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Water Conservation and Reuse in the Middle East

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TABLE OF CONTENTS

		Page
A.	Introduction	1
B.	Objectives	1
C.	Methodology	1
D.	Current Status of Water Resources in the Region	1
E.	Current Water Utilization Patterns in the Region	2
F.	Water Conservation, Reuse and Recycling Technologies: Quantity and Quality	4
	F1. Introduction	4
	F2. Water Conservation for Domestic Uses	5
	F3. Water Conservation for Industrial Uses	6
	F4. Water Conservation for Agricultural Uses	7
	F5. The Role Of Water and Waste Water Institutions in Water Conservation	10
	F6. Artificial Recharge	12
G.	Regional Experience in Water Reuse	13
H.	Regional Experience in Water Conservation	14
I.	Socioeconomic Background	15
J.	Conclusion	17

A. Introduction

The arid and semi-arid nature of the Middle East render it as a water scarce region. Population growth, agricultural and industrial development have imposed more pressure on the existing scarce resources. They are currently being exploited at their maximum capacity in most of the countries of the region to meet development needs. As a result, many environmental problems have arisen and will become more acute in the near future if the current resource utilization patterns continue. Therefore, there is an essential need to explore the different options and mechanisms available that will help decrease the escalation of environmental problems.

B. Objectives

The objectives of this report are:

- To assess the current status of the existing conventional resources and part of the potential water resources in the region. The report will also define the trends in water use and demand per sector for each country in the region.

- To highlight the various options and techniques that aim at optimizing the use and reuse of the existing water resources in the region in a manner that will insure sustainable development. The report will also highlight the existing water utilization practices as well as waste water reclamation and reuse practices and their socioeconomic impact on the region (Jordan, Egypt, Israel and Palestine).

C. Methodology

A literature survey has been carried out by the research team. The team identified the available relevant materials in the libraries of local universities, non-governmental organizations (NGOs) and other departments. They also identified the gaps in the existing literature. Letters were sent to EcoPeace offices and partners in the region asking them to provide the team with the requested information about each country. The reports obtained were sufficient to satisfy the objectives of this research.

Next, the social worker developed a questionnaire (Annex 1) related to the socioeconomic impact of water. The questionnaire was sent to Egypt, Jordan, Israel and the Palestinian territories. Feedback was received from the West Bank and the results were incorporated in this report.

Illustrative examples were given from the region for each method of water conservation and reuse. However, if there were no available examples from the region, other examples from different parts of the world were included to show the existing experience and to highlight the possibility of adopting it after all modifications been made.

D. Current Status of the Water Resources in the Region

Total available water resources in the region are estimated at 63.712 billion cubic meters (bcm). This amount is distributed at the four countries as follows: Egypt 94.80%, Israel 2.86%,

Jordan 2% and Palestine 0.34%. Table 1 summarizes the distribution of surface and ground water resources for each country.

Table 1. Available Fresh Water Resources in the Region

Category	Surface Water (MCM)	Groundwater (MCM)	Total (MCM)
Egypt[1]	55,000	4,900[a]	59,900
Jordan[2]	850	425[b]	1,275
Israel[3]	635	1,205	1,840
Palestine[4]	?[c]	212[c]	212
Total			63,212

Sources: [1] Abu Zaid M., 1991. "Planning for Groundwater Development in Arid and Semi-Arid Regions", RIGW/IWACO, Cairo- Rotterdam.
[2] Hijazin, S., 1991. "Planning for Groundwater Development in Arid and Semi-Arid Regions", RIGW/IWACO, Cairo- Rotterdam
[3] Eckstein, Z., & Fishelson, G., 1994. " The Water System in Israel". Report prepared for the Harvard Middle East Water Projects, Tel Aviv.
[4] United Nations, 1992. "Water Resources of the Occupied Palestinian Territory", New York.

[a] This amount is what can be abstracted safely from the groundwater in Egypt. It doesn't reflect the overall storage which estimated at nearly 500 Billion Cubic Meters (Abu Zaid 1991). Moreover, it doesn't include the fossil water.

[b] This component includes both renewable and fossil water as abstracted annually by Jordan.

[c] The exact magnitude of the Palestinian share of surface and groundwater resources is still under negotiation and not politically settled as of yet. The number listed under the groundwater component is what the Palestinians are using currently and not what is available. This is why Palestine has a low percentage of available water compared with other countries in the region.

E. Current Water Utilization Patterns in the Region

The overall water use pattern in Egypt, Israel and Jordan depends largely on the availability of resources and on the respective level of development. However, the issue is a little different in the Palestinian case in which the exact share of ground and surface water resources is still under negotiation. Thus, the water use pattern doesn't necessarily reflect the reality, and is a temporary situation created by the prevailing political conditions over the past 29 years.

Table 2. Current Water Use in the Region

Country	Total Water Use (MCM/Year)	Sectoral Water Use Pattern (MCM/Year)			
		Domestic	*Agriculture*	*Industry*	*Navigation*
Egypt[1]	59200	2960	49728	4736	1776
Israel[3]	1678	536	1035	107	-
Palestine[4]	212	53	152	7	-
Jordan[2]	883	180	660	43	-
Total	61973	3729	51575	4893	1776

Sources: [1] Abu Zaid M, 1991. " Planning for groundwater Development in Arid and Semi-Arid Regions", RIGW/ IWACO, Cairo- Rotterdam
[2] Hijazin , S., 1991. "Planning for Groundwater Development in Arid and Semi Arid Regions", RIGW/IWACO, Cairo- Rotterdam
[3] Israeli Hydrologic Service, 1994 " Summary of Water Resources in Israel". Jerusalem.
[4] United Nations, 1990. "Water Resources of the Occupied Palestinian Territory", New York

Based on the numbers given in Table 2 and the total population of each country, the per capita water consumption for any sector can be calculated. In this report we will focus on the domestic per capita water consumption and will try to estimate the total domestic waste water production by country.

Egypt per capita water consumption was calculated based on a population of 60 million people and the total water use as indicated in Table 2. The total is nearly 986.7 m^3/capita per year for all purposes. However, the domestic per capita water consumption is 49.3 m^3 per year. This differs in other countries; the per capita water consumption in Israel (population 5 million) is estimated at 335.6 m^3 per year, and the domestic per capita water consumption is 107.2 m3 per year. Jordan per capita water consumption is 259.7 m3 per year, while the domestic is 52.9 m3 per year (population 3.4 million). Finally the per capita water consumption in the West Bank and Gaza strip (population 2.3 million) is the most critical. It is estimated at 92.2 while the domestic water consumption is 23.04 m3/ year.

The average domestic per capita water consumption in the region is 58.11 m3/year. It is apparent that per capita water consumption in Israel is above the average while it is below the average in Egypt, Palestine and Jordan.

It is evident that all countries in the region need to utilize the available fresh water resources more efficiently. Moreover, they need to look for alternatives to the water supply. Of these alternatives, waste water can be considered the most significant. The produced quantities in the region vary from one country to another depending on the per capita water consumption, the collection percentage and the reliability of the conveyance system. Due to the fact that no exact data are available for all the countries in the region, it will be estimated based on the assumption that 60% or 70% of the water used for domestic purposes can be recovered back as sewage water. A large percentage of sewage water comes from toilet flushing and washing. The amount utilized for drinking and cooking might vary from 20-25% of the amount utilized. The remainder

will be considered as system loss. The estimated waste water production in the region based on these assumptions is summarized in Table 3.

Table 3. Estimated Waste Water Production in the Region

Country	Domestic Water Use (MCM)	Waste Water Production (MCM)	
		60%	70%
Egypt	2960	1776	2072
Israel	536	321.6	375.2
Jordan	180	108	126
Palestine	53	31.8	37.1
Total	3713	2227.8	2610.3

These numbers might increase parallel to the increase in per capita domestic water use, population growth and improvement in infrastructure. Although such an increase will be at the expense of other sectoral use, the produced effluent can be treated and reused for both agriculture and industry.

F. Water Conservation, Reuse and Recycling Technologies: Quantity and Quality

F1. Introduction

As the world's water resources, and those of the Middle East in particular, continue to be depleted, it is obvious that developing new sources of supply from the existing water resources may not be the best solution. In fact, this method may further decrease the quantity and quality, especially in arid regions where water is limited.

Conservation, reuse and recycling are the water "sources" of the future. Considering the fact that the sources of water in the Middle East are rapidly being depleted and demand is increasing, proper water management and efficient use of the existing fresh water resources is not an option but a necessity. Therefore, all parties must take an active role in initiating programs for efficient water use such as water conservation and enhancing the available water supply through water reuse and recycling.

Water conservation includes the use of water in a more efficient manner with the aid of water conserving fixtures, techniques and programming. Reused water, or water that has been used and is to be used again for a purpose other than the original one, must be of the quality specified in the European Community (EC) or World Health Organization (WHO) standards and can be used for landscaping, agricultural irrigation, aesthetics, and fire protection. In establishing water reuse programs, the following must be done: the possible reuse opportunities must be identified and the minimum quality for a given use specified; waste water sources and potential production capacities must be identified and transportation of the water to the new use is then determined; and the environmental impact of such programs must be assessed and considered.

For recycling programs, one must consider some additional factors such as the level of water quality degradation as a result of recycling and the level of required treatment. This is important because recycled water is water that will be used again for the same initial purpose.

As indicated earlier, one of the main objectives of this report is how to optimize the use and reuse of water through various techniques. The following sections will give a brief description of water conservation and reuse, including fixtures and programs employed by domestic, industrial, agricultural, and institutional operators as well as examples of the application of these techniques in the Middle East or elsewhere in the world.

F2. Water Conservation for Domestic Uses

Domestic water use can be achieved more efficiently by the implementation of water conserving fixtures. Such fixtures include low flush toilets, toilet displacement devices, low flow shower heads, faucet aerators, and pressure reducing valves. The reduction in water consumption eases the economic burden of the consumer. Low flush toilets use approximately 6 liters of water per flush while conventional toilets operate with 13 to 19 liters per flush. Toilet displacement devices are objects such as a simple water-filled plastic container, that are put into the toilet tank in order to reduce the amount of water used per flush. A toilet dam, which is a type of toilet displacement device, saves 3.7-7.5 liters per flush. Low flow showerheads are relatively inexpensive and save 7.5 liters per minute (EPA, 1995). Faucet aerators, which are devices that enter air into the water flow without decreasing wetting effectiveness, save 1 to 11 liters per minute (Jensen, 1991). Installation of pressure-reducing valves can save energy as well as water by reducing the probability of leakage and breakdowns in the system. The savings, when comparing a house with high pressure valves to a house with low pressure valves, was approximated by the U.S. Environmental Protection Agency (EPA) to be 6%. The disadvantages of pressure-reducing valves is that usually household fixtures, such as toilet and washing machines, require a controlled amount of water, and therefore pressure-reducing valves will have little impact on the amount of water used.

Besides the various fixtures that can be installed to maximize the efficient use of water brought into the household, techniques such as greywater use can be considered. Greywater is a term given to water that has been used for domestic purposes, such as wash water from washing machines and kitchen sinks, that can be reused for landscaping or flushing the toilet. Greywater can contain certain contaminants that can be harmful to humans and therefore should only be used if it is of certain quality or where people are not in direct contact with this water, such as in underground irrigation. The detergent used for domestic purposes contains alkalinity, conductivity, boron, sodium, and chloride which can be harmful to plants. Therefore, caution must be taken when using greywater for landscaping purposes. However, the phosphate contained in the detergent acts as a fertilizer for plants.

A good example of a greywater recycling system is in Tucson, Arizona. Casa del Agua (House of Water) is a house is designed to conserve water to the maximum degree possible. The home has an altered waste, vent and drainage system to accommodate this technique. It also has a piping system for greywater and another for toilet and garbage disposal that goes directly into the sewage system. Sufficient storage was provided and special filtration, treatment, and installation techniques were used to meet quality, health and legal requirements.

Casa del Agua's landscaping practices include grouping plants with the same water requirements together, watering in the evening and morning, using watering systems such as cycle irrigation (which provides the right amount of water at the right time), drip irrigation, and low precipitation rate sprinklers. These "xeriscape" landscapes reduce water use, energy costs, runoff, labor, and heating and cooling costs. Xeriscape landscaping is based on the principles of using the correct plant type in the correct position with respect to the house, soil analysis, mulch use, efficient irrigation, and proper planning, design, and maintenance.

In addition to the techniques and fixtures, a behavioral adjustment on the part of household members is required to further increase the water use efficiency. This cannot be achieved without conducting proper public awareness programs to the community. Such programs might include teaching people to turn off faucets while brushing their teeth, to run the washing machine at a suitable level, and to take shorter showers. Moreover, the education program might include teaching the community how to check for leaks, economic advantages of water-efficient appliances, adopting drought tolerant plants for landscaping, watering the lawn during the evening and early morning, washing cars on the lawn, and sweeping sidewalks instead of hosing them down. These are all practices that can help conserve water.

F3. Water Conservation for Industrial Uses

Industrial effluent, by law, must be discharged either to the main sewer system or to rivers and seas, with adequate quality. The requested treatment level varies from one country to another, according to the general WHO effluent water quality standards or according to the standards existing in the country if different than general standards. The process is important because industrial effluent is highly likely include toxic materials as well as other heavy metals that would endanger any water user.

Although treatment of the industrial effluent to usable level can be costly, it could be more economical than using fresh water for various reasons:

- Ideally all industries have their own treatment plants and they have to treat the effluent up to acceptable standards. Therefore, it is likely that the required treatment for an already treated effluent would cost less than the price of fresh water.

- Industries that reuse water in their processes reduce the amount of fresh water consumed. This can result in a profitable venture for the industry and will save fresh water for sensitive users.

Alternatively, industries can purchase treated effluent from the sewage facility and upgrade its quality using the industry's own treatment facility. In order for this alternative to be deemed economically feasible, the treated sewage effluent must be of a certain quality and cost. The required quality of the effluent varies for every industry, and therefore the sewage facility should choose the cheaper quality effluent required by most industries, and those industries requiring better quality can purchase the effluent and treat it themselves. The chemical industry generally requires reclaimed water to have neutral pH, be moderately soft, and have low turbidity but the requirements change depending on what is being produced. The textile industry requires non-staining water and therefore must have low turbidity, iron, color, manganese, hardness, and

nitrates and nitrites. The petroleum and coal industries require a pH between 6 to 9 and moderate suspended solids of no more than 10 mg/L (EPA, 1992).

However, in order to determine whether a reuse or recycling program is suitable for a certain industry, a water management scheme (WMS) should be devised to yield the cheapest cost (Law, 1986). The process of devising such a scheme requires construction of a water mass flow diagram (which includes the amount, daily variations, and quality of all waters consumed); identification of all unit processes that consume the most water and reduce the consumption and effluent produced from those processes; and modification of the mass flow diagram so that the reclaimed water passes through unit processes of decreasing quality requirements. A cost assessment of all feasible options will result in the cheapest WMS. An example of such a scheme is a polyethylene plant in Victoria, Australia where fresh water intake was reduced to such an extent that the company saves $80,000 per annum. This company disposes treated effluent to irrigation, had a 'conservation publicity programme' for its staff, and is undergoing the continual process of reducing the amount of discharge into the environment (Law, 1986).

Industry generally uses water for cooling systems, process water, material transportation, steam generation, utility power stations and petroleum refineries.

Industrial water conservation does not only mean the reuse of effluent in the industrial process or the use of saline or low quality water for cooling or any other similar purpose; it also relates to the behavioral practices of the system operators. It includes, but is not restricted to, changes in the habits of the staff which are similar to those specified for the domestic users, as well as monitoring the use of the water's quantity, quality, and pattern of consumption.

F4. Water Conservation for Agricultural Uses

The agriculture sector is the highest consumer of water in the region. It is therefore very important to adopt conservation methodologies that use water more efficiently. Of these methodologies, field practices are considered the least expensive and entail techniques used to prevent loss of water, distribute the water effectively, and allow the soil to retain more water. This in turn limits the amount of run-off produced, which implies fewer contaminants carried into the surface and groundwater sources.

Examples of field practices are loosening compacted soils, drip irrigation or leveling land, and furrow diking. In areas of low fertility, organic compounds can be added to improve water retention. Monitoring of the soil and water to make sure that water is used efficiently, is an important management strategy. The data received from the monitoring can check the efficiency of the current irrigation technique and help in making slight modifications to the irrigation system (to make it more water efficient). A more expensive way of conserving water is to modify or replace the existing old irrigation system with a new system such as drip or sprinkler irrigation. Another method called irrigation scheduling reduces the amount of water used to irrigate a crop. Through this method, the application rates and timing are designed to conserve water for a given yield. Factors that influence the schedule include the crop water demand, the amount of precipitation the crop is excepted to receive, the storage capacity of the soil, the irrigation system's pump capacity and the rising cost for pumping.

The types of irrigation that are currently in use in the Middle East can be summarized as follows: surface (flood), sprinkler, and drip irrigation. Surface irrigation generally has a large amount of water lost to run-off and evapotranspiration, and is also time- and effort- consuming. However, it is cheaper for the farmers with low income.

Sprinkler systems can clog if there is a large amount of salts or particulate and the nozzle size is too small. Sprinklers are also prone to wind drift, and therefore if reclaimed water is being used, buffers are obligatory. This can be remedied if the sprinklers are close to the ground.

Drip irrigation is one of the most technologically advanced irrigation systems and has an efficiency of about 85-90%, while sprinkler irrigation's efficiency is 65-70% and surface irrigation has a low 50-70% efficiency (EPA, 1992). Drip irrigation delivers low volume and pressured water uniformly at the plants' root zone. The low volume reduces the stress on the crop and therefore results in a higher yield. Polyethylene tubes and emitters carry the water to this zone and the soil is then kept at optimal moisture content. Emitters are usually positioned at the drip line so that roots can get the water more effectively. This technique can be varied according to the individual crop's needs and the season. The low volume of water prevents evaporative and run-off losses, particularly if the crop is on a slope. When irrigating, plants with the same water needs should be grouped together. In order to increase drought tolerance, crops should be watered deeply and irrigation should be widely spaced which increases the span of the crop. Salty soils are leached to remove salt from the root zone. There is less probability of hazards to public health if the drip system is buried under the ground. Regular maintenance checks and leak checks should be done on the system.

Advantages to using drip irrigation include the great amount of water that is conserved when compared to surface irrigation at a given yield. Better control over location, flow and timing occurs with its application. Drip irrigation can provide chemigation (fertilizer and pesticide injection) more effectively. There is a low labor cost and it is generally cost effective over large areas. Drip irrigation increases the amount of water retained by the soil and therefore the land capacity is increased.

A disadvantage to drip irrigation is that it is a continual operation and therefore requires the technical, practical and agricultural know-how. Drip irrigation increases the yield for the amount of water applied, and is therefore considered to be water efficient. However, the amount of water conserved is dependent on the land quality and crop type. It is important, therefore, to know the crop's interaction with the equipment and the soil before this expensive technology is applied (Caswell, 1989).

In order to apply drip irrigation, the cost of the water, crops, and the irrigation system must be less than the profits produced from the yields. This can be achieved either by giving the farmers low interest loans, by partially subsidizing the crop, or by adopting the right cropping pattern and low water consuming crops. Table 4 lists some of these crops.

Table 4. Crop Salt Tolerance (compiled from EPA, 1992, Table 17)

Sensitive	Moderately Sensitive	Moderately Tolerant	Tolerant
Avocado	Corn	Artichoke	Asparagus
Carrot	Cucumber	Barley	Barley
Grapefruit	Eggplant	Fig	Bermuda grass
Lemon	Peanut	Jujube	Cotton
Lime	Pepper	Papaya	Durum wheat
Mango	Sugarcane	Pomegranate	Jojoba
Orange	Sunflower	Soybean	Sugar beet
Plums	Tomato	Wheat	Wheat grass
Strawberries	Watermelon	Zucchini Squash	

There are other irrigation techniques that exist, but they are generally not used in the Middle East. Among these techniques is micro-irrigation, which applies water underground at a slow rate. This method is good when water is scarce, the soil is sandy, and/or moisture control is important. It requires careful inspection and maintenance so that emitters do not get clogged. Biological growth in micro-irrigation increases with the use of reclaimed water instead of potable water.

An alternate way of conserving water in agriculture is the use of reclaimed water. The use of this water on plants requires that the water not be applied directly to the part of the crop that is consumed, especially for fruit and vegetables that are not cooked before they are consumed. When using reclaimed water for irrigation, one must be cautious of the amount of salinity, sodium, trace elements, and excessive chlorine residual that may be present. Leaching removes the salt from the root zone; however, when using reclaimed water, the amount of salt contained in the reclaimed water determines the salt accumulation. Soil salinity can be detrimental to young crops and during germination. Salinity reduces the intake of water and therefore the crop yield and plant growth as well, especially in hot and dry areas like the Middle East region. Some crops are more salt tolerant than others (see Table 4).

Trace contaminant build-up, which may affect human health and cause phytotoxicity in plants, can be caused by the concentration of specific ions. The combination of greywater for irrigation and overhead sprinklers in hot and dry weather can be lethal to crops. Salty water applied to the plant can cause leaf injury. Sodium decreases the soil's permeability, resulting in less water available to the plant's roots. Organic matter, oxides, calcium and magnesium counteract the affects of sodium. Reclaimed water contains calcium and therefore, depending on the amount of sodium also contained in the water, can leach sodium away from the crop. Trace elements can be toxic at high levels. Elements to look out for are cadmium, copper, molybdenum, zinc and nickel. Reclaimed water contains little copper and zinc, and fertilizers generally contribute more heavy metals than does reclaimed water. Sensitive crops can be damaged with a chlorine dose greater than 0.05 mg/L, but in general, a free chlorine dose less than 5 mg/L is fine (EPA, 1992). Too much nitrogen in the water may be harmful to the crop, and large amounts of phosphorus can cause run-off problems. Elevated TDS levels, saltwater (chloride) intrusion into the sewer system, and toxic compounds discharged by industry into the municipal sewer system can all deplete the quality of the reclaimed water required for agriculture.

When using reclaimed water for irrigation practices, system reliability, site use control, monitoring requirements, and run-off controls are issues that must be addressed. The quality and quantity of the reclaimed water must match the demand, and treatment and distribution systems must meet standards. Buffer zones around the irrigated area (depending on the quality of the water), restricted access to irrigated areas, and signs to prevent the public from eating the crop or coming in contact with it are all precautionary measures to ensure public health is maintained. Monitoring of the quality of the reclaimed water as well as of the groundwater at the site is required. Depending on the type of irrigation, run-off should be controlled. The chemical components of the reclaimed water, such as nitrogen and phosphorus, also reduce the need for fertilizer and bring some economic savings.

F5. The Role Of Water and Waste Water Institutions in Water Conservation

There is much that the government or water and sewage facility operators can do to cause an improvement in the amount of water consumed. Urban reuse in landscape irrigation, ornamental landscaping, dust control and concrete production, fire protection, and toilets in industrial and commercial buildings are a few of the concerns of the institutional operators. Reclamation plants, distribution systems, program initiation, legislation, and implementation of techniques (such as groundwater recharge) are under the authority of the system operators.

Pricing can influence water demand based on the consumer's desire to save money. Water utilities must set a suitable price for the water so that the costs are fair and yet at the same time provide incentive to conserve water. Pricing systems that encourage water conservation are tiered pricing, decrease block rate pricing, time of day pricing, and water surcharges (EPA, 1995). Tiered pricing implies that the more water a customer uses, the more surcharge he has to pay above the base rate. Time of day pricing is simply higher prices at peak demand time; this method reduces demand on water and expensive secondary fuels, and also cuts generating capacity (Sexton *et al.*, 1989). Water surcharges are higher rates for excessive use. There could be surcharges for all customers in the summer due to a comparatively higher demand than winter, or a year-long arrangement where there is a higher rate for anything above average winter use.

The use of meters for billing purposes can reduce the amount of water consumed. In addition, meters can be used to find leaks in the system. Leak detection, by meters or listening devices, is very cost effective for deteriorating networks (even with its high initial cost) since the loss of water in the system means the customer pays for less water than actually consumed. Therefore, regular water main checks and rehabilitation must be maintained. This can be achieved more efficiently if using a distribution system database that can assist in designating the amount of funds required for rehabilitation, reduce the maintenance cost and, therefore, efficiently use the water source (Habibian, 1992).

Retrofit programs are cost effective and can be applied for all users. A retrofit program includes the replacement of plumbing and infrastructure with a more water-conserving alternative. Residential audit programs consists of an auditor coming to the consumer's household and suggesting improvements with water use techniques or plumbing. Public education plays and important role in any effort to conserve water and can be highly effective when combined with pricing incentives. Public education (via news media, booklets, posters, and other communication means) explains how water is brought to the user, the cost of maintaining the water system, water conservation and the users participation in the water conservation. Other tools to promote water

conservation include the Index of Water Efficiency, or the W-index, which is a measure of water use efficiency. The W-index promotes residential conservation by numerically evaluating the type of water-conserving features. This tool has been used for Casa del Agua and the surrounding area in Tucson, Arizona (EPA, 1995).

The implementation of programs that encourage water conservation requires careful planning. For example, the Metropolitan Water District of Southern California has established "Best Management Practices" (BMPs) for all water uses. The California Urban Water Conservation Council has the authority to amend or delete BMPs that are not cost effective. The BMPs include "interior and exterior water audits and incentive programs; plumbing—new and old retrofit; enforcement of requirements for ultra-low-flush toilets in all new construction; support of state and federal legislation prohibiting sale of toilets using more than 6 liters per flush; leak detection and repair; metering with commodity rates for all new connections and retrofit of existing connections; large landscape water audits and incentives; landscape water conservation requirements; public information, including school education; commercial and industrial water conservation; new commercial and industrial water use review; conservation pricing; water waste prohibition; financial incentives; and ultra-low-flush toilet replacement."(Gibson for the Metropolitan Water District of Southern California).

Care needs to be taken when considering the use of reclaimed water for various purposes. For example if greywater is to be used for flush toilets, a dual distribution system must be constructed. Such a system must take into account the prevention of inadequate quality for ultimate use, improper operation, improper use of reclaimed water, and cross connections with potable water supply lines. For urban usage, filtration and chlorination are required. Any reclaimed water that is in contact with humans must be of high quality. The WHO describes the impact of reclaimed water usage on public health in "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture", 1989. Depending on the ultimate use, the reclaimed water quality and maximum allowable concentrations of pathogenic substances will vary. The WHO report suggests different standards which provide protection of the public's health for a greater number of people around the globe. At the same time, these standards are economically and technologically feasible for developing countries. The report also describes economical treatment technologies for the revised guidelines and application methods in wastewater irrigation to reduce risk of infection.

In addition to promoting conservation on the part of all users and utilizing techniques to augment or reuse water supplies, institutional operators must also be concerned with resource protection. This technique protects the quality of water and reduces the need for treatment facilities. Resource protection can be brought about by controlling landfills near water supplies, implementing land use controls such as land preservation, establishing regulatory and non-regulatory watershed programs, zoning, and environmental assessment and general water supply protection (Gollnitz, 1988). Protection of supplies from contamination by toxins or saltwater intrusion due to over-pumping is a necessity so that additional sources of water do not need to be found and costly treatment facilities do not need to be constructed.

Instream flows required to sustain wildlife habitat, aquifer recharge, effluent discharge dilution, channel maintenance, and maintenance of supply for downstream user demand must be of a certain quantity and quality to sustain all users. A drought management planning concept needs to be adopted to insure sufficient instream flow during the drought. It consists of defining

the available supply and demand; comprehending the possible lack of supply; describing actions to be taken in event of a shortage of supply; involving the public and implementing new legislation, procedures and agreements; and a drought management event plan containing specific actions to be taken in a certain event and predicts the event dates.

F6. Artificial Recharge

Another method of water reuse is for groundwater recharge. It is a technique used to increase the potable or non-potable water supply, to prevent or control ground subsidence, to provide barriers against saltwater intrusion, to store reclaimed water, and as treatment for future reuse. This technique is based on the principle that the subsoil provides natural filtration and biodegradation and therefore on-site treatment. Before considering this technique, the proper downstream and hydrogeological conditions must be present. Although this technique appears outstanding from afar, there are some serious disadvantages to using this technique. The foremost disadvantage is that there are psychological impacts that must be considered prior to application. The amount of land required for spreading basins is large and the risk of aquifer contamination due to recharge is possible. Aquifer remediation, the energy required for recharge, and injection wells are all expensive. Aquifer recharge also may take many years.

Surface spreading is one of the techniques used for recharging groundwater. It occurs by allowing water from the land to infiltrate and percolate into the soil. Soil conditions and geologic and subsurface hydrologic characteristics must all be suitable for the ultimate end use when using surface spreading. Depending on the ultimate use, the reclaimed water goes through secondary treatment and disinfecting prior to surface spreading. Additional treatment may be required. Infiltration basins, the most commonly used spreading technique, is suitable for highly permeable soil. Advantages of high loading rates and low maintenance and land requirements overwhelm the manageable disadvantages of algae and insects in percolation ponds.

Direct injection, another groundwater recharge method, pumps reclaimed water into the groundwater zone in a confined aquifer. This technique is good for areas where the groundwater is deep and the hydrogeological conditions make surface spreading infeasible. A freshwater bubble produced by this method in a saline aquifer can be later extracted and reused. Direct injection can also provide a barrier against saltwater intrusion. The disadvantages of this method are that a higher quality of water is required than for surface spreading because the hydraulic capacity must be maintained and there is no soil matrix treatment.

Reclaimed water provided for all users must meet the demand and must be treated and distributed to meet permit conditions. Quantity and quality of the water must be suitable for the ultimate use, whether it is for agriculture or cooling water. Economic benefits provide incentives for the consumer to switch to using reclaimed water.

Increasing potable water supply with reclaimed water must be done with great caution and consideration of public health. The quality of this water must be of the same standards as the drinking water. There also may be site specific characteristics that do not mix well with the contaminants and result in a health hazard. Contaminants also change with time. Thus, studies of the potential effects on public health must be conducted. Since reclaimed water is of poorer quality than freshwater, potable reuse will require more disinfectant such as chlorine, a carcinogen, than conventional treatment. Direct potable reuse implies that the reclaimed water is

treated and then discharged directly into the potable water supply pipeline. The problem with this is that any implementation of a program must have the public's approval, and since direct reuse is considered a poorer alternative in the eyes of the public than indirect potable reuse (even t-hough this treatment evades the degradation of water quality that indirect treatment may have), problems may arise. Indirect potable water reuse implies that the treated reclaimed water is discharged into a water body and used later as potable. This type of water can be used if adequate filtration and disinfection is provided. Groundwater recharge for potable reuse via surface spreading uses the soil matrix to treat the water. Los Angeles County in California conducted a health study over a short period of time on groundwater recharge project and found that the risks of using reclaimed water, storm water run-off, and surface water do not differ greatly and there appears to be no short term effect on public health (EPA, 1992). An example of its application in an unconfined aquifer is in El Paso, Texas, where this method, the reliability of the plant's treatment, and the role of each unit's process of producing potable water were studied.

G. Regional Experience in Water Reuse

Countries of the region are aware of the importance of reusing water. They started to investigate the potential for reusing water in both industry and agriculture decades ago. For example, Egypt initiated the first approach in 1915 when it treated the effluent produced in Cairo, and reused it in desert cultivation. Despite this effort, waste water reuse is not common in Egypt. Rather, they have paid more attention to the methodology and technical aspects of water reuse for agriculture, especially because it is expected that waste water production from the greater Cairo area will increase from 0.9 billion m^3 in 1990 to 1.7 m^3 and 1.93 billion m^3, in 2000 and 2010 respectively. Moreover, Egypt is currently reusing 4.7 billion m^3 from agriculture drainage in irrigation (Abu Zaid, 1991) . The amount of produced waste water in Jordan in 1991 was 45 mcm, and it was reused completely for irrigation. This amount has certainly increased now as a result of the increase of domestic water supply and house connections to the sewer lines (Salameh, 1993).

Israel is the most advanced in waste water reuse in the region. It is reusing some 170 m^3 per year mainly for agriculture. Israel uses 66% of its wastewater (Avnimelech, 1993). With the assistance of computerized automation with high frequency and drip irrigation, Israel has doubled its yield over the past 20 years but is still irrigating with the same amount of water (National Geographic, 1993). The reuse program was initiated in 1972 by the National Sewage Reuse Project. The typical sewage reuse plant contains treatment such as an oxidation pond for small municipalities and mechanical systems for cities and reservoirs. The use of reclaimed water reduces the need for, and therefore the cost of, fertilizer. Hydrologically sensitive areas and karistic (cracked limestone) and sandy formations over active aquifers are not irrigated with reclaimed water. Israel's main concern is the concentration of chromium in the reclaimed water. The country also has a high soil salinity as well as high salt content in the water due to the food industry (koshering process), water softeners, and industrial cooling. In the Negev, brackish water is used for irrigation (National Geographic, 1993). Despite its value, the Ministry of Health has restricted reclaimed water irrigation to cotton, corn, fodder, and other such crops. Orchards can be irrigated with highly treated (chlorinated) reclaimed water. The use of reclaimed water on vegetables that are consumed directly without cooking is prohibited (Gabbay, 1994).

Water reuse in the Palestinian case is not yet developed. This is due to the fact that the existing infrastructure is not capable of handling the produced effluent completely. Moreover, no

treatment plants exist within Palestinian-controlled territory. The Palestinian National Authority (PNA) is currently working to improve the infrastructure to a level where it can make use of the produced effluent.

Another example of water reuse in the region is in Riyadh, Saudi Arabia, where the treatment facility pumps reclaimed water to Dariyah and Dirab to irrigate date palms, fruit trees, vegetables, fodder, and wheat. Another example of reuse of treated sewage effluent in Saudi Arabia is the Petromin Oil refinery, which upgrades effluent from the treatment plant in Riyadh and reuses it for high quality boiler feed water, cooling, fire fighting purposes, and crude oil desalting.

H. Regional Experience in Water Conservation

Various conservation measures have been adopted in the region in nearly all water sectors. Since the largest amounts consumed are utilized in the agriculture and domestic sectors, conservation in these sectors is more developed. The techniques used include adopting modern irrigation, reusing lower quality water in irrigation, increasing public awareness campaigns, and adopting various low flow fixtures in homes. Specific examples of agricultural water conservation from Jordan, Egypt and Palestine are summarized below.

Jordan is treating and reusing a large percentage of its sewage effluent in agriculture. It is also adopting the use of modern irrigation techniques wherever possible. For example, the Royal Society for the Conservation of Nature organized a workshop on drip irrigation in order to further develop the concept of water use efficiency among farmers. The country recently adopted an ascending water pricing strategy for agriculture in order to reduce the inefficient use of water. This policy is a good tool for water conservation. It is not, however, a common strategy in other parts of the region. The Jordanian Society for the Control of Environmental Pollution and the U.S. Agency for International Development have also sponsored a program to encourage women to take control over water conservation in their households.

Egypt has already started a number of public awareness programs in order to use water more efficiently. The programs were initiated in Cairo by the National Community Water Conservation Program (NCWCP) (Middle East Times, 1996) in order to educate the public on how to use water more efficiently, to develop the concept of protecting water resources, and to teach people the economic value of water. However, the reuse of sewage effluent and the use of modern irrigation techniques are developing slowly.

The Palestinian case is special. The political conditions prevailing over the past 29 years have restricted the use of water for all sectors and particularly for agriculture. Irrigated areas have decreased sharply to less than 5% of the overall cultivable land. The water quality deteriorated sharply due to the increasing demand and limited resources, especially in the Gaza Strip. More than 90% of the groundwater in Gaza has become unsuitable for drinking purposes as a result of over-pumping to satisfy the growing demand and due to the poor infrastructure which contributed substantially to the contamination of the groundwater. Despite these difficulties, the Palestinians are using modern irrigation techniques and are doing their utmost to save water and retain its quality. Public awareness of the water problem has spread with the help of a number of leading NGOs such as the Palestinian Hydrology Group. The programs focus on

women and school children encourage better water use at home and to instill the concept of water use efficiency in the habits of young kids and thus in the culture.

I. Socioeconomic Background

Middle Eastern countries share the same characteristics related to water. The region can no longer meet the growing demands on water, and water scarcity constitutes a constraint to further economic development.

The Middle East region is known for its:

- Natural scarcity of water supply
- Inefficient maintenance and improper operation of water facilities
- Poor coordination among countries
- Sharing common resources
- Increased water consumption linked to population growth, industrial and agricultural expansion, and increased urbanization.

Given the problems the region faces, water must be consumed efficiently at the point of use. Restrictions on water use must be enforced, particularly on farmers. Israeli settlements receive heavy subsidies for water from the Israeli government to promote the expansion of agriculture. Water consumption in more than 100 Israeli settlement is one-third that of the entire Palestinian population.

Palestine has been fully incorporated into the Israeli water management system to the general benefit of Israelis and to the detriment of Palestinians. Developments in the West Bank are carefully controlled by the Israeli Ministry Authority, working in collaboration with the water commission.

The West Bank depends on agriculture and thus on water; 85% of the water used in the region is for irrigation (¼ of its Gross Domestic Product). Only 17% of underground water supplies are available to the people in the West Bank. Arab communities and farmers get ⅓ of their total use from wells and ⅔ comes from springs and cisterns that collect run-offs.

Per capita income of the West Bank is only 20% of that in Israel. Palestinian farmers pay the same amount for irrigation water that settlers pay for drinking water. ⅔ of the population is refugees, half under the age of 15. 75% of population lives outside the cities and towns, either in villages or refugee camps. Camps are organized as small townships, highly and densely populated areas like towns, but lacking other attributes of civic life such as infrastructure, civic services and employment opportunities.

It is readily apparent that there is a large gap among the socioeconomic conditions of the families in the West Bank. Villages, towns and cities are a little more fortunate than the refugee camps. Therefore, our random questionnaire distribution process has taken into account such variation, and a total of 195 questionnaires were distributed in four cities, nine villages and three refugee camps in the north, middle and southern parts of the West Bank. A list of these locations is given in Table 5.

Results obtained from the questionnaire are as follows:

- 100% of the sampled families stated that available water resources are not enough to cover daily domestic and agricultural needs.

- 91% of the families receive water via a water supply network, 5% from cisterns, and 4% via water tanks and then stored in either cisterns or roof tanks.

- 60% of the sampled families stated that the best way to resolve the water problem is by collecting rainfall, whereas 40% stated that recycled water can be considered as a solution. Of this 40%, 82% of the families who were in favor of recycling water are from urban areas, 43% from rural areas, and 96% from refugee camps. This variation in the percentages originated from the fact that people living in the camps are suffering from the sewage problem more than those living in the villages or cities. Sewage systems inside the camp are uncovered and sometimes overflow into the streets. Therefore, they have reached a level where they want to get rid of the sewage by any means available. Furthermore, people living in the camps have reached a higher level of social acceptance of sewage treatment and reuse than people living outside the camps, because they are living with the problem everyday and merely need a solution. Accordingly, it seems that those living in refugee camps become more aware of the overall problem than others who do not live in these conditions. In the remote villages, people lack the proper environmental education programs and they do not experience the problem. However, the level of social acceptance in the cities might be a result of the high level of environmental awareness which exists in the cities due to cultural exchange.

- 100% of the sampled families were against the use of recycled water for drinking purposes or domestic use, but were in favor of it for agriculture and landscaping purposes.

Table 5. Distribution of Questionnaire in the West Bank

Category	Number of Samples
Cities	
Jenin	20
Nablus	20
Ramallah	15
Halhoul	10
Villages and Towns	
Silwad	15
Bani Na'im	10
Toubass	15
el Naqura	10
Burqa	10
Beiteen	10

Category	Number of Samples
Bateer	10
Kufur Ni'meh	10
Soreef	10
Refugee Camps	
Amari	10
el-Dheisheh	10
Ein Beit el Ma'	5

Table 6. Classification of Family Size and Monthly Water Purchase

Group	1	2	3	4	5
Family Members	2-3	4-6	7-9	>9	>9 and Garden
Monthly water purchase in NIS	<20 NIS	20-40 NIS	41-60 NIS	61-80 NIS	>80 NIS

J. Conclusion

The greatest water user in the Middle East is the agricultural sector, followed by industrial and then residential users. In order to combat the approaching water crises in the Middle East, water conservation techniques for agricultural users should be implemented swiftly and at full force. Keeping in mind the interaction between the irrigation system, land quality, and the crop, the implementation of drip irrigation must be carefully investigated throughout the region. This includes avoiding salt sensitive crops in saline areas, eliminating surface irrigation, and using reclaimed water for irrigation purposes.

Reclaimed water can also be applied for industrial and residential reuse. Reclaimed water plants must be managed strictly under the institutional operators and proper incentives for their use must be provided by the operators. Any area that does not have a fully developed sewage system should consider a more economic dual distribution system. The possibility of using techniques such as groundwater recharge must be fully explored by the operators. System operators must provide incentives to conserve water, whether it is through pricing to public education to legislation. Proper maintenance of infrastructure and leak detection as well as metering will assist substantially in reducing water losses.

Considering that industries use most of their water for cooling processes, conservation techniques and the application of cooling towers or cooling ponds are of prime importance. A proper water management scheme will reduce the amount of water wasted unnecessarily. Industries can use their on-site treatment facilities to treat water and sell it at a profit. Proper rinsing modifications can also be profitable. In addition, salt production from industry should be reduced so that agricultural users do not have to contend with saline water. As with any user, staff in the industry should be educated in proper water conserving behavior.

Although residential users consume the least amount of water in the Middle East, proper water conserving fixtures and behavior can help reduce the overall demand for water. Greywater use and correct landscaping practices are other techniques that follow in the water conserving and reusing philosophy.

The current change in the political circumstances must be associated with some change in the overall water use patterns in the region. An integrated regional planning approach could be considered to establish some new concepts whereby a redistribution of cropping patterns can be established throughout the region.