ASSESSMENT OF BEST AVAILABLE TECHNOLOGIES (BAT) FOR WASTEWATER TREATMENT AND REUSE IN RURAL/LOCAL AREAS IN SOUTH MEDITERRANEAN COUNTRIES

Version	Document Title	Author	Review and Clearance
1	ASSESSMENT OF BEST AVAILABLE TECHNOLOGIES (BAT) FOR WASTEWATER TREATMENT AND REUSE IN RURAL/LOCAL AREAS IN SOUTH MEDITERRANEAN COUNTRIES	Charbel Rizk	Hosny Khordagui, Stavros Damianidis and Vangelis Konstantianos

.....Water is too precious to Waste

TABLE OF CONTENTS

ACRONYMS

BAT	Best Available Technology
BOD	Biochemical Oxygen Demand
CAPEX	Capital Expenses
CW	Constructed Wetlands
EU	European Union
MOE	Ministry of Environment
NTS	Natural Treatment Systems
OPEX	Operating Expenses
RBC	Rotating Biological Contactor
SAT	Soil Aquifer Treatment
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

Executive summary

The purpose of this report is to present and discuss Best Available Technologies (BAT) for wastewater treatment and reuse in rural areas. Most wastewater treatment technologies are suitable for rural areas. The report defines the characteristics of rural areas that are applicable to most rural areas in the Partner Countries (PCs). These characteristics will be cross-matched with the specifications of the wastewater treatment plants in order to select the appropriate treatment process, technology and treatment train.

A short review of the specification of wastewater treatment technologies is presented in the report. The reviewed technologies include conventional mechanical treatment systems, natural treatment systems and advanced membrane bioreactors. Criteria relating to suitability of use in rural areas are highlighted. Tables cross-matching the specifications of wastewater treatment with characteristics of rural areas help identify the most suitable technologies for rural areas.

The report comes to the conclusion, however, that there is no one technology that suits all conditions. This is due to the high variability of conditions in the different PCs and even in the same PC. Land availability and public acceptance are two major criteria that affect the choice of process. Consequently, a selection process has been devised in order to help PCs select the BAT that most suits their conditions.

As a general recommendation, all things being equal, it is advisable to choose the cheapest technology in terms of capital, operation and maintenance cost. In addition to lowest cost, the technology that requires the least skills in management should be selected. Natural treatment systems are the cheapest, least skill requiring technologies. These technologies, however, require significant amounts of land (between 3-5 m2/PE), which might not be available.

As relates to wastewater recharge, three systems exist: infiltration basins, injection wells in the vadose zone, and direct injection wells in the aquifer. Of the three technologies, infiltration basins are the most suited for rural areas. Injection wells require skilled knowledge to operate and maintain and accordingly not suitable for rural areas. Injection wells, although needing less skill to operate will still need proper knowledge of the local hydrogeology and an appropriate monitoring system for the treatment station providing the treated effluent for recharge as well as the recharge system.

Irrigation is one the main reuse options for treated wastewater. Drip irrigation can also provide additional treatment to the wastewater effluent through the removal of four log units of microbial contaminants. In reusing wastewater for irrigation, care should be exercised in ensuring that farmers using the treated sewage are protected from contamination through either, the use of personal protection gear, the disinfection of treated sewage or the use, where possible, of irrigation techniques that minimize contact with treated effluent such as drip irrigation or sub-irrigation. In case where the planted crops cannot be irrigated using drip, contact with wastewater in furrows or with aerosols, in the case of sprinkler irrigation, should be minimized as much as possible. Farmer, and crop handler protection can be improved through a comprehensive and preventive medical coverage protocol including vaccination.

Finally, a key factor for the success of wastewater treatment and reuse projects is the involvement of the beneficiaries in the decision making process. Community awareness and involvement in the design, and selection of technology is crucial to the success of the project. Community involvement ensures proper understanding of needs and local capacities and guarantees ownership of the system. Projects have failed and stations have stopped operating not because of treatment and reuse technology selection but because of lack of understanding of the capacity of communities to manage and operate the system due to the lack of skills and to cover the required operation and maintenance costs.

Introduction

This report is an assessment of wastewater treatment and reuse technologies that are suitable for rural areas of the partner countries (PCs). It is based on a review literature and some feedback from stakeholders in PCs. The study was commissioned based on the requests of PCs for a tool to help them select the most appropriate technology that fits their national context for wastewater treatment and reuse in rural areas. Although the study will provide insights into the technologies for wastewater treatment and reuse in rural areas but since conditions vary from one PC to another and from one region in the PC to another, its main objective is to instill a selection process and methodology to be sued for the selection of wastewater treatment and reuse technologies

The assessment reviews best available technologies (BATs) currently used for the treatment of wastewater and develops guidelines for the selection of the BAT. These guidelines will be based on the characteristics of the technology itself and of rural areas. Cross-matched, these characteristics will narrow down the choices for appropriate wastewater treatment and reuse technologies to be used in a specific country context. This will help the PCs choose systems that produce treated water with the lowest possible cost per cubic meter and the highest possible treatment efficiency for the selected reuse with a technology that functions under local conditions and is accepted by the local community. It will help them likewise; select the most appropriate reuse technology fitting their local context.

Most of the partner countries, especially Tunisia, have started building urban wastewater treatment plants since the early 60s. However, most of these countries lag behind when it comes to treatment in rural areas. Outside main urban centers, one can safely say, that wastewater is not being treated properly. Most villages and remote areas rely on unsanitary septic tanks and wells, which lead to contamination of soil and groundwater aquifers through sewage seepage.

Reuse of treated urban wastewater started in parallel with the construction of wastewater treatment plants (WWTP). Irrigation perimeters were setup and supplied with treated wastewater. The farmers accepted to irrigate their crops using treated wastewater only when fresh water and/or sufficient rainfall were not available. If fresh water and rainfall are accessible and available in quantities that can cover the irrigation needs, then farmers will seldom resort to the use of treated wastewater in watering their crops. Consequently, there is a need for a detailed appraisal of local conditions before initiating a reuse project.

Attempts at groundwater recharge with treated sewage were not very successful in the PCs. Officials and decision makers, in general, are worried of using treated sewage for replenishing aquifers from fear of contamination. The lack of knowledge of local hydrogeology is also a barrier to aquifer replenishment.

The selection of an appropriate treatment and reuse technology is based, not only, on engineering criteria but on other, sometimes more important, variables such as social acceptability, economics, climate, skills, cost, etc. These selection criteria will be developed and discussed in this review.

Wastewater treatment and reuse technologies have been used since the late 1800s. These technologies have been engineered and re-engineered and their performance tested and improved. Several technologies exist, each differing in processes, spatial footprint, power requirements, ease of use, treatment capacity, social acceptability, climate adaptability, costs of operation and costs of maintenance.

Success or failure of wastewater treatment projects, has rarely been related to its engineering (design and construction) but to other external factors such as the availability of lifetime financing for the operation and maintenance of the facility, the level of expertise needed to operate the plant, the close availability of spare parts and technically trained personnel that can intervene in a reasonable time limit to repair any malfunctions, local sanitary habits and customs, etc… The technology selection process needs to take into careful consideration among other criteria, the social, economic, educational and financial aspects of the served region and population along with the technical specifications of the WWTP. Local populations need to be closely informed and involved in the decision making process in order for the project to go through without opposition.

An assessment by the Lebanese Ministry of Environment through the EU funded MSC-IPP Project[1] of 44 donor funded small scale wastewater treatment plants in Lebanon has shown that only 5 were operational. Some of the plants have been abandoned before finalization of construction and the rest are malfunctioning mainly due to lack of sustainable funds and skills of operators. The lack of appropriate funding averted some municipalities from purchasing back-up generators to ensure 24/7 operation and maintenance of pipes, grids, tanks, pumps and the purchase of chemicals such as chlorine for disinfection. In the case of Lebanon, it is to be noted that the initial investment for the construction of the plants has been provided by external donors mainly USAID, the operation and maintenance costs, however, have been left to the municipalities. It can be concluded form the above study that the main factors that have affected the performance of the plants where related to financing and skills more then to engineering.

For the purpose of this assessment, the selected technologies for wastewater treatment and reuse including ground water recharge and irrigation have been pre-screened to fit a rural context where rural areas are defined as an underdeveloped remote community with limited access to adequate fresh water resources for basic needs.

Complete project success can only be achieved if national policies accompany local actions. Consequently, this assessment will include guidelines for including wastewater treatment and reuse in rural areas in national policies, strategies and IWRM management plans.

Finally, this review does not aim to present a definitive answer to which is the most appropriate technology for wastewater treatment and reuse in rural areas; the variability among PCs is too high for that, but more of a logical analytical process for selection based on criteria selected for the chosen locality and the technology.

[1] Ministry of Environment (MOE). 2004. The Inspection of Rural Wastewater Treatment Plant -Draft Final Report. Beirut. 2004

1 Characteristics of rural areas related to wastewater treatment and reuse

1.1 SCOPE

The scope of this section is to define the characteristics of rural areas that have a direct bearing on wastewater treatment and reuse. These characteristics are variable among PCs and do not necessarily apply to all of them.

1.2 INTRODUCTION

For the purpose of this assessment, rural areas are considered as: "areas with limited access to fresh water and lack adequate wastewater treatment facilities".

A set of criteria of relevance to rural areas and of significance to the selection of the best available technologies for water wastewater treatment in these same areas has been selected. It is of utmost importance to understand local conditions before initiating a wastewater treatment and reuse project and selecting the most appropriate technology. Failing to do this has resulted in total breakdowns of sewage plants. The selected criteria are listed below.

1.2.1 Extremely variable population size

Rural areas are subject to yearly variations in population size. The number of people changes with seasons. Summers usually witness migrations from cities to villages with multifold increase in the number of residents and consequently, wastewater flows. Treatment systems have to be able to absorb some fluctuations in flow.

1.2.2 Relatively low level of education

Rural populations have mostly low education levels and low access to information. These populations are not frequently targeted by awareness raising campaigns. Education and awareness are key factors that influence the acceptance of wastewater treatment and reuse systems. Understanding the need for and functioning of WWTP is crucial for its acceptability by the local population. Consequently, there might be a need for a substantial communication and awareness raising efforts prior to embarking on treatment and reuse project.

1.2.3 High poverty and low income levels.

In rural areas, the main livelihood stream is agriculture accompanied by other income generating side jobs. Income is low tending towards poverty. Ability to pay for service is restricted.

Consequently, and in the case were subsidies have not been foreseen by the government to cover the CAPEX and OPEX of treatment systems in rural areas, it is important to choose a low cost technology specially as relates to O&M. The initial investment costs can be covered by the national budget or through grants from international organizations and donors. O&M costs, however, are usually born by the users with subsidies from central governments.

1.2.4 Clustered and/or spread dwellings

Houses or dwellings in rural communities can be clustered close together or spread over a vast area of land. Dwellings are usually single thus refurbishment works are easy. Dwellings can be spread or concentrated. Treatment technologies have to be selected to fit the spatial distribution of dwellings especially when sewage networks are non-existent.

1.2.5 Low access to services and sanitation

Rural areas have, in general, low access to services and sanitation. Infrastructure for water distribution, sewage collection, and treatment, is practically non-existent. The lack of infrastructure, specially, for wastewater conveyance has a direct impact on the selection of wastewater treatment systems and technologies specially when the dwellings are not concentrated in one cluster but are distantly spaced. The cost of the wastewater collection systems can amount to 80% of the sewage treatment and collection costs, consequently it is important to evaluate the economic value of central vs. decentralized treatment systems when the piping infrastructure does not exist.

Access to power is highly intermittent in many places. Treatment systems for rural areas should have a very low reliance on power.

1.2.6 Higher access to land areas then urban areas

Rural areas have a relatively high access to privately owned but cheap land or freely available state or local government controlled land. If land is available then the spatial footprint of the technology will become irrelevant otherwise the choice becomes restricted to mechanical systems.

1.2.7 Local habits and beliefs don't always match treatment systems

Sanitation habits might negatively affect the operation of treatment plants. High BOD levels resulting from wastewater being mixed with animal waste and blood negatively affect the treatment capacity of wastewater treatment plants. These plants are usually not designed to absorb levels of BOD that are higher than municipal wastewater. In one of the MENA countries the villagers used to pour caustic soda in the waste water pipes to clean them. At every cleaning routine caustic soda flows out to the wastewater treatment plant, a trickling filter, and completely stops it by killing the micro-organisms especially grown to treat domestic wastewater.

In countries were irrigation with untreated wastewater is still practiced, farmers have resorted to breaking the inflow pipes to the treatment station to use the wastewater for irrigation if they are not provided with an alternative solution.

It is of critical importance, for the wastewater plant designer, to properly inform himself of local needs, practices and habits that will affect the choice of the WWTP.

1.2.8 Immediate need for wastewater byproducts

One of the advantages of rural areas is the direct need of wastewater byproducts such as treated water for irrigation and nutrients found in the wastewater and sludge. The main economic stream in rural areas is agriculture. There is no need for transport and expensive conveyance structures. Treated water and extracted nutrients can be used locally.

The precipitation in the MENA countries varies between regions. In many PCs the irrigation season extends for 12 months. Consequently, there is no need for groundwater recharge works since all the treated wastewater is needed for irrigation.

The selected treatment systems should be able to produce treated water for irrigation of restricted crops, and keep a level of N and P in the water that is enough to support plant growth without causing pollution.

1.2.9 Low access to technology and resident skilled staff

Access to skilled labor, technology and its accompanying services and spare parts is very low in rural areas. Rural areas are most of the time located far from city centers and consequently technology and technical skills are far from reach. It is rare for highly skilled technicians to accept residing in a village unless the financial rewards are high but consequently out of the reach of the local community.

Operating a wastewater treatment plant requires advanced skills and a strong knowledge of the involved biochemical and physical processes. It also requires routine and emergency maintenance needing special parts and skilled labor.

Inspection and regular monitoring of performance by the relevant state agency is weak due to the long travel times and the lack of adequate human and financial resources with the consequent drop in plant operation levels. For the same reason, delegating maintenance to private companies tends to be an expensive option.

Consequently, "low tech" should be high priority on the selection criteria list for WWTP fit for rural areas.

1.2.10 Might be close to ecologically sensitive or high value heritage areas

Rural areas might be close to protected forests, wetlands and the like, landscape expanses of high value, historical and cultural sites, etc. The selected technology needs to provide adequate treatment so as to ensure the protection of these sites, reduce the visual disturbance or foul odor in the landscape and if possible contribute to the enhancement of biodiversity and the beauty of nature.

1.2.11 High temperature

Farm activities happen mainly in the summer month when temperatures can reach highs of 40^{o}C and above. Protection gear is essential for preventing diseases due to contact with wastewater. Due to high temperatures and the fact that protection gear is mainly made of plastics that heat up, famers become highly reluctant to wear it.

Centralized or decentralized? The benefits of decentralized wastewater management in rural and peri-urban environment

(Case study from: Water Reuse in the Arab World: from principle to practice. The World Bank, May 2011)

Recent studies in Egypt have indicated that for economic reasons, it may not be possible to provide sewerage facilities for all residents of rural and peri-urban areas—either now or in the near future. As a result, the Government of Egypt has begun considering refocusing its wastewater management strategy from the construction and management of regional sewerage systems to that of decentralized wastewater treatment facilities. Given the fact that in the near future, increasing demands are being made on freshwater supplies, it is clear that decentralized systems will increase opportunities for localized reclamation/reuse. Unbundling sanitation projects into smaller-scale projects can bring benefits at an affordable cost to those in greatest need. In the case of rural Egypt, decentralization enables the division of investments into more realistic and manageable components. From a technical perspective, decentralized sewerage is also appropriate in areas with flat terrain and a high groundwater table such as the Nile Delta region. Dividing such areas into self-contained zones eliminates the need for expensive pumping stations and interceptor sewers required to serve the whole area with a regional sewerage system.

2 BAT for wastewater treatment and reuse in rural areas

2.1 SCOPE

This section covers the review of pre-selected wastewater treatment and reuse technologies currently available on the market. Sewage treatment and reuse technologies fitting the rural context of PCs have been selected and reviewed.

2.2 APPROACHES TO WASTEWATER TREATMENT AND REUSE

There are two approaches to deal with sewage so that it does not pollute its receiving body and its useful byproducts can be safely and most efficiently reused. These approaches are:

- Separation of waste at the source
- End of pipe treatment of waste

The "At the source" approach aims at reducing the volume of wastewater generated by reducing the amount of fresh water that is introduced in the waste cycle an improving the recyclability of sewage. It also intends to decrease the biochemical and microbial load of wastewater through the separation of the different components such as separating urine (yellow water) from feces and/or separating gray from black water. This approach conserves freshwater and reduces the need for complex and sizeable sewage networks and wastewater treatment stations. It moreover improves the reusability of the waste through the reduction, in the effluent, of harmful constituents and the enhancement of the extraction potential of added value components such as agriculture fertilizer and compost.

The "End of pipe" approach relies on the treatment of mixed wastewater effluents (Black or gray water) using different types of technologies to reduce biochemical and microbial loads in sewage. End of pipe treatment requires larger more expensive facilities and achieves less extraction of components relative to separation at the source. End of pipe treatment systems can be categorized into:

1. Mechanical and
2. Non-mechanical or natural

The different approaches will be presented and analyzed for their relevance to treatment and reuse of wastewater in rural areas.

2.3 DESCRIPTION OF AVAILABLE TECHNOLOGIES [3-4].

2.3.1 Separation at the source

2.3.1.1 Dry and urine separation toilets (yellow water)

Dry toilets or composting toilets collect a mix of urine and feces in a pit, dug under the toilet seat or a bit offset. Water is not added to the system for flushing and consequently, a substantial amount of water is conserved. Collected waste ferments and can be used as soil conditioner and fertilizer compost.

Urine separating toilets can be dry or wet toilets that separate urine from feces. Urine and feces are split to different containers and can be used immediately as fertilizer. Separating toilets reduce the contamination of urine with pathogens normally found in feces thus eliminating the need to disinfect urine prior to reuse. Waste from dry and separation toilets does not need treatment. These types of toilets have been greatly improved and their use is now possible even in buildings in urban areas. They are a very good option for rural areas.

Bearing in mind that 45% of domestic water use is in flushing toilets; using dry toilets will almost double the amount of water that would be available for other uses. Dwellings in rural areas usually consist of single homes and not buildings, consequently re-piping the sanitary system to fit a dry or separating toilet is relatively easy. Acceptability of urine separation and dry toilets in rural areas seems to be satisfactory as reported by the Zero M project (http://www.zer0-m.org/ CD-ROM Video). Comparison of costs for separation at source or end of pipe treatment systems depend on the existing conditions for sanitation and the need for wastewater by products.

2.3.1.2 Gray Water

Gray water is wastewater that does not contain fecal mater. It is the collection of wasted water from the bath/shower, washbasin and kitchen sink. These fixtures are piped separately from the water closet and bidet. Gray water has a low microbial load and its use under specific conditions such as restricted irrigation can be direct without need for treatment. Systems have been developed to allow the collection of gray water without the need for re-piping the residence. Dwellings in rural areas usually consist of single homes and not buildings, consequently re-piping the sanitary system so that grey water can be separated from black water can be relatively easy. If a new construction is being planned it is judicial to install the drainage piping in such a way as to allow gray water separation. Separating gray water from black water will reduce the cost and size, in terms of pipe diameters, of the sewage network.

2.3.2 End of pipe solutions

For the purpose of this assessment end of pipe wastewater treatment technologies will be subdivided into 2 main categories:

Conventional treatment system: Power-driven mechanical systems for the treatment of wastewater.

Natural treatment systems: Nature driven wastewater treatment with minimal power input mainly for pumping

2.3.2.1 Treatment trains

A treatment train is a series of wastewater treatment processes each with a specific waste removal function. A treatment train can be constituted of a preliminary treatment process made of a bar screen for the removal of large objects, a grit chamber, a primary treatment system for the settling of solids, a secondary treatment process for the removal of organic matter and a tertiary treatment refining the treated wastewater for various reuses. Different technologies and processes can be combined in a train to achieve the required treatment level.

2.3.2.2 Preliminary or pre-treatment

Preliminary treatment also known as pre-treatment consists of the removal of large size and very coarse debris using different types of bar screens. This is customarily followed by a grit chamber to remove settling inorganic particles. In some instances preliminary treatment is the only treatment process in the WWTP.

2.3.2.3 Primary treatment

Primary treatment is the settling of about 60% of the TSS found in sewage and 30% of BOD_5 in the wastewater. Settling tanks (clarifiers) are used to reduce the solid load of wastewater. Certain types of primary treatment systems, such as septic tanks, can achieve acceptable treatment levels when the criteria of discharge in the receiving medium are not stringent.

2.3.2.4 Secondary treatment

Secondary treatment is the step that follows primary treatment. Most treatment stations will achieve secondary treatment levels, which consist of the breakdown of mostly soluble organic matter that is still in the wastewater after passage through a clarifier. The process relies mainly on the biological activity of mostly aerobic and anaerobic bacteria found in the wastewater. Different systems and technologies exist. The wastewater treatment technologies that are suitable, in general, for rural areas will be detailed hereafter. The final choice of technology will depend on the local context. These systems have been categorized into conventional mechanical treatment systems and natural treatment systems.

2.3.2.4.1 Conventional mechanical treatment systems

Mechanical treatment systems have been put in operation decades ago in urban centers in particular. They are the most used wastewater systems in the world. They have been tried, tested and their performance and efficiency improved over the years. The first treatment systems date from the early 1900s.

Mechanical treatment systems require the construction of structures such as concrete or plastic tanks. They necessitate the continuous input of electrical and mechanical power. Mechanical systems can be designed to treat wastewater flows of large cities, individual dwellings and any size population or PE load in between. Their spatial footprint is relatively low. High initial and O&M costs are incurred and trained technicians are required to properly run the treatment plant, otherwise breakdowns occur and the treatment process fails.

Mechanical treatment systems cannot absorb extreme fluctuations caused by seasonal changes in populations in certain rural areas. These systems are not easily adapted to changes or modifications of wastewater flows and composition. Sludge is produced in the process and needs to be treated and properly disposed of. Performance of all selected systems can reach acceptable removal values and effluent concentrations for discharge and reuse if they are properly designed.

Mechanical treatment systems are socially accepted and understood by the public at large and the decision makers.

These systems can only receive wastewater effluent after it has been through preliminary and primary treatment. They can achieve treatment levels required by any discharge standard except for the removal of nitrates, phosphates and some microbial elements, which will require the addition of precipitating chemicals and disinfecting agents or radiation. For reuse in irrigation, and since nitrates and phosphates are used as fertilizers in agriculture then there is no need for their removal. More stringent standards, however, are required for other reuse options such as groundwater recharge and accordingly tertiary treatment levels might be required.

2.3.2.4.1.1 Activated sludge.

Most commonly used mechanical secondary treatment system. It relies on floating aerobic bacteria in the wastewater to degrade organic matter activated by recycling some 20% of the active sludge. Aerobic conditions in the wastewater are produced by pumped air from blowers or through mixing with atmospheric air. Activated sludge treatment can effectively remove suspended solids, organic matter, and some pathogens. BOD_5 removal can reach 95%. Sludge production is high and needs a accompanying sludge treatment system. Activated sludge treatment plants can be, to a certain extent, built in a modular fashion to accommodate changes in flows. The system however does not function well with extreme flow fluctuation ranges. Operation requires skilled technicians. Noise is generated by blowers or mixers. CAPEX and OPEX are relatively high. Socially, it is the most understood and accepted system. Extended aeration is a variation of activated sludge suitable for small volumes of waste.

2.3.2.4.1.2 Rotating Biological Contactors (RBC)

Rotating biological contactors (RBCs) are rotating discs partially submerged in wastewater. They provide secondary treatment through a film of bacteria or biofilm growing on the discs. The discs are rotated at a speed of 1-2 rpm for sequential wetting and aeration cycles. RBCs have operating problems mainly caused by mechanical failures of shafts and bearings. RBCs can be used for small and large communities. They might have odor problems and freeze in extreme cold weather if not covered. BOD removal rates vary between 80 to 95% depending on loading rates. RBC can be upgraded easily. O&M is relatively simple and not requiring skilled labor. CAPEX and OPEX are acceptable.

2.3.2.4.1.3 Trickling Filters

A trickling filter is a secondary biological treatment system that consists of a tower filled with stones or plastic composites balls where a bacterial biofilm grows. Wastewater is delivered through a rotary distribution system on top of the tower, it trickles over the media where it gets treated by bacterial processes and is collected from the bottom. For aerobic filters, air flows (natural or pumped) through the tower and creates an aerobic environment. The performance and efficiency of the filter depends on the type of the material used to pack the tower and the height of the tower. Control of the treatment process is not exact. Operation needs constant supervision by operator. Trickling filters can be used for single dwelling and small groups; they have a low footprint. BOD removal can reach 85%.

2.3.2.4.1.4 Aerated lagoons

Lagoons are considered as natural treatment systems. The addition of surface aerators, to increase efficiency, necessitates the input of power and classifies these systems, for the purpose of this assessment, under mechanical systems. Aerated lagoons are made of earthen ponds with the addition of a surface aerator to improve the efficiency of mixing ambient air and create aerobic conditions for the degradation of waste. O&M is relatively easy. The area needed for aerated lagoons is relatively smaller than oxidation ponds but still relatively high compared to conventional mechanical treatment

2.3.2.4.1.5 Membrane filtration systems

Membrane filtration systems are highly sophisticated treatment technologies that can achieve vey high treatment standards. They are made of specialized membranes of different size pores with the finest being reverse osmosis unless there are no other possible solutions these systems are not suitable for rural areas. They require highly trained operators to run them, extensive pre-treatment and high power input. They can, however, be portable on trucks and can serve as a mobile treatment unit.

2.3.2.4.1.6 Packaged aerobic mechanical treatment plant

Packaged mechanical treatment plant comprising several treatment processes in one small tank and suitable for 4 to 20 people are available on the market. Aerobic plants require power to run a blower.

2.3.2.4.2 Natural treatment systems (NTS)

Natural treatment systems rely solely on natural processes without any mechanical input to treat wastewater. They use natural mixing with ambient air, sunlight, photosynthesis, root zone aeration, absorption, adsorption and natural decay processes to achieve reduction in organic mater, nitrates, phosphates and pathogens.

They are able to treat municipal and industrial sewage up to required standards of discharge. They can be designed to operate as the principal treatment facility or to polish the discharge of mechanical treatment systems especially in the removal of phosphates and nitrates (tertiary treatment). Sludge production quantities are variable. Some systems produce a fair amount of sludge others none and are capable of drying sludge at more then 10 times the efficiency of natural air drying systems.

Natural systems are easy to maintain and operate and need no skilled labor. Although initial costs might be equivalent to mechanical systems, O&M costs are minimal to non-existent.

Some systems require pre and preliminary treatment others can absorb raw sewage. Constructed wetlands, for example, can be designed with a settling tank for primary treatment or to directly take raw sewage.

The footprint of NTS is high and large areas of land are required for their construction. NTS can under long hydraulic loading rate times, achieve treatment of wastewater to tertiary treatment standards.

2.3.2.4.2.1 Septic tanks with filter fields

Septic tanks are watertight tanks made of concrete, plastic or fiberglass. They cater mainly for individual or small group dwellings. The tanks are designed to allow the settling of around 60% of the BOD. The tanks should be emptied of sludge every 6 month to one year otherwise sludge will transform into a solid cake that will fill a major part of the tank and reduce its storage volume. The septic tank needs to be followed by a treatment system. The most used system, when the geology allows, is a filter field. Filter fields are made of a perforated pipe network that spreads the effluent of the septic tank over an area of land with a certain thickness of soil or sand. There are several configurations of filter fields. They can be immediately installed on existing soils, if the geology permits, or constructed in dug waterproofed and sand filled surfaces. Treated wastewater can be collected and reused or left to trickle through the soil layers. Passage through thick enough soil and/or sand ensures treatment of the waste.

2.3.2.4.2.2 Lagoons

Lagoons are earthen ponds dug in soil at different depths depending on the type of conditions that the lagoon is designed for: aerobic, anaerobic and facultative. Aerobic lagoons are shallow lagoons that encourage the proliferation of aerobic bacteria that degrade organic mater. Anaerobic lagoons are deep thus creating an anaerobic environment. Facultative ponds are of medium depth thus encouraging the breeding of both anaerobic and anaerobic bacteria. Lagoons can be used as main treatment systems or to polish effluent from other systems. If sized properly, lagoons can ensure a good quality effluent. Their performance degrades however at low temperatures and they can be a breeding place for mosquitoes. In countries of the MENA region where temperatures and water evaporation are high, lagoon treatment systems lead to an increased salinity in the effluent. Lagoons can remove an average of 80% BOD.

2.3.2.4.2.3 Constructed Wetlands

Constructed wetlands are sometimes called lagoons with macrophytes. They follow the same principal of lagoons with the addition of aquatic plants and substrate.

Constructed wetlands can be designed in three different models:

1. Open water surface
2. Subsurface horizontal flow
3. Subsurface vertical flow

Intermittent loading has been added as a variation to improve the efficiency of CWs in terms of spatial footprint.

The system requires the construction of a pond or several ponds that are usually dug in earth up to a depth of 0.6m, lined with an impermeable membrane, filled with different grades of gravel (for subsurface and vertical flow wetlands) and planted with selected species of aquatic plants or macrophytes. The macrophytes can be also floating, submerged or emergent.

Constructed wetlands allow high fluctuations in wastewater flows that might be the case in some rural areas witnessing seasonal changes in populations. These systems are highly adapted to changes or modifications in wastewater flows and wastewater composition. CWs have been installed in hot and very cold weathers and they have performed as designed.

Constructed wetland systems are still not well understood and accepted by the engineering community and the general public. It is the mainly due to lack of awareness and weak understanding by the general public of the biological processes that operate in these systems.

Natural treatment system in Jougar, and Gharzouz

The village of Jougar in Tunisia houses a small community of around 750 gas line workers. These workers reside in the village and require wastewater treatment facilities. Land is available around the settlement and consequently a constructed wetland system has been installed. The system is made of a vertical flow wetland followed by a horizontal subsurface flow wetland. The relevant ministry undertakes effluent analysis and treatment is up to standard. The treated effluent is reused in agriculture. The system does not require any power input and practically no maintenance. In a similar location treated wastewater is discharged in the river and indirectly reused by the downstream community.

In the coastal village of Gharzouz in Lebanon, a training center including housing has been constructed. The center can cater for up to 50 resident trainees and is permanently inhabited by 5 people. Trainings are seasonal and consequently the “population” of the training center varies between 5 and 100. During the construction phase, it was decided to install wastewater treatment system. Two price estimates were acquired and the prices were as follows:

- Activated sludge system: 15,000 USD installation and 2000 US$ yearly maintenance contract
- Subsurface flow horizontal wetland: 4000 US$ installation and no maintenance contract needed.

The activated sludge system could not cater for the extreme variability in population, required and the natural treatment system was better fit in the landscape. Consequently the obvious choice was for the NTS. The treated effluent is used to irrigate an olive grove downstream of the wetland. Analysis of the treated effluent has shown removal rates of more then 85% for BOD, and coliforms.

2.3.2.4.2.4 Packaged anaerobic treatment plant

Packaged mechanical treatment plant comprising several treatment processes in one small tank and suitable for 4 to 20 people are available on the market. Anaerobic plants do not require power and can generate biogas.

2.3.2.4.2.5 Anaerobic reactors

Anaerobic reactors do not require power to run. They can produce effluent quality of acceptable standards and biogas. They can serve a wide range of populations starting with single households. Their capital and operating costs are relatively low with the possibility of energy production from the biogas. The flow process in the reactor is delicate and needs skilled operators.

2.3.2.4.2.6 Soil aquifer treatment (SAT).

SAT is a treatment method that relies on the treatment capacity of soils and its constituents to breakdown organic mater in sewage. Wastewater is collected in basins and trickles through the soil layers where different biochemical processes reduce organic matter, nitrates, phosphates and pathogens. Treated wastewater is then pumped using wells for later reuse. SAT requires a very good knowledge of local hydrogeological conditions due in order to avoid contamination of freshwater aquifers. SAT can achieve treatment levels up to drinking water standards. Treatment using SAT depends on the soil absorptive capacity. This capacity might deteriorate over extended use. Consequently, a good monitoring system should be in place in order to avoid environmental and public health accidents. Similar to groundwater recharge, SAT should be carefully considered and well planned in order to avoid contaminating fresh water aquifers with sewage.

Table one: Footprint, CAPEX and OPEX costs of selected wastewater treatment technologies.

System	Land Requirement (m2/inhabitant)	Construction Costs (euro/inhabitant)	O&M Costs (euro/inhabitant/year)
Conventional primary treatment	0.02-0.04	9-15	0.4-0.8
Facultative pond	2.0-4.0	11-23	0.6-12
Anaerobic pond +facultative pond +maturation pond	3.0-5.0	15-30	0.8-1.5
Constructed wetlands	3.0-5.0	15-23	0.8-1.2
Conventional activated sludge	0.12-0.25	31-50	3.0-6.1
Activated sludge +extended aeration	0.12-0.25	27-38	3.0-6.1
Conventional activated sludge+tertiary filtration	0.15-0.30	38-58	4.6-7.7
Trickling filter	0.12-0.3	38-46	3.0-4.6

The figures in the above table vary considerably from one country to another accordingly they should be taken more as orders of magnitude rather then exact costs. The table is meant to show differences between different systems in terms of capital and operating expenses and footprint.

2.3.2.4.3 Tertiary treatment

Tertiary treatment consists mainly of the removal of Nitrates, Phosphates and pathogens using rapid sand filtration, chemicals or radiation. The choice of adding tertiary treatment to the treatment train is dependent on the final use of the treated effluent and on public health protection issues.

2.4 REUSE OF WASTEWATER

Reuse of treated and untreated wastewater dates back to Greek and Roman civilizations. Irrigation and groundwater recharge are the reuse options tackle in this study. Different irrigation techniques exist. We will present and discuss all them from the point of view of suitability to irrigation using treated wastewater. Three techniques exist for groundwater recharge they will also be presented and discussed.

2.4.1 Benefits of REUSE of wastewater

Reuse of treated wastewater has several benefits including:

1. Conservation of fresh water resources for other uses.
2. Reduction in the need for wastewater infrastructure for treatment and disposal of sewage
3. Reduction in the need for nitrate and phosphate removal by the treatment system since these elements have added value in agriculture
4. Reduction of pollution from disposal of sewage into the environment
5. Combating desertification

With all the benefits of reusing treated wastewater in irrigation, there are associated health risks due to contact with reclaimed wastewater. Consequently, it is of utmost importance to make sure that these risks are minimized and monitored.

2.4.2 Irrigation

2.4.2.1 Selection criteria for irrigation projects

Irrigation is one of the main reuse options for treated wastewater. Treated sewage can be used in agriculture to irrigate crops of different types or in landscapes to irrigate golf courses, green belts, reforestation, etc.… Restricted irrigation is the only practice accepted so far in the PCs. Consequently, high cash value crops that are eaten raw cannot be irrigated using treated sewage. This restriction has strong implications on the acceptance of farmers to use recycled water. Treated wastewater is a constant source of water for irrigation unaffected by seasons, weather and recently climate change.

The success of agriculture irrigation projects with recycled water is dependent on the actual need for the water as felt by the farmers. From few visits to agriculture areas in the PCs, it is obvious that famers will use treated wastewater in the following conditions:

1. When freshwater is not enough to cover their irrigation needs
2. It is cheaper from an energy cost point of view to use wastewater as compared to freshwater that might need pumping from deep wells
3. If supplemental irrigation leads to increased yield
4. If using treated wastewater does not restrict the types of crops to be planted
5. If using treated wastewater does not affect sales of produce
6. If wastewater is adequately treated and doesn't pose any threats to public health

From the point of view of farmers, the above criteria are critical in the decision for developing an agriculture irrigation reuse project.

In addition, to the above and from the point of view of the governance structure in place, the following criteria should also be fulfilled:

1. A good understanding of the local pedology and hydrogeology
2. Possibility to enforce laws on crop restrictions, crop handling and public health
3. Capacity to monitor treated water quality, its use by the farmers, its effect on the crops (concentration of harmful compounds and pathogens), its impact on public health, and its impacts on the surrounding environment (soil salinization and clogging and surface and groundwater contamination)
4. Potential to provide treated water of the required quality for the intended reuse.

5. Capability to provide adequate medical protection for farmers, handlers and consumers.
6. Aptitude to develop and implement an information and awareness campaign targeting farmers, and consumers.

If the above criteria were fulfilled then the next step would be the feasibility and cost benefit analysis of the project. Cost benefit analysis for agriculture projects should also incorporate social factors in parallel to financial and economic. Most of the PCs subsidize irrigation water provided to farmers. Collected fees rarely cover the cost of the irrigation operation. Consequently, it is rare to find an irrigation project with a positive feasibility study.

Landscape irrigation using reclaimed wastewater is an easier project to achieve than agriculture irrigation. There is no produce to be consumed by people; human contact with wastewater is reduced compared to agriculture irrigation, reclaimed quality standards are lower then those required for agriculture irrigation, there is no social opposition and lower need for law enforcement.

The following box present baseline scenarios developed by the World Bank for reuse of wastewater in irrigation.

The World Bank Guide for Planners for Reuse of Wastewater in Agriculture (Khouri et al. 1994) suggests the following baseline scenarios for evaluation of water reuse for irrigation:

1. **No existing irrigation:** Where there is no existing agriculture or the only irrigation is from rainfall, benefits would be the introduction of agricultural production or more production from existing farms. Costs would include those for (a) setting up the irrigation system, and (b) transporting and treating the wastewater (but only the cost in excess of that required to discharge it into receiving waters). Where sound environmental disposal is enforced, the cost of treatment for reuse may be less than that for direct discharge, in which case the value for (b) would be negative--a benefit.
2. **Existing irrigation**: Where wastewater can provide supplemental irrigation, it might permit a shift to more profitable crops (for example, from grains to vegetables) or longer growing seasons. The additional revenues of this expansion minus its cost would be the benefit. Wastewater-associated costs would be the same as those in (1).
3. **Existing irrigation**: Where wastewater can substitute for scarce freshwater sources, a no-action scenario would imply (in the medium or long term) reducing or abandoning irrigated areas to increase the drinking water supply for domestic consumers; the crop production saved would be the benefit. Wastewater-associated costs would be the same as those in (1).
4. **Existing, uncontrolled wastewater irrigation:** This is a situation quite often encountered in developing countries. Shifting to a controlled operation using treated wastewater would result in public health and environmental improvements. These improvements should have a major weight in project development, even if they are difficult to quantify. Two situations might further increase the overall feasibility of the controlled-reuse option. First, land application of treated effluent might be part of the least-cost wastewater treatment alternative. Second, irrigating with treated wastewater might lead to the production of more profitable crops.
5. **Existing or new freshwater irrigation of public parks or greenbelts**: Where this is the case, shifting to wastewater irrigation would be justified if it cost less than wastewater discharge to surface water and/or if it provided environmental benefits equal to the cost of reclamation and irrigation investments. These could be quantified or at least described qualitatively. Another benefit would be the value of the potable water saved, which could be substantial in cities where water is scarce.
6. **No existing irrigation, wastewater application as land treatment:** In this situation, there is no existing need or demand for irrigation water. The, least-cost wastewater treatment alternative, however, would include the disposal of treated wastewater on land. The cost of the entire system, including irrigation, should be included in wastewater-associated costs. Benefits from irrigation could enhance the feasibility of wastewater treatment. (Khouri et al. 1994)

2.4.2.2 Reclaimed wastewater standards for irrigation

The 2006 WHO guidelines for the reuse of wastewater encourage countries to set their own standards for wastewater to be reused in irrigation. The “multiple barrier system” introduces a margin of maneuver for setting acceptable limits for the biochemical and pathogenic contents of wastewater effluent from WWTPs. The new guidelines rely on “barriers” for the removal of pathogens. These barriers include treatment processes, post harvest handling of produce to allow for microbial die off, washing, medical protection, etc...

2.4.2.3 Wastewater treatment technology for irrigation

The types of crops that can be irrigated using reclaimed wastewater are dependent on the level of treatment achieved by the WWTP. Crops eaten raw require tertiary treatment of wastewater, mainly disinfection, for the removal of pathogens. Wastewater, however, can be treated to primary and secondary levels and used in the irrigation of forests, golf courses, field crops, and crops used for energy production through biomass. Certain irrigation techniques can contribute to the reduction of pathogens in the treated wastewater. Drip irrigation, for example, can reduce pathogens by 4 log units. In planning irrigation projects with reclaimed wastewater two scenarios present themselves:

1. Existing WWTP
2. WWTP to be constructed

With existing treatment plants, two choices exist:

1. Restrict the crops to the treatment capacity of the plant
2. Upgrade the plant through addition of treatment processes or changes in the technology so that it can deliver higher treatment levels

With planned treatment plants the design of the plant and the selection of technology will depend on the choices made for irrigation.

2.4.2.4 Irrigation techniques

In this section we will approach irrigation techniques from the point of view of reuse of treated sewage. When using treated wastewater it is important to select an irrigation technique that reduces, as much as possible, the health risks to farmers. Most used irrigation techniques are the following:

1. Surface irrigation
2. Sprinkler irrigation
3. Drip irrigation

Surface and sprinkler irrigation methods have a high risk of human exposure through direct contact with the irrigation water in furrows or through aerosols produced by sprinklers. Drip irrigation minimizes human contact with treated sewage. It also reduces pathogens by 4 log units. Drip irrigation can be installed on the surface of the soil or buried underneath. Subsurface drip irrigation (drippers under the soil) eliminates all human contact with treated sewage. Drip irrigation, however, is not suitable for all crops. It also requires technical knowledge by the famers to operate properly. Adopting drip irrigation by farmers who are used to surface irrigation will require capacity building and support. Finally drip irrigation and especially subsurface drip irrigation reduce the need for disinfection of wastewater since human contact is minimum or non-existent.

2.4.2.5 Public health

Farmers in PCs using treated wastewater are highly exposed to microbial risks. Protection gears are rarely worn by farmers. Most farm operations happen in summer when temperatures might exceed 40^{o} C. Plastic boots, masks, head cover and gloves become unbearable when temperatures are high. Consequently, farmers, their wives and their kids in many instances are in direct contact with the irrigation water.

The availability of health protection and preventive vaccination protocols is variable among countries and farmers do not always benefit from them. There is also a lack of awareness, by the farmers, of the potential risks associated with the use of treated sewage in irrigation. Several international organizations have organized health related awareness activities and programs around the use of treated wastewater in irrigation but it seems, that the level of appreciation of the possible hazard is low. Even farmers, who use untreated sewage in some PCs, do not wear any protection gear nor get preventive medical protection.

Farmers using treated wastewater are rarely protected from potential risks of exposure to pathogens. Consequently, and when possible and feasible, it is advisable to disinfect the treated wastewater or use drip irrigation to reduce any risk of microbial infection. If the sewage is not disinfected and if there is contact with wastewater, the famers and their families run the risk of catching diseases of microbial and viral origin.

2.4.2.6 Conclusion and recommendations for irrigation

Based on the above analysis it can be concluded and recommended that in the case of reuse of wastewater in agriculture irrigation, the selection of crop and the irrigation method has a direct bearing on the choice of wastewater treatment technology. Choosing a wastewater treatment technology depends on the type of irrigation (agriculture or landscape), crop type, irrigation technology, and health and environmental safety measures in place. The project proponent should have a holistic picture of the local conditions for the most appropriate selection of technology.

2.4.3 Groundwater recharge

Groundwater recharge is one of the reuse possibilities for treated sewage. Fresh water aquifers, in most PC, are being exploited beyond their sustainable yield. Overexploitation has also led to salt water intrusion in coastal aquifers. Groundwater using treated wastewater has several benefits:

1. Recharge of depleted aquifers
2. Storage of water for future use at lower cost then dams
3. Reduction in the volume of discharged wastewater effluent
4. Reduction in the intrusion of salt water in fresh water aquifers

2.4.3.1 Selection criteria for groundwater recharge projects

The success of groundwater recharge projects is dependent on the following criteria:

1. Acceptance of local population and decision makers
2. Irrigation season less then 12 month and remaining volume of water for recharge.
3. Salt water intrusion in aquifers
4. Very good knowledge of local hydrogeology
5. Possibility to provide treated wastewater with adequate quality for recharge
6. Positive financial feasibility
7. Good comprehensive monitoring system in place

2.4.3.2 Wastewater standards for groundwater recharge

Standards for groundwater recharge vary with the recharge system being used. Infiltration basins overlaying a deep soil layer can contribute to wastewater treatment similar to SAT systems. Good knowledge of the local hydrogeology is essential in determining effluent quality coming from WWTPs. For direct injection, treated wastewater must be of a very high quality. In the USA, Membrane Bio Reactors and Reverse Osmosis is used to pre-treat wastewater before recharge in aquifers.

2.4.3.3 Groundwater recharge technologies

There exist three techniques for recharging aquifers:

1. Infiltration basins
2. Injection wells in the vadose zone
3. Injection wells directly in the aquifer

Keeping in mind the characteristics of rural areas in PCs, it is advisable to select the techniques that are cheapest to install and operate and that do not require highly skilled labor to manage. The only technique that is suitable for rural areas under these conditions is seepage basins. Injections wells require skilled personnel and engineers to build and operate.

2.4.3.3.1 Infiltration basins

Infiltration basins are earthen reservoirs sized based on specific design criteria and used to cause the seepage of treated wastewater into the groundwater aquifers. Although the simplest technique of groundwater recharge, seepage basins need some technical knowledge for properly operating them. There is a need for a good understanding of the local hydrogeology and a good monitoring system for water quality in order to avoid aquifer pollution accidents. The main concern with groundwater recharge with treated wastewater is the fact that contaminated aquifers are not easy to clean. Proper maintenance through cleaning is essential in order to keep the infiltration rates acceptable. In certain cases, several basins are used alternatingly in order to allow for cleanup and maintenance periods.

2.4.3.4 Conclusions and recommendations for groundwater recharge

Groundwater recharge is a wastewater reuse option that can make available additional water over long periods of time. This reuse option needs, however, careful evaluation from several points of view including economic feasibility, risk of environmental and public health accidents, and acceptability. Most decision makers are worried from groundwater recharge with treated wastewater due to fears of unrecoverable freshwater aquifer pollution.

3 Selection Criteria for wastewater treatment technologies

3.1 SCOPE

This section will list criteria that can be used for the selection of the most appropriate wastewater treatment technology or treatment train suitable for rural areas with the possibility to deliver reclaimed water for groundwater recharge. Each criterion will be linked to a generic criterion which it influences.

3.2 ADMINISTRATIVE CRITERIA

3.2.1 procedures and processes:

Required procedures and processes for the construction of wastewater treatment plants influence the selection of technology. Unlike natural treatment systems, mechanical treatment systems are fairly understood by administrators and construction licensing procedures and processes are in most cases existent. Procedure and process influence technology acceptability

3.2.2 Regulatory factors

Similar to procedures and process and due to better understanding of mechanical systems, the regulatory framework for mechanical systems is more evolved then the one for natural systems. When EIA studies are required, natural systems, specially constructed wetlands, have a lower impact on the environment as compared to mechanical systems. Constructed wetlands might even contribute to enhance the environment through habitat creation. Consequently, when regulations stipulate EIA studies it might be easier to select natural treatment systems for quicker and easier licensing. Regulatory factors influence technology acceptability

3.2.3 National and Local management setup and responsibilities

Management systems for wastewater treatment plants have a direct influence on the choice of system. When the responsibility for management of wastewater treatment plants is with central agencies that are located far from urban centers then it is advisable to select a low maintenance system. Due to the need for long distance travel central government supervision of treatment plants becomes lax with the consequent reduction in operation quality. Natural treatment systems are low tech-low maintenance systems. Regulatory factors influence technology need for close monitoring and skilled operation.

3.3 ENVIRONMENTAL CRITERIA

3.3.1 Climate

Rural areas situated in desert climates are subject to wide diurnal variations in temperature. Since most wastewater treatment systems rely on biological processes to treat wastewater, and since the level of activity of microorganism is affected by variations in temperature then it is of utmost importance to select a treatment technology that is not affected by temperature variations. Climate influences the choices of technology.

3.3.2 Ecologically sensitive areas and cultural heritage

The presence of ecologically sensitive areas has an impact on the selection of technology through the need for very precise discharge standards, the smaller spatial footprint and the lowest landscape disturbing construction. Operating and construction noise, power lines, transport of chemicals, parts and labor should also be factored in the selection. Natural treatment systems can have a positive impact on sensitive wetlands through the enhancement and or creation of habitat. An EIA study for the wastewater treatment plant should be mandatory in the case of rural areas that are close to sensitive ecosystems. What applies to ecological areas is also valid for cultural and historical heritage. The selection of technology must take into consideration the need to preserve and protect such heritage.

3.3.3 Hydro-geology

The local geology is a determining factor in system selection. Soil aquifer treatment, for example, requires depths of soil in excess of 15 meters in order to achieve proper treatment of wastewater effluents. Karstic geologies allow for very rapid water infiltration to aquifers. Consequently, care should be taken not to select treatment technologies based on soil transfers. In addition, it is important to ensure proper leakage and system overflow protection in order to prevent aquifer contamination.

3.3.4 Freshwater bodies

The ecological sensitivity of water bodies and the need for their protection has been discussed earlier. The presence of water bodies, however, might encourage reuse. People accept it more if water, even discharged from a wastewater treatment plant is collected from a water stream and not the treatment plant pipe. It feels more "natural". Consequently, technology selection should consider the presence of nearby water bodies in order to improve reuse.

3.4 COMMUNITY PROFILE CONSIDERATIONS, INCLUDING

3.4.1 Poverty levels, average income per family, and affordability of services.

CAPEX and specially OPEX costs can make or break a system. The choice should always be made for the lowest cost technology that can deliver the required treatment levels. The O&M costs should be crosschecked with actual income and basic expenditure levels to determine affordability. In low income/high poverty communities, system costs should be subsidized by the central government.

3.4.2 Willingness to pay,

Willingness to pay can be affected by income levels as well as understanding of the need for wastewater treatment and acceptability of the system. Communities should be consulted for their understanding of the service and the acceptance of the technology choice. Mechanical treatment systems are still more accepted than natural systems. A willingness to pay survey should be undertaken prior to system selection and as above the highest cost to treatment level ratio should be selected

3.4.3 Levels of education

The level of community education has a strong bearing on acceptance of the need for wastewater treatment, choice of system and reuse of water. Educated and informed communities accept better wastewater treatment and reuse projects. The level of education has also a strong influence on the choice of systems specification

3.4.4 Cultural constraints

Cultural constraints mainly affect reuse projects. Religious believes might represent an obstacle to wastewater reuse. Although religious fatwas (religious advice) have allowed reuse of treated wastewater, many communities are reluctant to accept it.

3.4.5 Degree of involvement and participation

Participation leads to informed decision and improved acceptance. Participation of local communities can lead to better acceptance of the need for treatment and reuse and the choice of system.

3.4.6 Population density in town/village/settlement.

The choice of treatment system depends on wastewater flows. Some systems have a minimum flow and flow variation limits. Any type of technology can treat wastewater from large clustered communities; the same does not apply to small, scattered populations with highly variable number of residents.

3.4.7 Current and projected water demand and supplies

The need for treated water will be a decisive factor for implementing a treated wastewater reuse project. Current and future water demand may increase water stress and consequently demand for non-conventional water sources. Wastewater treatment is a requirement for public heath safety and environmental and water resources protection. It is important, however, to evaluate the usefulness of a reuse project based on the demand for water for irrigation and groundwater recharge and the risks associated with aquifer contamination due to flawed aquifer recharge.

3.4.8 Current and projected wastewater flows and characteristics

Populations being the driving factor for water demand and consequently wastewater supply, treatment plants are sized and designed based on the current and future population using a population growth factor. In some cases, population growth has exceeded the average national or regional estimates and consequently the WWTP became undersized and incapable of delivering wastewater of the required standard. Upgrading natural treatment to absorb increases in flows and wastewater loads is relatively easier then conventional mechanical treatment. In case of high population growth indexes it is important to select technologies that are upgradable.

3.4.9 Sewage network

The non-existence of a network for sewage collection and conveyance narrows down choice of technologies to systems catering for individual households or dwellings. A technical and cost feasibility analysis should be undertaken by the project promoters to assess the choice between individual treatment systems or installing a sewage network and a collective treatment station. It should be noted that the cost of the sewage conveyance network amounts to 80% of the treatment and conveyance system.

3.4.10 Public acceptability

Public acceptability of the wastewater treatment plant and technology is a determining factor for undertaking a treatment project and the choice of systems. Communities might oppose the installation of the WWTP and the choice of technology. An understanding of the local community and their fears and aspirations, public information and awareness raising and participation are key for the advancement of the project.

3.5 ENVIRONMENTAL CONSIDERATIONS

Wetlands, rivers, highly sensitive biodiversity areas shallow or karstic aquifers, biodiversity sensitive areas should be taken into consideration in the selection of technology. The chosen system can damage the surrounding environment or contribute to enhance it such as in the case of constructed wetlands and their positive impact on bird populations though habitat creation. Initial Environmental Investigations or a complete Environmental Impact Assessments could be required before final system selection.

3.6 TECHNOLOGICAL CONSIDERATIONS

3.6.1 Treatment capacity

The capability of the technology to achieve required reductions in pollutants is the most important selection criterion. Set standards for treated wastewater effluent need to be reached by the treatment system especially when the water is being reused in irrigation and more importantly aquifer recharge. The selection of the treatment technology needs to be based predominantly on its capacity to achieve the needed removal rates.

3.6.2 Sludge production

Sludge is produced by almost all wastewater treatment technologies and needs to be treated causing an added burden on the process. All things being equal, the technology that produces least sludge should be selected.

3.6.3 Generation of nuisance

Smells, mosquitoes and noise produced by a WWTP lead to reduced public acceptability and even decommissioning of existing stations. Systems with the least nuisance possible should be selected to avoid future discontent by the served community. The location of the WWTP can also play a role in reducing the impact of nuisance. WWTP should be located as faraway as possible from dwellings and houses.

3.6.4 Impact of flow fluctuations

Fluctuations in flow caused mainly by changes in populations can highly affect the proper operation of WWTP especially conventional mechanical systems. Treatment plants are designed to take daily changes in flows at peak hours reaching twice the average flow. Shock loads and/or contamination of influent wastewater with toxic chemicals including drastic variations in pH might cause serious collapse of the biological treatment systems. Provisions are also made for normal increases in populations over the life years of the plant. In rural areas, however, seasonal migrations can cause the number of residents to change drastically with the consequent change in wastewater flows. A conventional mechanical WWTP would be designed to cater for the highest expected flows but would not function properly when flows are very low with a serious deterioration of effluent quality. Natural treatment systems , however, can take flow variation easily and are not affected by changes in population.

3.6.5 Existing in-country/in-rural area experience

Operating a WWTP, especially conventional systems need skilled technicians and engineers who possess a strong knowledge of and experience in wastewater treatment processes. Plumbers and electricians understand the functioning of the different components such as pumps and electric controls and boards. This type of knowledge alone is clearly not sufficient to properly run a station. Rural areas are unfortunately deprived of resident skilled workforces. Maintenance contracts can fill the gap for the lack of resident skills but tend to become expensive and unaffordable due to the need for long distance travel. Consequently, all factors being equal, the selected system should be able to rely on available skills for O&M otherwise partial or complete breakdowns and process failure will occur leading to the discharge of substandard effluent quality.

3.6.6 Reliability and risk

Certain technologies can achieve the required treatment levels but process control is not exact with the consequent change in effluent quality. The level of risk is dependent on the sensitivity of the effluent-receiving medium to fluctuations in effluent quality. The reliability of the wastewater technology and its capacity, when properly operated and maintained, to constantly deliver the same results should be factored in the technology selection process.

3.6.7 Ease of operation and maintenance

The easier the operation and maintenance of the treatment plant the better. Ease of O&M leads to lower costs, less breakdowns, reduced need for skilled labor.

3.6.8 Energy use

Energy consumption by a WWTP is a question of economics, environment and reliability. The lower the consumption the lower the costs, the lower the emissions if the energy source is fossil fuels and the higher the reliability in localities where access to power is intermittent. Low energy consuming plants can be easily supplied with electricity from an alternative energy source to ensure constant operation.

3.7 FINANCIAL CRITERIA

3.7.1 Capital and operation and maintenance costs

Choosing among different technologies that can deliver the same results it is evident that selecting the cheapest in terms of capital and operational cost will be the most appropriate choice. Costs should either be subsidized to be commensurate with income levels of the local community otherwise the system will fail due to lack of funding.

4 Assessing community suitability for wastewater reuse in rural areas

The following criteria can be used as a decision support tool for the selection of communities that will benefit from a reuse project. If not fulfilled the reuse project will not be destined to succeed.

4.1 SCOPE

The scope of this section is to define criteria to be used to profile communities to determine if they are in need for a treated sewage project reuse project and if one can be initiated. The below criteria need to be fulfilled to make sure the project will succeed.

4.2 TYPE OF SEWAGE

If municipal sewage is mixed with industrial sewage then wastewater reuse is prohibited for irrigation and groundwater recharge unless a reliable treatment system is in place. In most instances in the PCs, industrial sewage is illegally discharged in the municipal sewage networks and ends up in the WWTP that is not originally designed to treat this type of influent. If there exists a risk of industrial sewage intrusion in the municipal system then reuse should be prohibited.

4.3 MAIN SOURCE OF INCOME

Reuse in irrigation can only be successful if agriculture is a main source of income in the locality. There are two types of famers in the SWIM region; those who live from farming and those who practice agriculture as a second income stream. Agriculture development projects that introduce innovation and change have only succeeded in when the main income stream is agriculture.

4.4 TYPE OF CROPS

The selection of crops to plant is community driven. The types of planted crops will be a decisive factor in the selection of the treatment process and the treatment level (primary secondary or tertiary). Most PCs have prohibited irrigation of crops eaten raw with treated sewage. The WHO guidelines of 2006 link type of crop and its use to effluent quality for irrigation. Effluent quality drives the choice of technology and level of treatment through the capacity of the system to deliver the required effluent standard.

4.5 AVAILABILITY OF FRESH WATER

When the local community has access to fresh water then it will not use treated wastewater. Treated wastewater will only be used if fresh water is not available.

4.6 IRRIGATION SEASON

The length of the irrigation season in the selected community will determine the need for a reuse project either in irrigation and groundwater recharge. If the season is long and covers most of the year, then there is no water left for aquifer recharge since all the treated wastewater will be consumed for irrigation.

4.7 WATER STRESS

The higher the water stress the higher the need for additional non-conventional sources of water. Competition for water by different users with priority to potable water will push farmers to rely more on new sources of water and decision makers to accept groundwater recharge to stock water.

4.8 LOCAL GEOLOGY AND HYDROLOGY

Groundwater recharge projects are dependent on the local geology and hydro-geology. The depth of soil to groundwater is a determining factor in the quality of water to be used for recharge. A depth of 20 m of soil can ensure treatment of effluent from primary treatment facilities up to potable water standards.

4.9 MONITORING SYSTEM

The existence of a monitoring system is crucial for the proper operation of the WWTP. Even low-tech treatment systems will need some monitoring. Accordingly, the existence or the access to a monitoring system is a determining factor for the undertaking of a groundwater recharge project essentially and an irrigation project.

5 Selection chart for communities for wastewater in agriculture and ground water recharge

5.1 ASSESSMENT AND SELECTION OF BEST AVAILABLE TECHNOLOGIES

All available wastewater treatment technologies can, in principle, be used in rural areas. However, taking into consideration the characteristics of rural areas presented earlier, this review has narrowed down the selection to the most common technologies but kept the selection open in such a way that it fits the multitude of national and regional contexts that are present in PCs. Table 2 below cross-matches the characteristics of selected treatment technologies with the characteristics of rural areas.

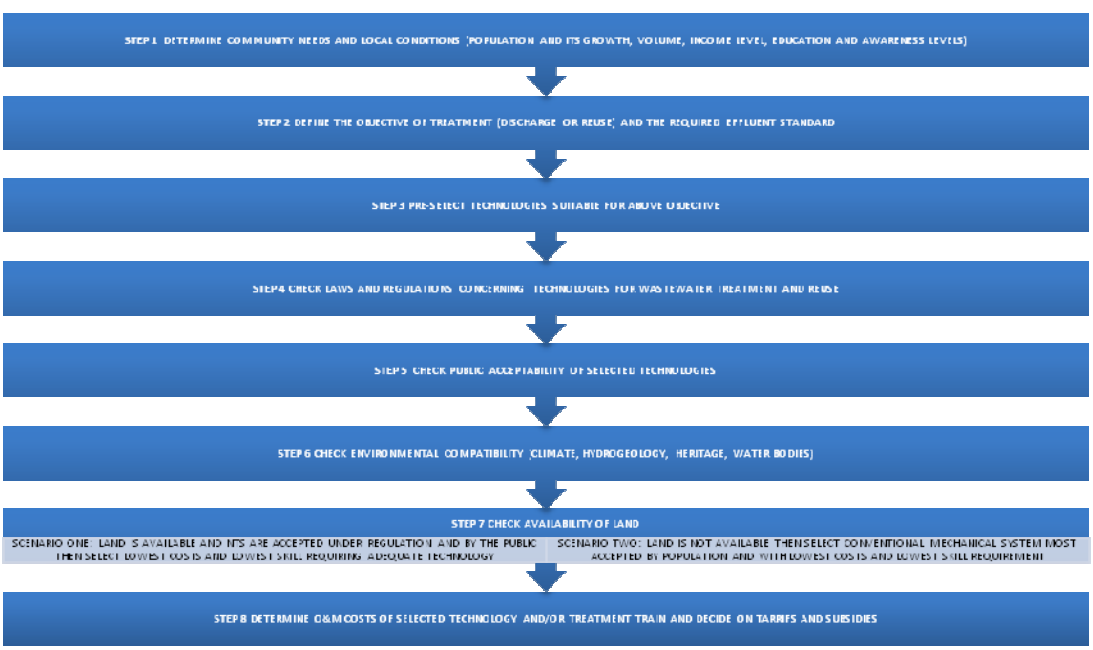
Selection Criteria	SECONDARY TREATMENT TECHNOLOGY											
	Separation at source	**Activated sludge**	**Rotating biological contactors**	**Trickling filters**	**Aerated lagoons**	**Membrane filtration**	**Packaged plant aerobic**	**Septic tanks**	**Lagoons**	**Constructed Wetlands**	**Soil Aquifer treatment**	**Packaged plant anaerobic**
Reliability and Risk	Selected technologies are reliable; risks are encountered when operation is not per specifications. Natural systems run lower risks then mechanical											
Management type	None	Close monitoring	Close monitoring	Close monitoring	Medium monitoring	Close monitoring	Minimal monitoring	Minimal monitoring	Minimal monitoring	Minimal monitoring	Minimal monitoring	Minimal monitoring
Capital Cost/PE	Very low	Very high	Very high	High	Medium	Very High	Very High	Very high	Highly dependent on cost of land	Highly dependent on cost of land	High	Very High
Operating Cost/PE	Nil	Very High	High	High	High	Very High	Low	Very Low	Vey Low	Low	Medium	Low
Footprint/PE	NA	Small	Small	Small	Large	Vey Small	Small	Medium	Very Large	Very Large	Large	Small
Needs power to run	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
Construction	Easy	Skilled	Skilled	Skilled	Skilled	Skilled	Easy	Easy	Easy	Easy	Skilled	Easy
Sludge production	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Affected by variations in flow	No	Yes	Yes	Yes	No	No	Yes	No	No	No	No	No
Requires skill to run	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No
Fits to different types of dwelling structure	Yes	No	Yes	No	No	Yes	No	No	No	Yes	No	No
Upgradeable	NA	Not easily	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Socially accepted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not well	No	Yes

										understood yet		
Is not affected by variations in temperature	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	No
Generates nuisance	No	Yes (noise and sometimes smell)	Yes (noise and sometimes smell)	Sometimes Smell	Mosquitoes	None		None	Mosquitoes	Sometimes smells	None	none
Hydrogeology affects system	No	No	No	No	No	NO	No	Yes	No	No	Yes	No
Fits ecologically sensitive areas	All treatment technologies can deliver required quality to protect heritage. Mechanical systems cause visual and noise disturbances							Natural systems blend more with the landscape and might enhance habitat				

Attempting to select one technology that is most suited for rural areas is not straightforward. Assuming that all technologies can deliver the required effluent standard, and taking O&M costs, required skills to build and operate and need for power as primary selection criteria then the definite choice is natural treatment systems. These systems are, however, extremely land intensive and require large spaces. If land is not available for a reasonable cost then natural treatment systems become irrelevant.

Since there is no definite technology that fits all wastewater treatment and reuse conditions then a selection process should be followed each time a project is being planned. The selection process is as follows:

TECHNOLOGY SELECTION PROCESS



5.2 CONCLUSION

As stated earlier, selecting a treatment technology as the definite solution in rural areas is not straightforward, However, always select the cheapest solution that requires least skill to operate and has the lowest O&M costs. Capital investments are most times born by donors or the state while O&M costs are born by the local population. In case of existence of land this review, favors natural treatment systems. They fit almost all the criteria of success for a “rural” wastewater treatment system. Lagoons and constructed wetlands have proven their capacity over decades to treat wastewater to required standards that can even reach tertiary treatment levels.

6 Guidelines on integrating BAT in wastewater in rural/local areas into National water resources management plans

In order for any action to succeed it needs to be properly supported by national policies, regulation and legislation. PCs differ in the level of policy and regulatory development related to wastewater treatment and reuse. It is important that PCs undertake a national policy assessment for wastewater treatment and reuse in order to identify policy gaps. The suggested policy elements below can be extracted from literature review and interactions with national stakeholders. They can serve as reference for policy reviews. It is important to note that national strategies for agriculture, education, information, environment, water, etc… need to be integrated within the national wastewater reuse strategies. The suggested policy elements are the following:

6.1 PUBLIC INVOLVEMENT

6.1.1 DEMAND MANAGEMENT

Reuse of treated wastewater in agriculture aims at increasing the availability of water and maximizing the benefits derived from the use of a rare resource in agriculture and other economic activities. Improving the efficiency of water use through demand management is essential for increased benefit and cost effectiveness of treated wastewater reuse projects. Consequently, all reclaimed water reuse policies should be accompanied by demand management policies, strategies and actions, otherwise the non-conventional water produced through treatment stations will be lost through inefficient use. In terms of reuse in irrigation, the trend is to increase as much as possible the amount of crop per drop of water in order to reduce the global demand for irrigation water, currently at an average of 70% of total water use. More crop per drop policies should be applied to reclaimed water reuse projects

6.1.2 EDUCATION

As stated earlier, education improves pubic acceptability of the need for wastewater treatment and the reuse of treated water in irrigation and groundwater recharge. Aversions against reuse of treated wastewater in irrigation caused by lack of knowledge of the treatment capacities of sewage plants and achievable contaminant removal rates have constituted a major impediment to the use of reclaimed water in irrigation and groundwater recharge. Education yields stronger results in behavior change then awareness. Consequently, it is pertinent to the success of wastewater treatment and reuse projects to develop educational curricula starting at school level on the treatment and reuse of wastewater and its associated benefits.

6.1.3 COMMUNICATION AWARENESS RAISING

Similarly to education, communication and awareness raising play an important role in advancing reclaimed water reuse projects. Awareness targets the general public, specially the segment that is out of school and not reachable by academic curricula. Continuous and frequent fact based communication programs by authorities responsible for WWTPs, and food security have led to the acceptance by the farmers and the general public of wastewater treatment and reuse projects. Farmers, in Jordan, using treated wastewater for irrigation supplied through the King Talal dam are provided with data sheets on water quality every three months. These data sheets assure them that reclaimed water quality standards are respected and help them calculate the amount of fertilizer present in the water so that they reduce chemical fertilizer application on their lands. A crop monitoring system that surveys and analyses crops produced using treated wastewater has helped regain consumer confidence in the produce. The results of the crop monitoring system are available to the public. Accordingly, the implementation of a long-term fact based awareness and communication campaign should be incorporated in wastewater reuse strategies.

6.1.4 REGULATED PUBLIC PARTICIPATION

Public participation and community involvement in the decision making process that concerns the initiation of a wastewater treatment project has been crucial in its advancement and success. Public participation needs to be supported by sufficient information and communication so that decisions are fact based and not based on impressions and misconceptions. Public participation should be regulated and covered by legislation. It should not be left to the desire of the promoter to engage and involve the local community. A defined process for participation should be codified and enforced by the local authorities. Policies for wastewater reuse should promote public participation in decision-making.

6.1.5 WOMEN INVOLVEMENT

Household related decisions are usually made by the women in the house. It is women who usually purchase fruits and vegetables for consumption and use water at home. Consenting to the use of treated wastewater by the farmers is tightly linked to the acceptance by the consumers to purchase his products. For women to accept using reclaimed wastewater for her chores there is a need for them to be convinced of the risk-free quality of the water. Consequently, the role of the female gender in supporting wastewater treatment and reuse projects is crucial and accordingly their role in the decision making process should not be neglected. Policies for wastewater treatment and reuse should strongly support the involvement of women in the education, awareness, communication and decision taking processes related to wastewater treatment and reuse projects.

6.1.6 HEALTH PROGRAMS

One of the suggested barriers by the new 2006 WHO guidelines is medical protection programs for farmers, handlers and consumers of products irrigated with treated sewage. Even with properly treated wastewater, famers, handlers and consumers are exposed to risks due to WWTP malfunction and failures in the monitoring system. Farmers in PCs, are extremely reluctant to wear protection gear, since high temperatures make it unbearable. Consequently, they become highly exposed to pathogens. An assessment of the potential health risks should be undertaken by the competent authorities and based on the results a preventive and curative medical protection programs should be developed and implemented. Implementation of such programs should be proactively pursued by the health authorities, since farmers rarely and comply with health programs such as vaccination protocols. The development and effective implementation of an adequate health protection program should be a priority of wastewater treatment and reuse strategies.

6.2 LEGISLATION AND REGULATION

6.2.1 RULES FOR WASTEWATER REUSE

Legislation has extensively supported the use of freshwater with laws, decrees. There is a legal gap however, in the regulations for the reuse of treated wastewater. This undefined and un-codified practice has lead to the failure of a wastewater treatment and reuse project in a one of the PCs. Untreated wastewater used by farmers for irrigation was collected in a pipe and conveyed to the WWTP. Farmers were deprived of the wastewater, which led them to break the sewage pipe to get the water back. Consequently, the WWTP is running at 10% of its original capacity. Collection sewerage need to be protected against illegal tapping while access and reuse of adequately treated wastewater need to be codified in legislation.

6.2.2 STANDARDS AND NORMS

Standards and norms should encompass treated wastewater quality along with crop quality, post harvest technology and treatment and reuse infrastructure. Using WHO reuse guidelines is not a legal requirement enforced on the countries but only a suggested guideline. The new 2006 guidelines are less stringent compared to the 1998 guidelines and offer countries a margin for adapting the standards to their local conditions and needs. National policies should provide a framework for the development of required standards and define acceptable limits based on the capacity of the country to enforce the application of and monitor compliance with the standards.

6.2.3 MONITORING

Implementation of an adequate monitoring program covering but not restricted to the quality of: treated sewage, crops, water in aquifers and soil is crucial for the avoidance of public health and environmental accidents and long term deterioration of freshwater, soil and health. Policies should enable the development of such monitoring programs and should define the scope and limits based on local conditions and capacities to enforce compliance and available resources for the implementation of the program.

6.2.4 REQUIREMENT FOR ENVIRONMENTAL INVESTIGATIONS

Depending on the scale of the plants and environmental sensitivity of the area, assessment of the environmental impact of wastewater treatment plants is a priority activity that need to be undertaken prior to the final decision on going through with the project. Communities in rural areas might be settled close to ecologically sensitive zones. The role of WWTP is to reduce environmental damage through reduction of pollution; it must not be a cause of damage itself. Natural treatment technologies can contribute to environmental enhancement such as creation of habitat for wildlife and specially birds in constructed wetland. The environmental study being an EIA or an IEE study will be a communication tool with the stakeholders showcasing the benefit of the system from an ecological point of view. Policies should explicitly state the need for environmental impact investigation for sewage treatment projects.

6.3 INSTITUTIONAL

6.3.1 INSTITUTIONAL RESPONSIBILITIES

Institutional responsibilities covering the use of treated wastewater in irrigation and groundwater recharge might shared and/or duplicated. Many ministries such as the ones responsible for water, irrigation, agriculture, environment, etc.… will have a stake in the project. Consequently, it is of the essence for best service provision, to ensure that responsibilities are clearly defined. Decentralized local management such as Water Users Associations (WUAs) is proving to be an efficient in service provision, reduction of losses and improved administration of irrigation projects. WUAs could be involved in the management of sewage treatment and reuse projects. Policies should include a description of the institutional framework governing the management of the wastewater treatment and reuse project.

6.3.2 FINANCING, TARIFFS AND COST RECOVERY

Policies should define responsibilities for financing capital and operational costs for wastewater treatment plans and reuse projects. Costs for irrigation water provided to famers in the PCs are usually subsidized. It is rare to find an irrigation projects were full cost recovery is achieved. Costs should be calculated keeping in mind the polluter pays principal. Treatment costs should be paid for, in essence, by the polluter. Additional costs for treatment needed to make the water suitable for irrigation is then covered by the farmer.

6.3.3 INTER AGENCY COORDINATION

A multitude of agencies and administrations are mandated to a certain extent over treatment and reuse of sewage. Cross-sectorial planning and integrated management approaches will improve efficiency and effectiveness in water management. Consequently, it is crucial that the mandated agencies plan together and coordinate their plans. Policies should be formulated in coordination with all concerned parties so that they favor integration and set a defined and clear mechanism for integrated management.

6.3.4 CAPACITY DEVELOPMENT

Although practiced by ancient Greeks and Romans, some PCs still lake capacity in the management of wastewater treatment and reuse projects. An assessment of needs should be undertaken and based on its results; a capacity building program should be developed and implemented. Policies should state the need for developing capacities for wastewater treatment and reuse projects.

6.3.5 SKILLS DEVELOPMENT

Academic institutions, in the PCs, have started including wastewater treatment and reuse in their curricula. There is still, however, a lack of expertise in some of the PCs in the operation and management of wastewater treatment plants. In rural areas, the lack of expertise has led to the failure of WWTPs. Skills development should focus on training technicians at levels below academic such as vocational training who can fill the expertise gap in rural areas. Policies should support skills development and improvement and target deficiencies strategically so that lack of skills does not constitute an impediment to the promotion of wastewater treatment and reuse projects.

6.4 STUDIES, RESEARCH AND DEVELOPMENT

6.4.1 UNDERSTANDING LOCAL GEOLOGY AND HYDROGEOLOGY

A good understanding of the local pedology, geology and hydrogeology is pivotal in the decision making process for initiating wastewater treatment and specially reuse projects. The success of groundwater recharge projects is highly dependent on the knowledge of geological formations, permeable and impermeable layers, aquifers, etc…. Hydrogeological investigations should be completed prior to the approval of reuse projects. Knowledge of the capacity of local soils to support plant growth when irrigated with wastewater and under increased salinity will help promote agriculture with treated sewage. Policies should strongly encourage research and studies in order create the required scientific basis for informed decision making.

6.4.2 Developing improved treatment and reuse system

Treatment technologies, especially natural treatment systems, are affected by local conditions and can make use of local macrophytes such as for constructed wetlands. Treatment performance and the quality of the effluent water are driven by local reclaimed water quality requirements for discharge and reuse. These requirements vary from country to country. Local socio-economic conditions vary within the same country. Consequently, it is important to find the most appropriate and adapted technologies and/or different treatment trains that fit as close as possible the local context and provide the best treatment performance for the lowest possible cost. Policies should support research and development in order to improve performance and possibly reduce costs

7 List of cited references in alphabetical order (around one page).

1. Choukr-Allah, R. & Hamdy, A. 2005. Wastewater treatment and reuse as a potential water resource for irrigation. International center for advanced Mediterranean Agronomic Studies, Options mediteranéennes, Series A: Mediterranean seminars, 66, 101-124
2. Khouri, N.; J. M. Kalbermatten and C. R. Bartone 1994: Reuse of Wastewater in Agriculture: A Guide for Planners. Water and Sanitation Report 6. UNDP-World Bank Water and Sanitation Program. Washington, DC: The World Bank. HTTP://WWW-WDS.WORLDBANK.ORG/SERVLET/WDS_IBANK_SERVLET?PCONT=DETAILS&EID=000009265_3961006165519
3. Kramer, Annika; Petta, Luigi; Post, Julika; Wendland, Claudia (2007): EMWaterGuide: Improving wastewater treatment and reuse practices in the Mediterranean countries -A Practical Guide for Decision-Makers. Prepared within the EMWater Project, InWEnt – Capacity Building International, HTTP://WWW.EMWATER.ORG
4. Tchobanogoulos, G, & Burton, F, 1991. *Wastewater Engineering: Treatment , Disposal and Reuse.* Third edition. New York, McGraw-Hill-Inc.

Useful references

1. WHO 2006: Guidelines for the safe use of wastewater, excreta, and greywater. Volume 2: Wastewater use in agriculture. Geneva: World Health Organisation. HTTP://WWW.WHO.INT/WATER_SANITATION_HEALTH/WASTEWATER/GSUWEG2/EN/INDEX.HTML
2. Mara, D. D. 2000: The production of microbiologically safe effluents for wastewater reuse in the Middle East and North Africa. Water, Air, and Soil Pollution 123, pp. 595–603. HTTP://WWW.LEEDS.AC.UK/CIVIL/CERI/WATER/TPHE/PUBLICAT/REUSEFILES/SAFEEFF.PDF
3. Neubert, S. 2002: Wastewater Reuse in Agriculture – A Challenge for Administrative Coordination and Implementation. In: S. Neubert, W. Scheumann and A. van Edig (eds.): Reforming Institutions for Sustainable Water Management. German Development Institute, Reports and Working Papers 6/2002. HTTP://WWW.DIEGDI.DE/DIE_HOMEPAGE.NSF/0/239E1156FCC4C4AFC1256C480033C548?OPEN
4. UNICEF 1999: A Manual on Communication for Water Supply and Environmental Sanitation Programs. Water, Environment and Sanitation Technical Guidelines Series No.7. New York:UNICEF. HTTP://WWW.UNICEF.ORG/WES/FILES/COM_E.PDF