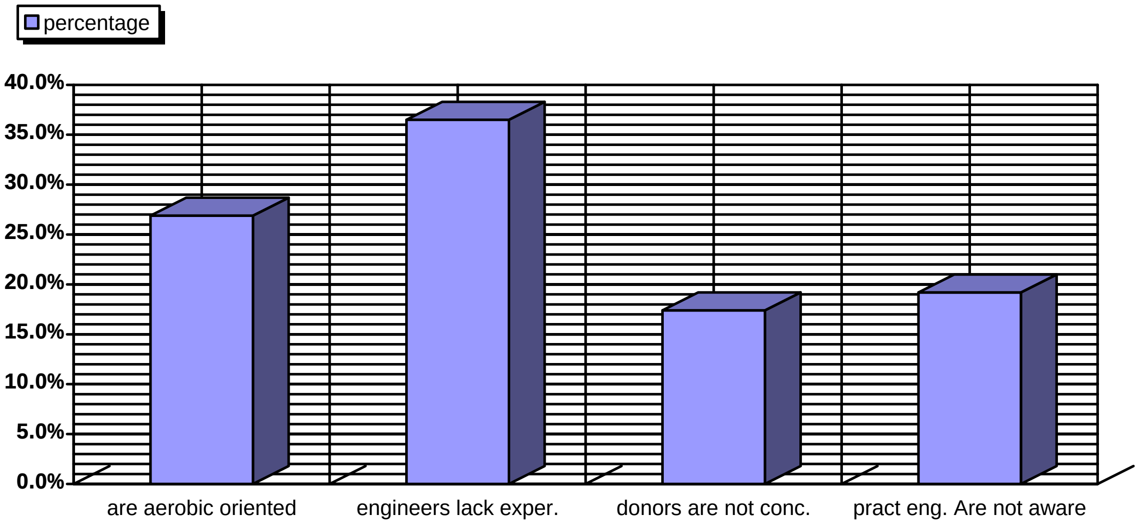

Figure (6.3): Percentages of the reasons of unpopularity of anaerobic technologies in practice

6.1.5 SLUDGE PRODUCED BY ANAEROBIC TREATMENT

In addition to what mentioned before about the advantages of anaerobic treatment technologies, another important one can be considered, which is related to the sludge produced by this technology. As the results show, the amount of sludge produced by this technology is less than the amount produced by conventional wastewater systems. Also, the management of this sludge is easier than the management of the others, Table (6.13) shows the quantity of sludge produced by anaerobic wastewater treatment systems and its management compared to aerobic systems.

Table (6.13): The quantity of the sludge produced by anaerobic wastewater treatment and the management of it

	Yes		**No**		**Missing**
Q.1 Do you have an idea about the quantity of the sludge produced by the anaerobic treatment technology?	Count	%	Count	%	
	15	**44.1**	**17**	**50.0**	**2**
	Yes		**No**		**Missing**
Q.2 Is this quantity of sludge considered to be more than the quantity produced by the aerobic treatment?	Count	%	Count	%	
	6	**17.6**	**22**	**64.7**	**6**
	Yes		**No**		**Missing**
Q.3 Is the management required for the sludge produced by anaerobic treatment easier than the aerobic treatment?	Count	%	Count	%	
	24	**70.6**	**4**	**11.8**	**6**

6.2 DONORS' QUESTIONNAIRE

As the results show in table (6.14), all of the donors agree about the parameters that should be taken into account during selection of wastewater treatment technology, and according to the results of the donors, there is one parameter that is accepted to be with less importance than the others and that is the existence of the same part of technology in operation, this means that selecting and starting a new technology can be done without the need for existence of the same technology in operation in the country. Related to weights of these parameters, according to the priorities as the donors think it should be, the most important one is the operational cost which is the same as the results obtained from analyzing the professionals' questionnaires. This certifies how much it is important for the technology to be with less operation and maintenance cost, and also it certifies what was mentioned before that the selected wastewater treatment technology should be with less operational and maintenance cost to continue sustain. Five of six (number of the interviewed donors) have an idea about the difference between aerobic and anaerobic wastewater treatment. Table (6.14) shows the parameters that should be taken into account during selection of wastewater treatment technology according to the interviewed donors and Table (6.15) shows the weights of those parameters according to their priority as the donors think it should be.

Table (6.14): The parameters that should be taken into account during selection of wastewater treatment technology and their consideration according to the donors:

Q.1 The parameters that should be taken into account during selection of wastewater treatment technology:	Donors N=6			
	Yes		No	
	Count	%	Count	%
Availability of expertise	**6**	**100**	**00**	**00**
Capital cost	**6**	**100**	**00**	**00**
Operational cost	**6**	**100**	**00**	**00**
Land availability	**6**	**100**	**00**	**00**
Existence of the same part of technology in operation	**4**	**66.7**	**2**	**33.3**
Energy consumption	**6**	**100**	**00**	**00**
Odor emission	**6**	**100**	**00**	**00**
Confidence in the technology performance	**6**	**100**	**00**	**00**
Standards	**6**	**100**	**00**	**00**

Others like

NO	
1	**Effluent quality, water Conditions environmental Impact Assessment**
2	**Availability of technicians**
3	**Social considerations ,cost recovery**

Q.2 Which of the above mentioned parameters taken into account during your organization technology selection?	All of them		The most important capital and operational costs		Cannot decide	
	Count	%	Count	%	Count	%
	4	**66.7**	**1**	**16.7**	**1**	**16.7**

Table (6.15): Weights (1-10) of wastewater treatment technology selection parameters according to their priority as donors think it should be (1 for very low, 10 for very high)?

Q.3 Please give these parameters weights (1-10) according to their priority as you think it should be (1 for very low, 10 for very high)?	Mean	Std. Deviation
Availability of expertise	**7.83**	**1.72240**
Capital cost	**7.83**	**2.40139**
Operational cost	**9.00**	**0.22222**
Land availability	**7.50**	**1.50000**
Existence of the same part of technology in operation	**6.17**	**2.78687**
Energy consumption	**8.67**	**0.33333**
Odor emission	**5.67**	**3.33333**
Confidence in the technology performance	**7.50**	**1.50000**
Standards	**8.50**	**1.04881**
Others like	**5.80**	**3.22222**

Related to the role of donor countries, the results obtained from the donors are somehow different than that ones obtained from the professionals; since most of donors mentioned that the role is recommendation and no imposition in the matter. This may be due to the fact of being very difficult for the donors to admit that they impose their technologies on the public. Table (6.16) shows the percentages of roles played by donors in wastewater treatment technology selection according to the donors.

Table (6.16): Percentages of roles played by the aid agencies and donors in selection of wastewater treatment technology in the Mediterranean Region

Q.5 You can describe the role of the aid agencies and donors in the selection of the wastewater treatment technology in your country as:	Donors N=6	
	Count	%
Recommendation	3	50.0
Participation	2	33.3
Imposition	00	00
All of them	1	16.7

Some donors say that they choose technologies in which the engineers in their countries familiar with and the others say they do not choose such technologies in that way. Of course, the donors all are not the same, each one of them has its special policy. According to the results, most of the donors say that the academic establishments in their countries have no role in decision making in the selection of wastewater treatment technology, which assures the results obtained from professionals' questionnaires. Table (6.17) shows the percentages of donors choosing the technologies in which engineers in their countries familiar with, availability of universities role or not and encouragement of applying anaerobic treatment technologies.

Table (6.17): Percentages of donors choosing the technologies in which engineers in their countries familiar with, availability of universities role or not and encouragement of applying anaerobic treatment technologies

	Yes		No		It depends		Missing
Q.7 The donors choose technologies in which the engineers in their countries familiar with:	Count	%	Count	%	Count	%	
	3	**50.0**	**3**	**50.0**	**-**	**-**	**-**
Q.8 Do you think that the academic establishments in your country have a role in decision making in the selection of wastewater treatment technology?	**Yes**		**No**		**It depends**		
	Count	%	Count	%	Count	%	
	1	**16.7**	**5**	**83.3**	**-**	**-**	-
Q.9 Do you encourage applying anaerobic wastewater treatment?	**Yes**		**No**		**It depends**		
	Count	%	Count	%	Count	%	
	3	**50.0**	**1**	**16.7**	**2**	**33.3**	**2**
Q10 Do you have enough knowledge about the anaerobic treatment technologies?	**Yes**		**No**		**It depends**		
	Count	%	Count	%	Count	%	
	5	**83.3**	**00**	**00**	**-**	**-**	**1**

Related to anaerobic wastewater treatment technology, most of the donors encourage applying this technology and recommend to use anaerobic treatment, in some cases, instead of other alternatives completely (not as pre-treatment). Also, most of them believe that this technology is well developed and giving the needed level. But they refer the unpopularity of this technology in the practice to mainly two reasons:

-Practice engineers lack confidence in the system, and so they do not want to take the risk of trying,

-Practice engineers are not fully aware and need more training and education.

So, both of the professionals and donors agree about this point which certifies that it is very necessary to train technical staff in municipalities and village councils in order to make them qualified to manage such projects.

According to Seghezzo (2004), in some developing countries, negative experience in the early stages prevented even further the introduction and diffusion of anaerobic systems for sewage treatment.

Table (6.18) gives the percentage of types of experience available in anaerobic treatment according to the donors, Table (6.19) shows some related incentives in applying anaerobic systems in the wastewater treatment scheme, and Figure (6.4) shows percentages of the reasons stand behind unpopularity of anaerobic wastewater treatment technologies in practice.

Table (6.18): Available experience in anaerobic treatment according to donors

Q.11 Do you believe that there is enough experience in anaerobic treatment?	Yes		No		No idea	
	Count	%	Count	%	Count	%
Research	**6**	**100**	**00**	**00**	**00**	**00**
Design	**2**	**33.3**	**4**	**66.7**	**00**	**00**
Operation	**00**	**00**	**6**	**100**	**00**	**00**
Construction	**2**	**33.3**	**4**	**66.7**	**00**	**00**

Table (6.19): Some incentives of applying anaerobic systems in the wastewater treatment scheme

Q.12 Can the anaerobic treatment be used, in some cases, instead of other alternatives completely (not as pre-treatment)?	**Yes**		**No**		**No idea**		**It depends**
	Count	%	Count	%	Count	%	
	4	**66.6**	**1**	**16.7**	**1**	**16.7**	**-**
Q.13 In case the coverage of wastewater treatment services in your country is poor, do you recommend to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	2	**33.3**	**3**	**50.0**	**1**	**00**	**-**
Q.14 Do you believe that the anaerobic treatment technology is well developed and giving the needed level or still needs progress?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	4	**66.7**	**1**	**16.7**	**1**	**16.7**	**-**
Q.15 Do you believe that the anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme?	**Yes**		**No**		**No idea**		
	Count	%	Count	%	Count	%	
	4	**83.3**	**00**	**00**	**1**	**16.7**	**1**

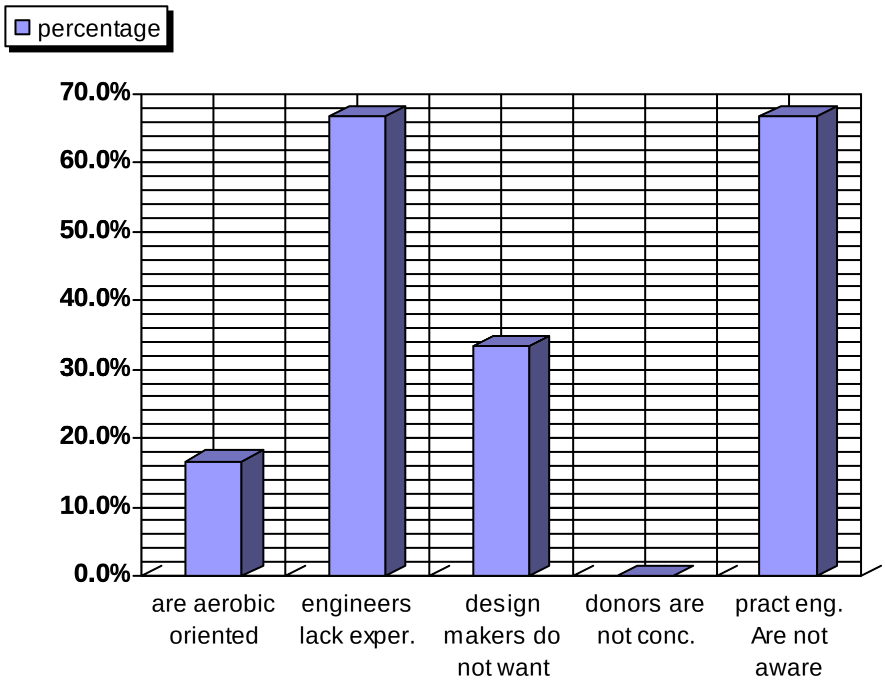

Figure (6.4): Reasons for unpopularity of anaerobic treatment technologies according to the donors

6.3 GENERAL DISCUSSION

In the Mediterranean Region, there is water shortage and it becomes very important to protect water resources, especially in the eastern and southern parts of the region, and since the overall economy of most of the region countries ranges between fair and bad, careful consideration must be given to proper wastewater treatment management from now on. The Mediterranean Region countries cannot afford any capital loss from wastewater treatment in the future as donor's financial support will decrease with time. The low cost sustainable alternatives should be implemented. To achieve such low cost sustainable alternatives, a number of parameters should be considered when choosing the appropriate technology. The best option for a wastewater treatment system will be selected from a shortlist after considering these parameters which are arranged below according to their priorities as:

1. Operational cost
2. Capital cost
3. Energy consumption
4. Standards
5. Confidence in the technology performance
6. Availability of expertise
7. Odor emission

8. Land availability
9. Existence of the same part of technology in operation
10. Others like: surrounding land uses e.g., in the case of effluent recirculation, type of pollution existing, end use & environment, qualified staff in charge of operation, appropriateness to sewage characteristics, acceptance to reuse water, political pressure and restrictions.

As it is observed from the above mentioned parameters, the most important one is the operational cost, so the selected technology must be low operational cost to consider it sustainable. Mostly, the following conventional wastewater treatment technologies are available in the Mediterranean Region:

-Activated sludge plants

-Trickling filters

-Aerated lagoons

-Oxidization ponds or wastewater stabilization ponds

There are considerable variations in sanitation provision between the Mediterranean Region countries, largely due to inequalities in income and the level of tourism. But in general the situation of wastewater treatment technology in the region ranges between poor and fair.

The roles in decision making in the wastewater treatment technology selection should be distributed carefully to the related stakeholders, all in his position and abilities, to achieve a sustainable and affordable technology. The most important parts included in the decision making are:

1. **The Community**: For the sustainability of a system, the use and maintenance has to be done by the community. This can only come when the community participates at all stages of the project. Unfortunately, in most of the cases, they do not play any role in the selection policies.
2. **The Academic Establishments**: Mostly, academic institutions in the region countries, especially in developing ones, have no weight in the national decision. However, there are many cases where consultants from the academy are participating in the design, supervision and providing solutions to wastewater projects, it mainly happens when the treatment plants experience some problems during operation. Actually, it is very important to involve the academic establishments in the technology

selection, because the academic establishments follow up the new and last technologies over the world and can provide a technical assistance with good bases from previous research in these regards, the academic establishments are able to control technology and to ensure the good transfer to the local users of it (especially in the developing countries), they can also train national technicians specialized in the selected technology, they must allow the autonomy of the country compared to the foreign expertise, finally, it is important to keep a strong connection between the applied engineering and the research sector for new promising technologies promotion.

3. **The Aid Agencies and Donors**: Donors do not all have the same policy. Some will try to impose their understanding of the best technology; others will conduct a participatory approach with local NGOs and other organizations and local communities. However, the general belief is that most try to recommend what donors think is the appropriate solution/technology. Although it seems to be participation or recommendation issue, but it is more likely to be polite imposition. Most of the time technologies developed in the donor's countries should be applied; the majority of the WWTP in the region were built within the framework of the international co-operation. The technologies used in the region are often imported and should be used as pilot for possible WWTP to be built in the future. The expertise is completely foreign and cost until 30 percent of the construction cost of the WWTP. They try to influence technologies they are using at their countries even if –O&M is high—or capital cost is high and there is no real body to interfere strongly on that, even there is no qualified people to do so (high position or decision makers). Although such economic aid is essential, especially for developing countries, but it is very important for the aid agencies and donors to take into consideration the local conditions to make full use of any aid.

Applying anaerobic wastewater treatment is mostly encouraged and can be considered as a reliable alternative, this is because the quantity of sludge produced by anaerobic treatment is considered to be less than the quantity produced by aerobic treatment, and the management required for the sludge produced by anaerobic treatment is easier than the aerobic treatment, also, the anaerobic treatment has little odor problems, especially for industrial wastewater, low energy consumption, low nutrient requirements, production of biogas, it can be applied for the wastewater with high organic load (the BOD of the domestic sewage influent in the region ranges between 600 - 1000 mg/l or more), and can be applied in rural areas. But it is believed that there is enough experience in anaerobic treatment in research, design and construction, and there is no enough experience in operation. In some cases, the anaerobic treatment can be used, instead of other alternatives completely (not as pre-treatment), also, in case the coverage of wastewater treatment services is poor, it is recommended to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available. The anaerobic treatment technology is well developed and giving the needed level and it is believed that the anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme. High rate anaerobic treatment technologies like UASB reactors remove more than 60% of the BOD and so reduce the volume/area of the subsequent treatment steps at almost the same ratio, however, anaerobic technologies are not enjoying the popularity they deserve in practice, the following item which is considered to be the main reason for that (according to the weight of the item obtained from the results in Figure (6.3)):

Practice engineers lack experience and confidence in the system, and so they do not want to take the risk of trying,

The public awareness to the pollution problem nowadays in the region differs from one country to another, while it is low in Palestine and Morocco it is high in Jordan, Greece, Turkey and Spain and it ranges between high to low in Italy. For this reason it becomes very important to train physical planners, decision makers, engineers, social scientists, representatives of non-government organization and target groups so that proper decisions can be done about proposed designs for treatment plants to be constructed in the near future. In addition training programs on environmental projects and pre-feasibility studies should be provided. The major problem of sanitation in the developing countries is not a lack or availability of technology. Rather, it is the fact that stakeholders are largely unaware of the alternatives available and the complexity of the suitability of one technology over the other, in their given situation.

Also, to get a sustainable technology the donor agencies, public and private sectors and academic establishments should work together as partners and they have all to decide and agree upon planned activities. This is very important since the users and communities will manage their responsibilities after handing over such projects to them. If this technology is introduced without involving the interested stakeholders, the operation and maintenance costs will be a major concern. A list of different technologies with complete and clear information on their financial and technical issues should be offered to the communities.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

- **Incentives of applying anaerobic technologies of sewage treatment in the Mediterranean Region**

- Anaerobic wastewater treatment systems are more sustainable with low operational and maintenance cost.

- Applying anaerobic wastewater treatment is mostly encouraged and can be considered as a reliable alternative**.**

- The anaerobic treatment technology is well developed and giving the needed level and anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme.

- The quantity of sludge produced by anaerobic treatment is considered to be less than the quantity produced by aerobic treatment, and the management required for the sludge produced by anaerobic treatment is easier than the aerobic treatment.

- High rate anaerobic treatment technologies like UASB reactors remove more than 60% of the BOD and so reduce the volume/area of the subsequent treatment steps at almost the same ratio**.**

- **Obstacles of applying anaerobic technologies of sewage treatment in the Mediterranean Region**

- In the Mediterranean Region there is enough experience in anaerobic treatment in research, design and construction, and there is no enough experience in operation.

- The interested stakeholders are mostly not involved in the selection and implementation processes, therefore, the operation and maintenance costs will be a major concern.

- The most important obstacle is that anaerobic wastewater treatment is not integrated in many recent wastewater treatment projects and this is due to mainly two reasons:

1. Practice engineers lack confidence in the system, and so they do not want to take the risk of trying,
2. Practice engineers are not fully aware and need more training and education.

Since 36.5% of professionals and 66.7% of donors, which is the majority, agree about these points.

- The situation of overall economy is bad in Palestine, fair in Jordan and Turkey, fair-good in Italy and Morocco and good in Greece and Spain. This in turn will affect the situation of wastewater coverage and water distribution.
- In general the situation of wastewater treatment technology is poor since 54.3% of the interviewed professionals said it is poor, 37.1% said it is fair and 5.7% said it is good.
- The most important parameter to be taken into account during selection of wastewater treatment technology is operational cost since 100% of both professionals and donors agree about this point. In the other hand, the less important parameter is existence of the same part of technology in operation according to the results of professionals 64.7% and of donors 66.7%.
- Since operational cost has the highest weight (8.23 of 10) related to the priority of wastewater treatment technology selection parameters in the region according to the believe of professionals and land availability has the highest weight according to the governments (7.45 of 10), this indicates that the governments are concerning much more in land availability than operation and maintenance and this will make it difficult for the project to sustain since it may stop to work as soon as handing it to the community.
- The majority of 54.3% of professionals said that the communities do not play an important role in wastewater treatment technology selection and 42.9% said that they do.
- Mostly, the academic establishments have no role in decision making in wastewater treatment technology selection since 52.9% of professionals and 83.3% of donors agree about this point. This may lead to a wrong selection and may slower the implementation stages of the project.
- Since percentages of types of role played by aid agencies and donors in the selection of wastewater treatment technology are near to each other (recommendation 35.3%, imposition 29.4% and participation 26.5%), this indicates that donors do not all have the same policy, but the general belief is that most try to recommend what donors think is the appropriate solution.
- 50% of the interviewed donors said that they choose technologies in which the engineers in their countries are familiar with, and the other 50% said they do not choose such technologies in that way.

7.2 RECOMMENDATIONS

- Low maintenance technologies should be chosen while selecting wastewater treatment technologies in Mediterranean Region even at the cost of treatment efficiency.
- The roles in decision making in the wastewater treatment technology selection should be distributed carefully to the related stakeholders, all in his position and abilities**.** Alternative options have to be examined with the involvement of all of the stakeholders.
- It becomes very important to train physical planners, decision makers, engineers, social scientists, representatives of non-government organization and target groups so that proper decisions can be done about proposed designs for treatment plants to be constructed in the near future.
- In addition training programs on environmental projects and pre-feasibility studies should be provided.
- Public and private sectors, academic establishments and aid agencies should work together as partners and they have all to decide and agree upon planned activities.
- A list of different technologies with complete and clear information on their financial and technical issues should be offered to the communities to select the most suitable one according to their technical and financial abilities.
- It is recommended to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available.

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Appendix A

PROFESSIONAL' QUESTIONNAIRE

جامعة بيرزيت

BIRZEIT UNIVERSITY

Questionnaire

Obstacles and incentives of applying anaerobic technologies of sewage treatment in the Mediterranean Region

Please fill in the blank:

Name: --

Country: --

Age: --

Qualifications: ---

Country of study: --

Graduation year: ---

Institute: ---

Position: ---

Experience period in the field of wastewater treatment: ---------------------------

Where: --

Field of experience (academic or consultant, etc.) -------------------------------

Eng. Mazen Yahya

Dr. Nidal Mahmoud

PROFESSIONAL' QUESTIONNAIRE

WATER RESOURCES

Q.1 Do you believe that there is water shortage in your country?

Yes No

Q.2 In general, how is the water quality in your country?

 Good Fair Bad

Q.3 How much percentage of the population in your country is served by municipal water distribution system?

In urban areas---

In rural areas--

Q.4 The average specific daily water consumption as liter/capita/day is: ------------

SOCIAL CRITERIA

Q.1 How is the overall economy of your country?

Good Fair Bad

Q.2 The percentage of wastewater coverage in your country:

In urban areas is---------------------

In rural areas is ---------------------

Q.3 The range of the BOD of the domestic sewage influent in your country is:

200 - 400 mg/l 400-600 mg/l 600-1000 mg/l More

Q.4 The public awareness to the pollution problem nowadays in your country is:

 High Low Very low

Q.5 Can pollution be minimized by recovery technologies or public awareness?

 Yes No

Q.6 Do you feel that the wastewater treatment is a priority in protecting public or environmental health in your country?

 Yes No

WASTEWATER TREATMENT

Q.1 Based on your experience, how can you describe the situation of wastewater treatment technology in your country?

 Poor Fair Good

Q.2 The parameters that should be taken into account during selection of wastewater treatment technology:

- Availability of expertise ĺ Yes ĺ No
- Capital cost ĺ Yes ĺ No
- Operational cost ĺ Yes ĺ No
- Land availability ĺ Yes ĺ No
- Existence of the same part of technology in operation ĺ Yes ĺ No
- Energy consumption ĺ Yes ĺ No
- Odor emission ĺ Yes ĺ No
- Confidence in the technology performance ĺ Yes ĺ No
- Standards ĺ Yes ĺ No
- Others like --

Q.3 Are the above mentioned parameters taken into account in your country?

ĺYes ĺNo

Q.4 Please give these parameters weights (1-10) according to their priority as you think it should be (1 for very low, 10 for very high)?

- Availability of expertise ---------------------
- Capital cost ---------------------
- Operational cost ---------------------
- Land availability ---------------------
- Existence of the same part of technology in operation ---------------------
- Energy consumption ---------------------
- Odor emission --------------------
- Confidence in the technology performance ---------------------
- Standards ---------------------
- Others --

Q.5 Please give these parameters weights (1-10) according to their consideration in your country (1 for very low, 10 for very high)?

- Availability of expertise ---------------------
- Capital cost ---------------------
- Operational cost ---------------------
- Land availability ---------------------
- Existence of the same part of technology in operation ---------------------
- Energy consumption ---------------------

- Odor emission -------------------
- Confidence in the technology performance ---------------------
- Standards ---------------------
- Others --

Q.6 Based on your experience, what kinds of treatment plants are available in your country.

Type of treatment	No. of plants	Capacity from----to---PE
□Activated sludge	-------	------------- to ----------
Aerated lagoons	-------	------------- to ----------
Trickling filters	-------	------------- to ----------
Stabilization ponds	-------	------------- to ----------
Anaerobic systems	-------	------------- to ----------
Anaerobic followed by aerobic	-------	------------- to ----------
Others:	-------	------------- to ----------

Q.7 Do you have an idea about the difference between aerobic and anaerobic wastewater treatment?

Yes No

Q.8 Do you believe that the community takes an important role in treatment technology selection?

Yes No

Q.9 You can describe the role of the aid agencies and donors in the selection of the wastewater treatment technology in your country as:

Participation recommendation imposition

Q.10 Explain how do the donors influence the selection of the treatment technology:

Q.11 Do you think that the academic establishments in your country have a role in decision making in the wastewater treatment technology selection?

Yes No

If yes, how: --

Q.12 Do you think that it is important to involve the academic establishments in the technology selection?

Yes No

Explain:--

ANAEROBIC WASTEWATER TREATMENT TECHNOLOGY

Q.1 Do you encourage applying anaerobic wastewater treatment?

Yes No Cannot decide

If yes or no why: --

Q.2 Can the anaerobic treatment be considered as a reliable alternative?

Yes No

Q.3 Does the anaerobic treatment have any odor problems?

No odor problems

Little odor problems

Too much odor problems

Q.4 Do you believe that there is enough experience in anaerobic treatment?

- Research	Yes	No	No idea
- Design	Yes	No	No idea
- Operation	Yes	No	No idea
- Construction	Yes	No	No idea

Q.5 Can the anaerobic treatment be used, in some cases, instead of other alternatives completely (not as pre-treatment)?

Yes No No idea

Q.6 In case the coverage of wastewater treatment services in your country is poor, do you recommend to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available?

Yes No No idea

Q.7 Do you believe that the anaerobic treatment technology is well developed and giving the needed level or still needs progress?

Yes No No idea

Q.8 Do you believe that the anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme?

Yes No No idea

If yes or no explain: ---

Q.9 High rate anaerobic treatment technologies like UASB reactors remove more than 60% of the BOD and so reduce the volume/area of the subsequent treatment steps at almost the same ratio, however, anaerobic technologies are not enjoying the popularity they deserve in practice, which of the following items is a reason for that:

 Donor countries are aerobic oriented,

 Practice engineers lack experience and confidence in the system, and so they do not want to take the risk of trying,

 Donors and/or practice engineers (consultants) are not concerned about the operational cost of the treatment system, as that is not under their responsibility,

 Practice engineers are not fully aware and need more training and education.

SLUDGE PRODUCED BY ANAEROBIC TREATMENT

Q.1 Do you have an idea about the quantity of the sludge produced by the anaerobic treatment technology?

Yes No

If yes how much: --

Q.2 Is this quantity of sludge considered to be more than the quantity produced by the aerobic treatment?

Yes No

Q.3 Is the management required for the sludge produced by anaerobic treatment easier than the aerobic treatment?

 Yes No

Appendix B

DONORS' QUESTIONNAIRE

BIRZEIT UNIVERSITY

Questionnaire

Obstacles and incentives of applying anaerobic technologies of sewage treatment in the Mediterranean Region

Please fill in the blank:

Name: ---

Country: --

Age: --

Qualifications: --

Country of study: --

Graduation year: --

Institute: ---

Position: --

Experience period in the field of wastewater treatment: --------------------------

Where: --

Field of experience (academic or consultant, etc.) ----------------------------------

Eng. Mazen Yahya

Dr. Nidal Mahmoud

DONORS' QUESTIONNAIRE

Q.1 The parameters that should be taken into account during selection of wastewater treatment technology:

- Availability of expertise ꞏ Yes ꞏ No
- Capital cost ꞏ Yes ꞏ No
- Operational cost ꞏ Yes ꞏ No
- Land availability ꞏ Yes ꞏ No
- Existence of the same part of technology in operation ꞏ Yes ꞏ No
- Energy consumption ꞏ Yes ꞏ No
- Odor emission ꞏ Yes ꞏ No
- Confidence in the technology performance ꞏ Yes ꞏ No
- Standards ꞏ Yes ꞏ No
- Others like:

Q.2 Which of the above mentioned parameters taken into account during your organization technology selection?

Q.3 Please give these parameters weights (1-10) according to their priority as you think it should be (1 for very low, 10 for very high)?

- Availability of expertise ---------------------
- Capital cost ---------------------
- Operational cost ---------------------
- Land availability ---------------------
- Existence of the same part of technology in operation ---------------------
- Energy consumption ---------------------
- Odor emission -------------------
- Confidence in the technology performance ---------------------
- Standards ---------------------
- Others --

Q.4 Do you have an idea about the difference between aerobic and anaerobic wastewater treatment?

ꞏYes ꞏNo

Q.5 You can describe the role of the aid agencies and donors in the selection of the wastewater treatment technology as:

ĺ Participation ĺ recommendation ĺ imposition

Q.6 Explain how are the donors influence in the selection of the treatment technologies:

Q.7 The donors choose technologies in which the engineers in their countries familiar with:

ĺ Yes ĺ No

Q.8 Do you think that the academic establishments have a role in decision making in the selection of wastewater treatment technology?

ĺYes ĺ No

If yes, how: --

Q.9 Do you encourage applying anaerobic wastewater treatment for centralized?

ĺ Yes ĺ No

Q.10 Do you have enough knowledge about the anaerobic treatment technologies?

ĺ Yes ĺ No

Q.11 Do you believe that there is enough experience in anaerobic treatment?

- Research ĺ Yes ĺ No
- Design ĺ Yes ĺ No
- Operation ĺ Yes ĺ No
- Construction ĺ Yes ĺ No

Q.12 Can the anaerobic treatment be used, in some cases, instead of other alternatives completely (not as pre-treatment)?

ĺYes ĺ No

Q.13 In case the coverage of wastewater treatment services is poor, do you recommend to apply only anaerobic treatment reactor without any post treatment as first phase, till enough fund is made available?

Î Yes Î No

Q.14 Do you believe that the anaerobic treatment technologies are well developed and giving the needed level?

Î Yes Î No

Q.15 Do you believe that the anaerobic treatment from the technical and economical point of view should be included in the wastewater treatment scheme?

Î Yes Î No

Explain:--

Q.16 High rate anaerobic treatment technologies like UASB reactors remove more than 60% of the BOD and so reduce the volume/area of the subsequent treatment steps at almost the same ratio, however, anaerobic technologies are not enjoying the popularity they deserve in practice, which of the following items is a reason for that:

Î Donor countries are aerobic oriented,

Î Practice engineers lack confidence in the system, and so they do not want to take the risk of trying,

Î Design makers do not want to take the risk of trying,

Î Donors and/or practice engineers (consultants) are not concerned about the operational cost of the treatment system, as that is not under their responsibility,

Î Practice engineers are not fully aware and need more training and education.

Appendix C

List of interviewed Professionals and Donors

No	Name	Country	Age	Qualification	Country of Grad.	Grad. Year	Institute	Position	WW Exp. (years)
Professionals									
1	Iyad yaqoub	Palestine	32	MSc Water Eng.	Palestine	1997	PWA	Head of Research Dep.	7
2	Marwan Al Akhdar	Palestine	45	Civil Engineer	Romania	1984	Hebron Municipality	Eng.of the Health Dep.	-
3	Saleh Faris Afaneh	Palestine	45	Civil Engineer	India	1986	Salfit Municipality	Head of W & WW Dep.	8
4	Waddah Al Labadi	Palestine	49	Civil Engineer	Yoguslavia	1986	Jenin Municipality	Head of W & WW Dep.	8
5	Abdal mo,men Afa	Palestine	44	Mech. Engineer	Jordan	1985	Qalqilya Municipality	Head of Water Section	Durations
6	Hussein Qaraein	Palestine	56	Civil Engineer	Syria	1975	Municipal Fund	Chief of Technical Division	4
7	Rayeq Hamad	Palestine	47	Mech. Engineer	USA	1983	I.I.T	Project Manager	Limited
8	Adnan Zahran	Palestine	51	Civil Engineer	Libya	1978	Municipal Fund	Senior Engineer	-
9	Adallah Atereh	Palestine	-	Civil Engineer	Palestine	1980	Ramallah Municipality	City Engineer	-
10	Jihad Khoury	Palestine	56	Civil Engineer	Syria	1973	Ramallah Municipality	Head of Sewage Dep.	15
11	Ziad Mimi	Palestine	37	PhD	UK	1999	Birzeit Univers. Water Institute	Director	2
12	Shakour S.Bitar	Palestine	47	MSc W.&Env. Eng	UK	1994	CDM International	Deputy Chief of Party	10
13	Belal Elayyan	Palestine	38	MSc W.&Env. Eng	Jordan	1993	Arabtech Jardaneh / Palestine	Head of W&WW Section	10
14	Jamal Burnat	Palestine	35	MSc W.&Env. Eng	Netherlands	1997	IHE	W&WW Engineer	8
15	Maher Abu Madi	Palestine	35	PhD.W&Env. Eng.	Netherlands	2004	Birzeit Univers. Water Institute	Assistant Professor	-
16	Omar Zimmo	Palestine	47	PhD	USA&Neth.	2002	Birzeit Univers. Water Institute	Assistant Professor	20
17	Nidal Mahmoud	Palestine	35	PhD. Env. Eng.	Netherlands	2002	Birzeit Univers. Water Institute	Assistant Professor	12
18	Hafez Q.Shaheen	Palestine	46	PhD	Germany	1992	Al Najah Univers. W. Resources	Faculty Member	9
19	Ramez El-Titi	Palestine	44	MSc W.&Env. Eng	Jordan	1987	GTZ	Local Advisor	18
20	Gerasinos Lyberat	Greece	47	Professor	USA	1984	MIT, CALTECH	Professor	Vast
21	Omar Assobhel	Morocco	44	Professor	-	-	Chouaib Doukkali Univers.	Lab. Director	-
22	Vasileios Diamanti	Greece	28	PhD Candidate	Greece	2005	Democritus Univers. of Thrace	PhD Student	4
23	Iosif Kapellakis	Greece	29	PhD	Greece, UK	2005	Glasgow Caledonian Univers.	Researcher	6
24	Luigi Petta	Italy	32	PhD Sanitary Eng.	Italy	1999	ENEA	Researcher	6

25	Ettore Trulli	Italy	40	PhD Sanitary Eng.	Italy	1989	Univers.of Degli Studi Basilicata	Professor	15
26	Rasher Al Saed	Palestine	-	-	-	-	-	-	-
27	Jordi Molina	Spain	56	Engineer	Spain	1969	Univers. Politecnica Catalunya	Coordination Manager	Yes
28	Burak Demirel	Turkey	33	PhD Env.Technolo.	Turkey	2003	Environmental Sciences	Research Assistant	2
29	Bashar Al-Shreideh	Jordan	44	PhD	Netherlands	1999	UNESCO	IHE	21
30	Nadhir Al-Ansari	Jordan	58	PhD	UK	1976	Earth &Environmental Sciences	Dean	9
31	Maha Halalsheh	Jordan	35	PhD Env.Technolo.	Netherlands	2002	Water & Env. Research Center	Assistant Researcher	2
32	Iyad A.Hussin	Jordan	43	PhD W. Resources	USA	1995	Consulting Engineering Center	Head of Env. Studies Dep.	10
33	Najeeb M.Atiyat	Jordan	32	MSc Env. Eng.	Jordan	1999	Royal Scientific Society	Researcher	2
34	Nawal Sunna	Jordan	48	PhD. Env. Eng.	England	1998	Newcastle Upon	Dir. of Lab. & Quality Dep.	15
Donors									
1	S. Gramel	Germany	37	Eng. & Economy	Germany	2002	KFW	Technical Advisor	N.A
2	Schlund Matheis	Germany	40	PhD	Germany	1992	KFW	Director of KFW Office	6
3	Mazen M.Nuri	Palestine	45	MSc Env. Eng.	Jordan	1988	PECDAR	Project Develop. Manager	20
4	Ghassan Madieh	Palestine	39	MSc W.Res. Eng.	UK	1995	UNRWA	Field Sanitary Engineer	7
5	Nadim Melhim	Palestine	41	MSc W&WW Eng.	USA	1994	GTZ	Director	15
6	Johny Theodory	Palestine	46	MSc Water Eng.	Palestine	2000	UNDP	Projects Manager	14

Eng.: Engineer; Dep.: Department; Env.: Environment; Univers.: University; W.: Water; WW.: Wastewater; Mech.: Mechanical; Lab.: Laboratory; Dev.: Development; Technolo.: Technology; Dir.: Director

الخلاصة

عوائق وحوافز استخدام تكنولوجيا معالجة المياه العادمة اللاهوائية في منطقة البحر المتوسط

بناءا على تقرير للبنك الدولي " التحدي الأكبر في قطاع المياه والصرف الصحي في العقدين القادمين سيكون إنجاز معالجة المياه العادمة بأقل تكلفة والتي بنفس الوقت أيضا ستسمح بإعادة استخدام المياه المكررة لأغراض الزراعة والصناعة. الهدف الرئيسي لهذا العمل هو البحث في عوائق وحوافز استخدام تكنولوجيا معالجة المياه العادمة اللاهوائية في منطقة البحر المتوسط.

ولقد تم تنفيذ طريقة البحث بواسطة توزيع نموذجين من الأسئلة، الأول للمحترفين في قطاع المياه العادمة والثاني للممولين، بواسطة البريد الالكتروني والفاكس ، أو بواسطة المقابلة الشخصية لعدد من الأكاديميين والفنيين والإداريين في عدد من دول منطقة البحر المتوسط أو دول تحمل مناخ المنطقة (فلسطين، الأردن، اليونان، ايطاليا، تركيا، اسبانيا و المغرب).

ولقد أظهرت النتائج بأن المسألة الرئيسية لاستخدام تكنولوجيا معالجة المياه العادمة اللاهوائية في منطقة البحر المتوسط ليست البحوث، التصميم أو الانشاء، وانما الخبرة في التشغيل. وبسبب النقص في الخبرة العملية والثقة في هذه التكنولوجيا مهندسو التنفيذ يفضلون عدم المخاطرة في تنفيذ مثل هذه المشاريع. وحسب نتائج نماذج الاسئلة، أغلب المحترفين (54.3%) يعتقدون بأن المجتمعات لا يتم اعطاؤها الدور المناسب في عملية اختيار تكنولوجيا معالجة المياه العادمة، وكذلك معظم المحترفين (52.9%) والممولين (83.3%) أجابوا بأن المؤسسات التعليمية ليس لها أي دور في صنع القرار في عملية اختيار تكنولوجيا معالجة المياه العادمة.

وأيضا فقد أظهرت النتائج بأن دور الممولين والدول المانحة في اختيار تكنولوجيا معالجة المياه العادمة يمكن وصفه بالتساوي على أساس ارشاد (35.3%)، فرض (29.4%) و مشاركة (26.5%). هذا يدل على أن الممولين ليس لديهم نفس السياسة. وايضا (50%) من الممولين الذين تمت مقابلتهم أخبروا بأنهم يقومون باختيار التكنولوجيا المعمول بها في بلادهم.

استخدام تكنولوجيا تنقية المياه العادمة اللاهوائية كمرحلة اولى مع تكنولوجيا أخرى هوائية، تعتبر الأكثر ديمومة وتعطي النتائج المرجوة، ويعتقد أن هذه التكنولوجيا من الناحية الفنية والمالية يجب أن تكون مشمولة في مجالات تنقية المياه العادمة. وكخلاصة عامة، أهم عامل يجب أخذه في عين الاعتبار أثناء اختيار تكنولوجيا معالجة المياه العادمة هو التكلفة التشغيلية، حيث أن (100%) من المحترفين والممولين الذين تمت مقابلتهم أجمعوا على هذه النقطة. ولذلك يوصى بتدريب المخططين والمصممين وصناع القرار والعلماء الاجتماعيين وممثلي المنظمات الأهلية وذوي العلاقة على استخدام أنظمة معالجة المياه العادمة اللاهوائية. وكذلك يوصى بتوزيع كافة الأدوار الخاصة بعملية اختيار التكنولوجيا على أصحاب العلاقة كل في تخصصه وقدراته.