Food and Agriculture Organization of the United
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Proceedings

Expert Consultation for Launching the Regional Network on Wastewater Re-use in the Near East

Food and Agriculture Organization of the United Nations. Regional Office for the Near East

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Cairo, 2003

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Foreword

Water shortage and quality degradation are constraining the economy and development of most countries in the Near East region. As a contribution to addressing the issue, the use of marginal quality water in agriculture is becoming an integral part of water resources management strategies. It is now generally accepted that wastewater reuse in agriculture is justified on agronomic and economic grounds provided that care is taken to minimize its adverse impacts on health and the environmental. From the decision-making standpoint, the importance of wastewater as a valuable source of water is being gradually accepted and the benefits of investments in the sector are being recognized. This is illustrated by the number of countries that have initiated ambitious programmes for wastewater reuse during the past few years.

FAO and its Regional Office for the Near East (FAO RNE) have given the reuse of treated wastewater a particular attention for the past thirty years. This has resulted in the production of a series of reports, technical bulletins and manuals to promote the concept of efficient and safe reuse of treated wastewater in agriculture. Similarly, World Health Organization and its Regional Office for the Eastern Mediterranean (WHO/EMRO) have addressed the health aspects of wastewater reuse, through various forums and outputs. FAO and WHO have co-organized many regional events and forums on the subject, with contributions from the Regional Inter-agency Task Force on Land and Water Resources (IATF) which comprises eight organizations.

The idea of having a “Regional Network” on wastewater reuse emerged as a sound and necessary step to reduce duplicative efforts among national institutions, and to provide a cost-effective instrument for information exchange, institutional building, and training. Mutual benefit could also be reaped and shared by all countries from co-operation in such fields as exchange of experience, linkages with other regional and international organizations, research results, etc.

FAORNE and WHO/ROWA organized a Technical Consultation in November 2001, in Amman, Jordan. Participants to the event included designated Focal Points from several member countries, in addition to invited experts and technical staff from some of the agencies and organizations active in the subject. The objective of this Consultation was to launch the “Regional Network on Reuse of Treated Wastewater, to discuss and adopt the framework and working procedures of the Network and to elaborate a framework for future activities to be implemented at the national and regional levels”.

The Proceedings of the consultation presented here provide detailed information on the dimension of the problem in a number of countries and the precautions to be taken for the safe reuse of this resource. They further explain the objectives of the Regional Network and provide its basic organization and working mechanisms.

The Network is the result of joint collaborative efforts between countries of the Near East Region and several organizations concerned with the reuse of treated wastewater. Its establishment is the materialization of many recommendations made during the past few years, in response to both the potential benefits and the problems posed by the reuse of wastewater in the Region. By fostering technical cooperation among the concerned institutions, particularly the exchange of information and experience among its member countries, the Network should be able to reach its aim of contributing to solve the problems posed by the reuse of wastewater in the region. However, meeting its expected mandate will depend to a large extent on cooperation between its member countries, which are its owners, and on the importance they give to keep it alive and active. FAO and WHO will continue to provide support, but the lead should be taken by the Network members.

Cairo, December 2003

FAO/RNE and WHO/EMRO

Acknowledgements

This workshop could not have achieved its objectives without the contribution of many persons and the close collaboration of several agencies and organizations. Deep gratitude and appreciation is expressed to the Government of Jordan for the support provided throughout preparation for and holding of the consultation. The usual hospitality of this beautiful country and the good working conditions enabled the consultation to proceed in very favorable conditions. His Excellency Dr Faleh Al Nasser, Minister of Health, and His Excellency Dr Mahmoud Duwairy, Minister of Agriculture, opened the event in person and ensured that all necessary arrangements were made. Thanks and gratitude are expressed to both, and through them to the government of Jordan and the staff of their ministries, for their continuous support, cooperation and assistance.

Thanks are extended to all participants for their valuable contributions, be it for preparing and presenting important papers or for enriching the discussions. They include country representatives - Focal Points to the Regional Network – WHO/EMRO Temporary Advisers, FAO RNE consultants, delegates from regional organizations and bilateral cooperation agencies and staff from FAO and WHO. It is hoped that cooperation with these organizations and agencies will continue in the future, in support of the newly established Regional Network, and for the sake of the much needed synergy created by joint efforts.

Most of the draft papers submitted had to undergo some editing, without changing the main ideas conveyed by their authors. In other cases, no papers have been submitted although presentations were made during the consultation, but summaries prepared by the authors have been included in the proceedings. Thanks are also due to FAO and WHO staff who contributed their time for editing the papers.

The consultation was held in the premises of the WHO Centre for Environmental Health Activities in Amman. Officials and staff of the center provided valuable support for the smooth running of the event. Special thanks are extended to all those who contributed one way or another.

Recommendations

The meeting endorsed the establishment of the Regional Network described in the attached document titled “Presentation of the Regional Network on Reuse of Treated Wastewater” and called on WHO/EMRO and FAO/RNE to take the necessary steps towards the materialization of its establishment and functioning.

The meeting accepted that safe and efficient wastewater reuse, being a multi-sectoral task, requires the positive collaboration of all partners involved.

The meeting agreed that all aspects of wastewater management should be driven, by options, re the end of uses of reclaimed water since reclaimed wastewater can help meet increasing demands for agriculture and landscape irrigation, for industrial abstraction and for possible recharging of aquifers.

The meeting observed that capacity building in the wastewater reuse concept of risk analysis, in all its aspects, is urgently required in the region; a fact that involves the responsibilities of several ministries, agencies and semi-government organizations.

The meeting concluded that there is an urgent need launch a programme for strengthening national capacities including provision for technical assistance and training programmes in water quality management with emphasis on particular issues.

The Meeting agreed that the training needs assessment, for all aspects of wastewater reuse: planning, management, communication, networking, etc.

The meeting observed that with the data presently available, the determination of the burden of disease associated with wastewater reuse is not feasible. Ongoing WHO research on the burden of disease should incorporate water borne diseases as a determinant for the global burden of disease. Countries participating in this exercise are encouraged to facilitate this endeavour.

1 Experience on wastewater reuse in the Near East

DR MOHAMED BAZZA[1]

1.1 Introduction

Fresh water shortage is becoming an increasingly acute problem facing many nations in the world. In the Near East Region, some 16 countries out of 29 member states are classified as water-deficient, with less than 500m^3 per capita of the annual renewable fresh water resources (FAO, 1997a). Although the Near East Region occupies about 14 percent of the world area and embraces almost 10 percent of the world population, it only receives 3.5 percent of total precipitation and only 2.2 percent of the annual internal renewable water resources (IRWR). The per capita of these IRWR is hardly 22 percent of the global one. The average per capita in the Region is 1577m^3/yr, ranging from virtually zero in Kuwait to about 10,000m^3 in Tajikistan (FAO, 1998).

The most obvious uses of fresh clean water are domestic, industrial, and irrigated agriculture for food and fiber production. On a global scale, withdrawals for irrigation represent nearly 70 percent of the total consumption; those for industry 20 percent and those for municipal or domestic use 10 percent. In the Near East the situation is somewhat different. Irrigated agriculture accounts for an average of 91 percent of total water use whereas industry and the domestic sectors account for 4 percent and 5 percent, respectively. Table 1-1 and Table 1-2 give an overall picture of water resources in the 29 member countries of the Near East Region (FAO, 1997a).

The potential for irrigation to raise both agricultural productivity and the living standards of the rural poor has long been recognized. Irrigated agriculture occupies approximately 17 percent of the world's total arable land but the production from this land comprises about 34 percent of the world total. This potential is even more pronounced in arid areas, such as the Near East Region, where only 30 percent of the cultivated area is irrigated but it produces about 75 percent of the total agricultural production. In this same region, more than 50 percent of the food requirements are imported and the rate of increase in demand for food exceeds the rate of increase in agricultural production (Papadopoulos, 1995).

The rapid development of irrigated agriculture in the Near East has meant that easily accessible water resources, such as river flows and shallow good-quality groundwater, are now almost entirely mobilized. The resulting scarcity of water has caused national concern. It is gratifying however to report that planners are increasingly involved in devising ways to optimize available supplies, as well as to augment available water resources non-conventionally, this includes treatment of wastewater and its reuse for irrigation.

Water has always been used and reused by man. The natural water cycle - evaporation and precipitation - is one of reuse. Cities draw water from surface streams and discharge waste into the same streams, which in turn become the water supplies for downstream users. In the past, dilution and natural purification were usually sufficient to allow such a system to be satisfactory, but in recent years, population and industrial growth have meant that wastewater must be treated before its discharge to maintain the quality of streams. Treated wastewater is now considered an additional water resource.

As a substitute for freshwater in irrigation, wastewater has an important role to play in water resources management. By releasing freshwater sources for potable water supply and other priority uses, wastewater reuse makes a contribution to water conservation and takes on an economic dimension. Moreover, wastewater-use schemes, if properly planned and managed, can have positive environmental impact, besides providing increased agricultural yields. Environmental improvement and benefits accrue as a result of several factors (Mara and Cairncross, 1989), including:

- Prevention of surface water pollution, which would occur if the wastewaters were not used but discharged into rivers or lakes. Major environmental pollution such as dissolved oxygen depletion, eutrophication, foaming, and fish kills can be avoided. Planned reuse of wastewater

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for irrigation prevents such problems and reduces the resulting damage that if quantified, can partly offset the costs of the reuse scheme.

- Conservation of fresh water resources, or their more rational usage, especially in arid and semi-arid areas: freshwater for urban demand, wastewater for agricultural use.
- The use of wastewater for irrigation may lessen the degree of groundwater exploitation, avoiding seawater intrusion in coastal areas.
- The plant nutrients which may eventually pollute environment if raw wastewater or even treated effluent (especially organic matter, nitrogen, phosphorus and potassium) are discharged directly to the environment may serve as plant nutrients when applied as irrigation water. This reduces requirements for artificial fertilizers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere.
- The organic matter added through wastewater irrigation serves as a soil conditioner over time, increasing its water holing capacity. In addition through the soil humus build-up, preventing of land erosion and soil conservation could be achieved.
- Desertification and desert reclamation, through the irrigation and fertilization of tree belts.
- Improved urban amenity, through irrigation and fertilization of green spaces for recreation (parks, sports facilities) and visual appeal (flowers, shrubs and trees adjacent to urban roads and highways).

Some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agriculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant system.

The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines, both at low cost and with minimal operational and maintenance requirement. Adopting as low a level of treatment as possible is especially desirable in the Near East countries, not only from the point of view of cost but also in acknowledgement of the difficulty of operating complex systems reliably.

This paper aims at giving a brief overview of the following:

- Past and on-going activities and programmes on wastewater reuse in the Near East Region;
- Cooperation between FAO and countries of the Region for planning and implementing programmes and activities on wastewater reuse for agriculture;
- Needs of the countries in the Region regarding wastewater treatment and use, and FAO strategy for assisting in the fulfillment of these needs.

1.2 Activities on wastewater reuse for irrigation

Although the interest in reusing treated wastewater is comparatively recent in most Near East countries, the concept of using sewage effluent for agriculture is more than 2000 years old. Several Near East cities (Damascus, Fes, Marrakech, etc.) used untreated sewage effluent for irrigating fruit orchards and vegetables for many centuries. The following are the activities of some Near East countries on reusing treated wastewater for irrigation.

1.2.1 Cyprus

An island with a population of 700,000 in the Mediterranean and a vigorous tourism industry, Cyprus is facing two major obstacles to its continued development: a growing scarcity of water resources in the semi-arid regions of the country and degradation of water at its beaches.

In Cyprus the annual precipitation is about 500mm, 80 percent of which are estimated to be lost by evapotranspiration. Current total water use is $300Mm^3$/yr, almost 80 percent used for irrigation. The government perceives that a programme of water reclamation and reuse would address both problems. It is planned that the wastewater generated by main cities, about $25Mm^3$/yr, will be collected and used for irrigation after tertiary treatment. This will reportedly allow irrigated agriculture to be expanded by 8-10 percent, while conserving an equivalent amount of water for other use sectors (Papadopoulos, 1995).

The Nicosia treatment plant produces an outflow of about 3,500m^3/d, but the treated effluent is not used extensively for irrigation. The government has begun implementation of a new sewerage and wastewater treatment and reuse programme in two major tourist areas: Limassol in the southern coast and Larnaca and Ayia Napa-Paralimni in the southeastern coast.

For a small country such as Cyprus, conventional biological treatment and tertiary filtration and disinfection are more feasible and acceptable in some situations, such as tourist areas along the coast, than the use of stabilization ponds. In other areas, and depending upon the crops to be grown, ponds may be the proper alternative.

The Limassol area is expected to have a population of about 150,000 in 2010. The current project area will serve about 50,000. Later phases will serve another 50,000. The initial phase of the project, for which the World Bank is providing assistance, is to include laterals, main sewers and a conventional secondary (activated sludge) treatment plant of 20,000m^3/d; in addition to a sea outfall. The latter discharges the treated wastewater at a depth of 12m into the sea, 600m away from shore. It is designed to take only the initial phase effluent; storage for higher flows is to be provided in impoundment, to permit full use of the reclaimed water and limit sea discharges.

The initial phase of the project also includes, inter-alia, effluent and sludge reuse as well as studies to identify the range of appropriate options for cities in Cyprus. The study will identify the most promising uses, taking into account for each use the quality and quantity of the reclaimed water to be produced, potential markers, health hazards, cost and benefits, etc. The required treatment and infrastructure needed will be identified and pilot demonstration projects will be implemented. The second phase will include a review of the pricing policy for reclaimed water.

The Southeast Coast Sewerage and Drainage Project in Larnaca include sewerage systems, treatment plant and distribution system for the reclaimed water to the farmers' fields. Some service areas in Larnaca are low-lying and because of the potential danger from saltwater intrusion care has been taken to protect the quality of the reclaimed water. Financial arrangements for cost recovery are to be integrated (as a surcharge on water consumption) for the sewerage and the reclaimed water services.

Generally, in Cyprus reusing treated effluent for widespread irrigation is limited by certain economic, technical and public health uncertainties about the impact of such use. In assessing these hazards, various pathways for dissemination of undesirable pollutants and, therefore, the possible risks to health and the potential environmental damages have to be studied.

1.2.2 Egypt

In Egypt, about 96 percent of the country is desert, rains are rare, even in winter, and occur only in the north. Moreover, oases and wells are limited and cannot cover water needs in the region where they exist. Thus, other sources must be considered.

One of the main targets of the Water Master Plan, which started in 1977, was to analyze all forms of usable water resources, including wastewater reuse. At present, wastewater is estimated at 4,930Mm^3/yr. It is also estimated that Egypt has 22 operational wastewater treatment plants, and about 150 plants under construction (FAO, 2000).

The most readily available and economic source is the wastewater effluent from Greater Cairo, Alexandria and other major cities. Since 1900, sewage water has been used to cultivate orchards in a sandy soil area at El-Gabal El-Asfar village, near Cairo. The area gradually increased to about 10,000feddans (1 feddan equals nearly 0.42 ha).

In Egypt, no guidelines have yet been adopted but the 1984 martial law regulation prohibits the use of effluent for irrigating crops unless treated to the required standards of agricultural drainage water. The irrigation of vegetables eaten raw with treated wastewater, regardless of its quality level, is also forbidden. Crops chosen for cultivation using sewage effluent are those that cannot be contaminated, such as wood trees, palm trees, citrus, pomegranates, castor beans, olives and field crops, such as lupines and beans. However, no adequate planning, monitoring and control measures are being taken, and, because of this, spreading of certain diseases does occur. Several studies are being conducted in Egypt to detect changes in the physical and chemical properties of the soil caused by using sewage effluent. Other studies are attempting to identify the most appropriate irrigation methods for reusing wastewater. A third category of research is studying the effect of sewage effluent on legume growth under mineral fertilization.

1.2.3 Jordan

Of Jordan's total area of 88,945km^2, only 9 percent receive more than 200mm of rain annually. The average annual volume of rainfall over the country is estimated at about 7000Mm^3, but most is lost through evaporation. Total annual surface water resources are about 720Mm^3, in addition to 356Mm^3 of groundwater. Irrigation uses about 75 percent of the total demand. To meet future domestic and industrial water demands, treated wastewater has to be considered as a major source of irrigation water (FAO, 2000).

The produced wastewater in Jordan is reported to be 300Mm^3 and the volume of treated wastewater available was about 50Mm^3 in 1993 and 69Mm^3 in 1995. At present, the country has 16 major wastewater treatment plants. Six are wastewater stabilization ponds and 10 are conventional Electro-mechanical plants. Over 85 percent of the total wastewater generated is treated in waste stabilization ponds. This is clearly sensible given that over 95 percent of the country is desert, so land availability for such stabilization ponds is not a significant problem (Mara and Pearson, 1998).

Five of the waste stabilization pond systems serve relatively small communities of up to 50,000. The other system, at Al Samra, near Amman, is the largest in the Region: it serves Amman and the neighboring industrial city of Zarqa. The total population served by the Al Samra treatment plant is around 1.4 million.

Nearly 85 percent of wastewater in Jordan is reused for crop irrigation, representing around 12 percent of the total irrigation water use. All of the Al Samra treatment plant effluent is reused for irrigation. It flows 42km, via the Wadi Dhuleil and the Zarqa River and enters the King Talal Reservoir. The Al Samra effluent, together with effluents from the wastewater treatment works at Jarash and Abu Nuseir, contributes 20-40 percent of the inflow to the reservoir, the balance coming from the Zarqa River, into Wadi Rumeimin. Water from the King Talal Reservoir is released through a distribution network for unrestricted irrigation in the Jordan Valley. An area of around 10,000ha is irrigated, either solely or partially, with water from the King Talal Reservoir.

Effluent from Jarash wastewater treatment plant, averaging 600m3/d, is discharged to Wadi Jarash, a Zarqa River tributary. Jarash effluent is diluted about 1:1,200 by the base flow of Zarqa River, although much of this is effluent from Al Samra. Downstream of the junction point between Zarqa River and Jarash Wadi at the Jarash Bridge, the river water is used for unrestricted irrigation of about 3000 feddans of vegetables located on the banks of the river between the bridge and King Talal Dam.

The effluent from Salt wastewater treatment plant (4,500m^3/d) discharges into Wadi Shueib, where it is diluted with the base flow. When the stream reaches the Shueib Dam, over 10km away, treated effluent constitutes over 10 percent of the dry weather flow. About 1,000 feddans are irrigated along the banks of the wadi between the treatment plant and the dam. The annual stream flow of Wadi Shueib averages 9.8Mm^3, including 1Mm^3 as return flow. The dam's capacity is 2.3Mm^3. It is used as an artificial recharge basin, with a small portion of the water used for unrestricted irrigation in the Jordan Valley.

Effluent from the Aqaba stabilization ponds averaged 8,100m^3/d in 1995. Some of this effluent is used to irrigate a 0.5ha plot planted with barley and wheat. The rest is recharging a shallow semi-saline aquifer. Due to the concentration of algae in the effluent, clogging is a major problem in drip irrigation. Salinity build-up is another problem due to the high evaporation rate. Good management practices regarding salinity are needed.

The effluent from Mafraq wastewater treatment plant was estimated at about 1,520m^3/d in 1995. This effluent is used on-site to irrigate 270 feddans of available land. About 2400m^3/d is the effluent from Madaba treatment plant and 2,100m^3/d from Ramtha stabilization ponds.

Kufrinjeh wastewater treatment plant serves the towns of Ajloun, Anjarah, Ein Janneh and Kufrinjeh. The effluent of the plant is about 1,800m^3/d. To prevent polluting the Kufrinjeh stream, the effluent is injected into the salty fossil aquifer near the site.

In Jordan, standards for wastewater treatment and reuse in the form of a Martial law were introduced in 1982. In 1989, a new version of the Martial law was enforced which could be considered more liberal than the previous one. As in other countries of the region, problems have been reported such as the inadequate planning of the wastewater reuse scheme, insufficient medical control of the agriculture workers, inadequate training, and insufficient resources to monitor and control treated effluents.

1.2.4 Kuwait

Untreated sewage has been used for many years to irrigate forestry projects far from the inhabited areas of Kuwait. Effluent from the Giwan secondary sewage treatment plant was used to irrigate plantations on an experimental farm from 1956. Following extensive studies by health and scientific committees within the country and by FAO, the government of Kuwait decided to proceed with a programme of sewage treatment and effluent use. In all, by 1987 four sewage treatment plants were in operation: the 150,000m^3/d Ardiyah sewage treatment plant (secondary stage) was commissioned in 1971, the 96,000m^3/d coastal villages and the 65,000m^3/d Jahra sewage treatment plants were commissioned in 1984 and a small (10,000m^3/d) stabilization ponds treatment plant has also been installed on Failaka Island. The effluent from the Ardiyah, coastal villages and Jahra, activated sludge treatment plants was upgraded in the middle 1980s by the provision of tertiary treatment, consisting of chlorination, rapid gravity sand filtration and final chlorination (FAO, 1992).

Initially, the treated secondary effluent from the Ardiyah plant was distributed to the experimental farm of the Department of Agriculture at Omariyah. Trials were undertaken in the early 1970s to compare crop yields from irrigation with potable water, brackish water and treated effluent. A 850ha farm was established in 1975 by United Agricultural Production Company, under government license, especially for the purpose of utilizing the treated wastewater. The directors of this close shareholding company represented the main private organizations involved in Kuwait agriculture, in particular the local dairy, poultry and livestock farming organization. In 1975, only part of the area was under cultivation, with forage (alfalfa) for the dairy industry as the main crop, using side-roll sprinkler irrigation. However, peppers, onions and other crops were grown on an experimental basis, using semi-portable sprinklers and flood and furrow irrigation (FAO, 1992).

In Kuwait, the decision was taken to exclude all amenity uses from the treated effluent and to restrict agricultural use to safe crops. Furthermore, areas of tree and shrub planting and the agricultural farm were to be fenced to prevent public access. An efficient monitoring system for the treated effluent, the soil and the crops has been implemented since the experimental farm was initiated. The guidelines for tertiary-treated effluent quality used in irrigation are:

Suspended solids	10mg/l
BOD	10mg/l
COD	40mg/l
Cl2 residual	about 1 mg/l after 12 hours at 20 ˚C
Coliform bacteria	10,000/100ml for forestry, fodder and crops not eaten raw
	100/100ml for crops eaten raw

Even the tertiary-treated effluent meeting these guidelines is not to be used to irrigate salad greens or strawberries. Cadmium was the only heavy metal of concern and special attention was given to monitoring the effluent and crops for this element and to measuring Cd in the kidneys of animals fed on forage irrigated with treated sewage effluent. Agricultural workers dealing with sewage effluent are medically controlled as a pre-employment measure and given periodic (6 monthly) examinations and vaccinations. No outbreaks of infectious disease have occurred since this procedure began in 1976. The impact of treated effluent irrigated vegetables on the consumers has not been possible to assess because no segregation of vegetables produced in this way is effected in the market.

1.2.5 Morocco

Morocco is an arid to semi-arid country, despite the influence of the Atlantic Ocean which provides it locally with relatively abundant precipitations. Out of 150,000Mm^3 of annual rainfall, only 30,000Mm^3 are estimated to be usable (22,000Mm^3 as surface water and 8,000Mm^3 from aquifers). These resources are very unevenly distributed: the catchment areas of the Sebou, Bou Regreg and Oum er Rbia wadis alone represent two-thirds of the hydraulic potential of the country.

Approximately 11.5,000Mm^3 of water are used annually, including 3,500Mm^3 from groundwater. Nearly 93 percent of this amount is used to irrigate 1.2Mha, including 850,000ha irrigated more or less permanently throughout the year.

Most Moroccan towns are equipped with sewerage networks, frequently collecting also industrial effluent. The volumes of wastewater collected were estimated at 380Mm^3/yr in 1988 and are expected to reach 700Mm^3 in 2020. For Casablanca alone, the annual production of wastewater was estimated at 250Mm^3 in 1991, with forecasts of around 350Mm^3 in 2010. However, out of the 60 largest towns only 7 have treatment plants, but both their design and operation are considered insufficient. As a consequence, most of the wastewater produced by the inland towns is used to irrigate about 8000ha of crops after insufficient or even no treatment. A high proportion of the remaining water is discharged to the sea (Makhokh, 2000).

Wastewater reuse is not a major issue for the management of water resources in Morocco at the moment. However, the authorities think that the situation may be different in a few years. Due to the increase of the urban population by 500,000 inhabitants per year, a rapid increase in drinking water consumption in towns is expected. This will require the transfer of freshwater resources from one catchment area to another and the replacement of freshwater by wastewater for irrigation. The volume of wastewater available for reuse will also increase with the improvement of sewerage networks.

At least 60Mm^3/yr is reused, mainly as raw wastewater, sometimes mixed with water from the wadis into which they spill. The irrigated crops are mainly fodder crops (4 harvests of corn per year around Marrakech), fruit trees, cereals and produce. The growing and selling of vegetables to be eaten raw is in principle prohibited.

While reducing its environmental impact on the receiving waters, the lack of wastewater treatment before reuse in inland cities results in adverse health impacts, a high incidence of waterborne diseases exists in Morocco. Improvement in wastewater reuse methods and in the quality of reused water for irrigation is recognized as essential. Major improvements are needed urgently because of the strong migration of the rural population towards the towns and the very fast demographic expansion.

The country does not have yet any specific wastewater reuse regulations; reference is usually made to the WHO recommendations. There are a number of controlled pilot wastewater reuse irrigation schemes currently in place in the country:

- Quarzazate: A UNDP-WHO-FAO project covering 5ha and combining wastewater treatment system and crop irrigation with effluent.
- Agadir: A pilot plant is located in Ben Sergao, a version of soil-aquifer treatment (infiltration-percolation) to treat 750m^3/d of wastewater. Effluent is applied to 5 infiltration basins of 1,500m^2

each. Percolation and groundwater recharge take place before pumping for irrigation of crops, grass, alfalfa, wheat, and corn. 40,000m^3/d could be treated using such a system.

- Rabat: A pilot plant with high rate algal ponds and irrigation of vegetable crops is under study.
- Marrakech: A system with stabilization ponds followed by irrigation system has been tested. The amount of wastewater that could be treated and reused in this area is about 70Mm^3/yr.

1.2.6 Saudi Arabia

The Kingdom of Saudi Arabia, being an arid country, lacks perennial rivers. Groundwater constitutes the main natural water supply, of which agricultural irrigation consumes a major share (90 percent). Rainfall is low and therefore recharge of the deep sedimentary aquifers is insignificant. Over-extraction of groundwater to meet the demand in various sectors means that the water levels of non-renewable aquifers are declining significantly. Wastewater effluent can supplement these demands in non-domestic sectors.

The Kingdom's policy is to use all available treated municipal wastewater particularly for agriculture. Reclaimed wastewater can help meet increasing demands for agriculture and landscape irrigation, for industrial abstraction and for possible recharging of aquifers. At present, about 674Mm^3 of reclaimed wastewater is available in Saudi Arabia, the reused portion is estimated at only 217Mm^3/yr.

Some projects have been completed or are planned for using treated wastewater. Sites where wastewater is presently used (or planned to be) include Jubail, Medinah, Jeddah and Qassim. In Riyadh, several projects are already complete or underway. At the new campus for King Saud University, treated wastewater is used for a power-plant cooling water (3000m^3/d) and for landscape irrigation (1,000m^3/d). The Ministry of Foreign Affairs Housing Project uses treated wastewater through a drip irrigation scheme for its extensive landscape gardening. The new King Khalid International Airport also uses treated wastewater for landscape irrigation.

Using effluent from the Riyadh Wastewater Treatment Plant for industry, landscape and agricultural irrigation is one of the largest projects underway in Saudi Arabia. This plant treats over 250,000m^3/d of wastewater. The treated effluent has been used by the Petromin Oil Refinery in Riyadh, and for agricultural irrigation at Dirab and Dariyah. A 1000mm diameter, 55km transmission line to Dirab carries 92,000m^3/d of treated wastewater, while the 300mm diameter, 50km transmission line to Dariyah carries 70,400m^3/d for agriculture. In the Riyadh area alone, about 4,000ha are expected to be irrigated by wastewater.

In Saudi Arabia regulations for wastewater reuse require secondary and tertiary levels of treatment for unrestricted irrigation (Papadopoulos, 1995).

1.2.7 Syria

In Syria, agriculture is an important economic sector. In addition to the role it plays in enhancing food security, it accounts for 60 percent of non-oil exports. The sector employs over 27 percent of the total manpower in the country.

In view of the harsh conditions of the climate and its capricious nature, irrigation is given a high priority as a means to boost agricultural production and to ensure a high level of food security. The total irrigated area in Syria is in the range of 1.2Mha, with water coming from groundwater for 61 percent or close to 700,000 ha, and from surface water sources for the rest.

Irrigation is faced with the major constraint of water scarcity. The total inland renewable water resources are estimated at 10,500Mm^3/yr, including groundwater (2,300Mm^3), springs (3,700Mm^3) and internal surface water (4,500Mm^3). The total water consumption in 1998 was estimated to be 13.0 BCM, including consumption from the so-called unconventional water sources. Irrigation consumes nearly 89 percent of the total water use, while the remaining 11 percent are used for domestic and industrial purposes. The water resources of the country, especially groundwater, have been exploited to support agricultural development, which has expanded rapidly over recent years.

Until recently, the amount of municipal wastewater was small because of the limited population in cities. Most of these waters were not used because of their quality on one hand, and the availability of good quality water for irrigation on the other. With the increase of urban population and generalization of drinking water supply connection, particularly in large cities, the volume of municipal wastes increased rapidly. The volume of wastewater in Syria was estimated at 451, 650 and 1,642Mm^3/yr, respectively for 1995, 2000 and 2025. At the same time, good quality water started to shrink around cities, which led farmers to start using untreated wastewater. However, this wastewater was generally mixed with good quality water and was used essentially for irrigating trees and forage crops (FAO, 2001).

A treatment plant was constructed in 1998 and is intended for all the municipal wastewater from the City of Damascus and its surroundings. The mean treatment capacity is 485,000m^3/d, whereas the maximum can reach 970,000m^3/d. Discharge from the plant is presently 2.5 to 3.0m^3/s or 90-100Mm^3/yr, and is expected to reach 130Mm^3/yr, after the completion of the sewerage system in Damascus City and its surroundings.

Public investments were allocated for the construction of several treatment plants in recent years. As a result, three units are currently operating (Damascus, Hems and Salamiya) and two are in the final stage of construction and expected to be operated by the end of the year 2001 (one in Hama and the other in Aleppo).

Except part of Damascus sewage waters, for most cases in Syria, the collected raw sewage from the cities, villages and other residential areas where sewerage systems are in operation, is used without any treatment either for direct irrigation of agriculture crops or, if not disposed in the sea, is disposed in water bodies which are used for unrestricted irrigation (FAO, 2001).

1.2.8 Tunisia

Tunisia is rapidly approaching full utilization of its available water resources. A comparison of water resources and requirements shows that although water requirements will be generally met up to 2015, some areas (coastal and southern) are already suffering from water shortage and groundwater overexploitation. Furthermore, existing water resources often have a certain content of salts and are highly exposed to different pollutants of industrial, domestic, and agricultural origins.

In Tunisia, wastewater is reclaimed in about 44 treatment plants with a total design capacity of 130Mm^3 per year. Several of them are located along the coast to protect coastal resorts and prevent sea pollution. Municipal wastewater is mainly domestic (about 82 percent domestic, 12 percent from industries and 6 percent from tourism) and goes through secondary biological treatment. No further treatment is provided due to cost. The treatment processes vary depending on wastewater origin and local conditions. Out of 44 treatment plants, 15 are activated sludge (medium and low rate), 2 trickling filters, 6 facultative and 4 aerated ponds, and 17 oxidation channels. Five treatment plants are located in the Tunis area and produce about 60Mm^3/yr of treated wastewater. They account for 57 percent of the country's treated effluent, estimated at 24Mm^3 in 1995. This means that in 1995, only 21 percent of the available treated wastewater was reused.

Irrigation with treated wastewater is well established in Tunisia. Wastewater from la Cherguia treatment plant in Tunis has been used since 1965 to irrigate the 1,200ha of la Soukra (8km North East of Tunis) and save citrus fruit orchards as aquifers had become overdrawn and suffered from saline intrusion. The effluents from the treatment plant were used, mainly during spring and summer, either exclusively or as a supplement to groundwater.

Water from la Cherguia's secondary sewage treatment plant is pumped and discharged into a 5,800m^3 pond before storage in a 3,800m^3 reservoir. The water is then delivered by gravity to farming plots through an underground pipe system for an area of about 6,500ha (Bahri, 1998).

Different problems and constraints have been reported such as the inadequate planning of the wastewater reuse projects, the insufficient resources to monitor and control treated effluents and products, insufficient medical control of the agriculture workers, some equipment and management problems, and the inadequate education and training for farmers and extension services.

1.2.9 Yemen

Yemen occupies a significant portion of the southwestern part of the Arabian Peninsula, with a coastline of some 400km along the Red Sea and about 1200km along the Arabian Sea. The population of the country was 16 million in 1996, and has been growing at a rate of 3.7 percent. It is expected to reach 25 million by the year 2015 and 34 million by the year 2024.

Over the last thirty years there has been a rapid increase in the irrigated area, up from 230,000ha in 1970 to 488,000ha in 1996, and most notably a ten fold increase in well irrigation, from 37,000ha in 1970 to 368,000ha in 1996. Production pattern has intensified, with a rapid shift away from subsistence crops to high value market-oriented production.

Irrigated agriculture is estimated to use almost 93 percent of water. Total water demand for the country during 1996-2015 is estimated to increase from 2817Mm^3 in 1996 to 3970Mm^3 in year 2015. Sectoral-share for the base year includes 90 percent for agriculture, 8 percent for domestic water supply and 1.5 percent for industry. These shares are likely to change towards 2015, the share of agriculture is forecast to be reduced to 84 percent while those of the municipal and industrial sectors would increase to 14 percent and 2 percent, respectively.

Major cities such as Sana'a and Taiz are desperately short of water. Irrigated agriculture is in jeopardy, irrigation efficiencies are low, operation and maintenance of existing systems is practically absent, water quality is deteriorating rapidly, and in coastal areas there has been intrusions of salinity from the excessively saline seawater around the country (FAO, 1997b).

With progressive coverage of urban water supply and sewerage services, increasing quantities of wastewaters are being produced. It is estimated that, some 74Mm^3/yr of effluent will be potentially available for reuse in the near future, and that up to 15,000ha of land will be irrigated with treated wastewater.

At present, wastewater treatment plants in Yemen are as follows: Sana'a (50,000m^3/d), Hodeidah (18,000m^3/d), Taiz (17,000m^3/d), Ibb (5,000m^3/d), Dhamar (5,000m^3/d), Radaa (3,000m^3/d), Al Byda (500m^3/d), Haja (1500m^3/d), Aden (old 15,000m^3/d), Tarim (3,500m^{3}d), and Al Mukalla (8,000m^3/d). The planned wastewater treatment plants in the near future are as follows: Aden (new 60,000m^3/d), Bagel (3,500m^3/d), Bit El Fakih (2,500m^3/d), Omran (2,400m^3/d), Yarim (3,500m^3/d), and Zabid (3,800m^3/d). Most wastewater treatment plants in Yemen are suffering from lack of maintenance and operational control (Sorour, 1999).

Due to the very high demand for water, particularly for irrigation, farmers throughout the country use even untreated wastewater freely for irrigation at their own initiative, and seemingly without any concern about the quality of water used. Such use, which is mainly for growing corn, wheat, sorghum and barley, is currently taking place in an increased rate in Taiz and Aden.

It should be noticed that, there is no formal national policy on wastewater reuse until now, although the practice is encouraged by officials of the Ministry of Agriculture and Irrigation. In the absence of a formal policy and governing legislation with appropriate regulations, reuse is widespread through private initiatives without surveillance and public health safeguards.

1.3 Cooperation between FAO and countries of the Near East Region

FAO started working on the subject of wastewater reuse in the Near East Region many years ago. The following activities summarize the efforts that have been done in cooperation with many countries and international organizations.

1.3.1 Cooperation through projects

Several countries in the region were provided with support and technical guidance for forming national programmes in the field of treating and reusing sewage effluent for irrigation. Sample projects include the following:

REUSING WATER FOR AGRICULTURE PURPOSES IN MOROCCO

This national project for demonstration and applied research became operational in Morocco in 1988, with UNDP financing and with FAO as the executing agency. It aimed to evaluate the effects of reusing wastewater for agriculture irrigation. The evaluation and identification objectives of the techniques in reusing water for agriculture were defined along with the project data. The following scientific evaluation was performed:

- Study the behavior of different cultures on soil
- Study the effects of raw and treated wastewater on soil
- Comparative study of methods of irrigation and adaptability of irrigation material.

The budgetary support for the project was secured by both the UNDP and the Moroccan government, while FAO was responsible for technical assistance, technical follow-up of the project activities, training abroad and for purchasing and testing irrigation project equipment.

FAO REGIONAL PROJECT ON WASTEWATER TREATMENT AND REUSE FOR CYPRUS, EGYPT AND JORDAN

Through its Technical Cooperation Programme (TCP), FAO financed this project that involved Cyprus, Egypt and Jordan, and which started in 1988 at the main duty station of Jordan's Water Authority in Amman. The project main objective was to assist participating countries to improve the efficiency of water use for crop production, through properly treating and using sewage effluent for irrigation. The detailed goals of the project were:

- Help participating countries to develop the technology of sewage treatment and reuse
- Recommend the most suitable technology for sewage treatment
- Study the impact of water reuse on soil and crops
- Draw up the proper specifications for reuse
- Select suitable crops and proper irrigation methods
- Train personnel from participating countries
- Implement pilot projects for water reuse in participating countries
- Encourage other countries to join the project activities.

The Project main outputs included substantial training, technical assistance in participating countries, demonstration sites and some equipment for quality testing and monitoring.

The first training seminar was held in Cyprus in 1988 and benefited 40 participants, of whom 12 from Egypt and Jordan. The main topics were wastewater treatment plant management and design as well as reuse in agriculture. A second training seminar took place in Jordan the same year with 70 participants, of whom 14 from Cyprus and Egypt. The main topics were wastewater recharging of groundwater reservoirs, health aspects and safety factors in treatment plants. A third seminar took place in Cairo and concerned also 70 participants, including 35 from Cyprus, Iraq, Jordan, Morocco, Saudi Arabia, Sudan, Tunisia, United Arab Emirates and Yemen.

FAO provided also consultancy services to the project as required. A number of FAO international consultants and two from the World Bank/UNDP visited Jordan and Cyprus, to advise on project activities. Their visits resulted in comprehensive reports and plans for the cooperation programme between these countries.

A 45ha demonstration site was selected, planned, designed and implemented in Jordan, 1.5km to the southwest of the Al-Samra stabilization ponds. Three different crops were investigated (beans, wheat, and alfalfa), in addition to comparison between treated wastewater and fresh water.

ASSISTANCE TO POLICY FORMULATION AND DEMONSTRATION OF SUSTAINABLE REUSE OF WASTEWATER IN AGRICULTURE IN EGYPT

Through its Technical Cooperation Programme, FAO financed this project which started in 1995 for a period of 2 years. The objective of the project was to assist the government of Egypt to:

- Formulate a national policy and strategy for the comprehensive management of treated wastewater,
- Establish a 5ha wastewater reuse farm and a programme to demonstrate appropriate on-farm irrigation methods,
- Build national capacity, with particular reference to trained human resources for further training of national staff.

The Project main achievements and outputs can be summarized as follows:

- A Training of Trainers (TOT) workshop was held in Cairo for 2 weeks, for 10 participants. The main topics were wastewater quality guidelines for agricultural use, wastewater treatment methods and agriculture use of sludge.
- Establishment of a 5ha demonstration farm at Abu-Rawash area, adjacent to Abu-Rawash treatment plant, which is a primary treatment system planned to be upgraded to include secondary treatment. In addition, equipment for irrigation and quality monitoring was provided.
- A second workshop around one-day visit to the demonstration plant, by over 50 participants.
- Provision of technical assistance through consultancy services by four international consultants, for periods ranging from 3 to 12 weeks to advise on project activities. These visits resulted in several field reports on the subject.

STRENGTHENING CAPACITY FOR THE REUSE OF TREATED WASTEWATER IN IRRIGATION, SYRIA

Through its Technical Cooperation Programme, FAO will be financing this project during the coming two years. The overall objective of the project is to build the capacity of the Ministry of Irrigation, for the safe and efficient use of treated wastewater for agricultural production. In particular, the project objectives are:

- Formulate a strategy in the Ghouta region for the comprehensive management of water resources, including wastewater with special reference to its utilization for crop production, to be used as a pilot strategy for other regions;
- Establish a 10ha wastewater reuse pilot area and a programme to demonstrate appropriate on-farm irrigation methods, crops and management practices for the safe use of treated wastewater in crop production;
- Build national capacity for the safe and efficient reuse of treated wastewater in agriculture, through the following:
    - Training of engineers and technicians on treated wastewater reuse;
    - Contributing to the equipment of a laboratory for the analysis of treated wastewater, and train the laboratory staff on measurement methods;
    - Establishing a programme for quality control monitoring of reuse of wastewater in irrigation, and providing the necessary training for implementation of the programme;
    - Familiarize field staff with the safe use of treated wastewater for irrigation.

ASSISTANCE TO WATER RESOURCES COMPONENT OF LAND AND WATER CONSERVATION PROJECT, IN YEMEN

This project started in Yemen in 1995 for 6 years, with funding from the World Bank/IDA. It had several sub-components including the enhancement of policy and institutional building in the field of wastewater treatment and reuse in agriculture. The achievements in this area were considerable and the first of their kind to tackle the issue, gather information and create a basis for following activities. FAO provided technical assistance through several missions by qualified consultants that gathered and treated data on the various aspects including:

- Location, availability, quality characteristics, treatment, use and disposal of wastewater in the country;
- Potential for wastewater reclamation and reuse for irrigation;
- Potential adverse health and environmental impacts that may result from the use of wastewater;
- Technical documents with special reference to conditions that prevail in Yemen on safe use of wastewater in crop production.

In addition, substantial training was provided to a large number of national counterparts and officers on various aspects of wastewater treatment and reuse for irrigation. This included in particular a large workshop held in 1997 in Sana'a, on the topic: Water Resources Management in Yemen with Emphasis on Wastewater Treatment, Reclamation and Reuse and Effluent Disposal. The workshop, which was attended by over 50 participants, targeted the evaluation of currently applied technologies on reclamation and reuse of marginal waters in Yemen, as well as the assessment of quality requirements of reclaimed waters for various uses. Further training was also organized in Sana'a to build national capacity, with particular reference to trained human resources for further training of national personnel on a permanent basis.

WATERSHED MANAGEMENT AND WASTEWATER REUSE IN PERI-URBAN AREAS OF YEMEN

With support from the Netherlands Bilateral Cooperation and FAO's technical assistance, the project came as a follow-up to the above one and built on its foundations. It started in 1998, for an initial duration of 3 years, with a strategy that opted for a multi-faceted and cross-sectoral approach, offering the best opportunities for a sustainable development in the periphery of rapid expanding cities in Yemen, in the coming years. In addition it focused on the most optimal use of treated wastewater for the restoration and plantation of vegetation, fodder, and (if possible) also food production, as well as the conservation and upgrading of the existing vegetation, the protection of soils and the implementation of agreed land use schemes in the selected sites.

The project is implemented with the participation of grassroots communities and in close cooperation with them, as it aims to training also non-staff capacities and promoting group and community work. Such training and community organization have been organized in four of the main cities in Yemen (Sana'a, Aden, Hodeidah and Dhamar.) Through trained nationals and international staff, awareness was created among farmers on the danger of using untreated wastewater in agriculture and on the means of overcoming these dangers. In addition to training, many pamphlets were prepared and distributed to show the precautions that should be taken for the safe reuse of treated wastewater. In the Sana'a area, the project assisted the beneficiary community for establishing the so-called Wastewater Reuse and Valley Co-operation for Land Resources Management, to manage the safe reuse of treated wastewater and sludge.

The project developed a long-term monitoring programme, which could be used by plant operators in order to keep all records of plants performance. Its friendly use was achieved through the elaboration of a computer software (Expert System) that contains the database, the monitoring system, start-up procedures, the list of routine maintenance tasks, and possible problems and recommended actions.

The project also prepared a User Manual in English and Arabic, dedicated to plant operators. It includes precise rules and instructions of maintenance, operation, monitoring, troubleshooting, and possible problems and recommended action.

1.3.2 Workshops and publications

In addition to field projects, FAO has undertaken a range of activities aimed at macroscopic capacity building in member countries with planning and managing the use of treated wastewater for irrigation. This includes the organization of seminars and workshops and the publication of technical bulletins and manuals that are made available to decision-makers, technicians and users. Some of the major publications and various types of forums are summarized below:

- In 1985, a Regional Seminar on the "Treatment and Reuse of Wastewater for Irrigation" was held in Nicosia, Cyprus. Proceedings of the Seminar were published in 1988.
- Following this seminar, several countries in the Near East Region requested the assistance of FAO, and FAO responded by executing several projects in countries of the Region in order to develop a strategy on the treatment and reuse of treated wastewater. This assistance included organizing a Regional Workshop, held in Amman in August 1986. Following this workshop, FAO financed the Regional Project, which, as mentioned before, included three countries of the Region, Cyprus, Egypt, and Jordan.
- FAO convened a Regional Seminar on "Strengthening the Near East Regional Research and Development Network on Treatment and Reuse of Sewage Effluent for Irrigation", in Cairo, December 1988. The FAO Regional Office for the Near East published the proceedings of this seminar entitled "Wastewater Reclamation and Reuse" in 1991.
- In 1989, a joint mission of FAO/World Bank/UNDP/WHO visited eight countries in the Region to identify projects on the reuse of wastewater. The report of this mission was presented at the 7th World Congress on Water Resources, Rabat Morocco, May 1991.
- An Expert Consultation was held on the "Safe and Efficient Irrigation with Treated Sewage Water in the Near East Region" in Rome, in March 1991. This Expert Consultation was instrumental in providing the framework for FAO involvement in the reuse of wastewater for irrigation in the following years. A draft of the FAO Irrigation and Drainage Paper No 47 on "Wastewater Treatment and Use in Agriculture" was presented at the above Expert Consultation, the final edition was published in 1992.
- FAO Regional Office for the Near East published in 1993 a series of 7 technical bulletins, addressing planners, agriculturists, and extension agents involved in irrigation projects, using wastewater.
- FAO Regional Office for the Near East published in 1995, a paper entitled "Wastewater Management for Agriculture Production and Environmental Production in the Near East Region".
- The International Action Programme on Water and Sustainable Agricultural Development (IAPWASAD), lunched in 1992 in close cooperation with other UN organization, was specially designed to promote and initiate national action plans for the efficient and sustainable use of water in agriculture. One of the actions called for was the preparation of strategies for the rational use of wastewater for agriculture. In a number of countries, including Egypt, Syria and Turkey, such national action programmes were initiated. Also within the framework of sustainable development and food security, FAO published in 1996 guidelines on "Control of Water Pollution from Agriculture", FAO Irrigation and Drainage Paper No 55.
- Based on procedures developed and studied in a FAO project in Chile, FAO published in 1997, in its Water Report Series (No. 10), a paper on "Quality Control of Wastewater for Irrigation Crop Production". The paper describes an approach that promotes safe production areas, as an interim measure, whenever treated wastewater does not meet health production standards for unrestricted irrigation. This approach is utilized in several developing countries including Kuwait and Tunisia.
- The Regional Inter-agency Task Force on Land and Water Resources (IATF), spear-headed by FAO Regional Office for the Near East and WHO called, in December 1997, for an Expert Consultation on "Reuse of Low-Quality Water for Sustainable Agriculture" which was held in Amman, Jordan. Participants at this Consultation requested IATF to take the necessary steps to initiate actions on preparing a "Wastewater User Manual" and establishing a "Network on Wastewater Reuse". FAO Regional Office for the Near East published the proceeding of this Consultation in 1998. In response to these recommendations, the Regional Office, in co-ordination with WHO Regional Office, published in 2000, the "User Manual for Irrigation with Treated Wastewater" in Arabic and English. The Manual is intended to help farmers, irrigation operators, and extension agents, using treated wastewater.

- During the first session of the "Agriculture, Land and Water Use Commission for the Near East Region (ALAWUC)" held in Beirut, Lebanon, in March 2000, the commission recognized the importance of establishing a regional network for research and management of water use in agriculture, including the use of low quality water.
- In November 2000, a Regional Workshop on "Water Quality Management and Pollution Control" was held in Cairo, Egypt. Proceedings of the workshop will be published in 2001. The participants recommended the establishment of a "Regional Network" as a vehicle to share experience in use of low quality water in agriculture.

1.4 Implications of FAO activities

As a result of cooperation between FAO and countries in the Near East Region, the situation concerning wastewater reuse has changed and can be described as better than before. At present, in all countries that were involved in these activities, there is a background on wastewater reuse for restricted irrigation, with varying levels between countries. From the decision-making standpoint, the importance of wastewater as a valuable source of water is gradually being accepted and the benefits of investment in the sector are well recognized. Codes of practice and legal regulations concerning the use of the treated effluent have been developed in several countries of the region or are under preparation. As a result, there is some control in these countries where the situation appears to be substantially different from that in the countries that have not yet implemented programmes on wastewater reuse.

Training, sensitizing and awareness creation have concerned a high number of persons from different levels (policy-makers, technicians, farmers and communities.) There are currently a large number of recognized experts and qualified engineers and technicians in the Region, to the point where the Region is near self-sufficiency in terms of manpower to run future activities. The subject of wastewater treatment and safe reuse for environment control is also incorporated in the training curricula of several universities and institutions of the Region. The global area under irrigation from treated wastewater has also increased substantially over the past twenty years.

For example, in Egypt, the amount of treated wastewater reused for agriculture has increased from 200Mm^3 in 1993 to 700Mm^3 in 2000. New wastewater reuse projects have been established in Ismailia, Luxor, Sadat City, Borg El Arab, and the New Valley. In Jordan, the amount of reused wastewater for agriculture has increased from 50Mm^3 in 1993 to 69Mm^3 in 1995. Also a new version of the Martial law on wastewater treatment and standards was enforced. Moreover, crop restriction is enforced and no vegetables cooked or uncooked are allowed to be irrigated with treated wastewater. In Cyprus, guidelines concerning the quality and use of treated wastewater have been formulated and adopted. These guidelines are followed by a code of practice intended to further ensure public health and environment. Also demonstration plots using treated wastewater from sewage plant of Limassol-Amathus have been established. After 5 years of the establishment of these demonstration plots, it is documented that under Cyprus conditions the use of treated wastewater for agriculture purpose is the best from the economic, environmental, and public health aspects.

Generally, most countries of the region that embarked on their own, or in cooperation with FAO and other organizations, have included treated wastewater as an important dimension of water resources. Some countries, such as Kuwait, Jordan, the Gulf States, Saudi Arabia, and Cyprus, have a national policy to reuse all treated wastewater effluents and have already made considerable progress towards this end. A second category of countries are mid-way in the process and have already accomplished tremendous advances in various aspects, from policy on wastewater safe reuse to strategies and their implementation. The situation however is lagging behind in several other countries where the subject matter has received no attention so far, for various reasons. These countries are currently faced with the most acute problems and needs for capacity building and adoption of strategies on treatment and reuse of wastewater. These countries are at the foremost level of need from policy-makers, investors and donors for assisting them to lift the constraints and upgrade their capacity.

The efforts undertaken over the past three to four decades, and particularly since the eighties, have achieved substantial positive results as described above. However and as expected in view of the limited time since these efforts have started, the situation is far from being perfect in most if not all countries.

Several problems and constraints still persist and need to be addressed. These include in particular the following:

- Policy and Planning: Clear policies are lacking or, when they exist, they have deficiencies. No adequate planning, monitoring and control measures are being taken, and, because of this, spreading of certain diseases in the region is quite often.
- Regulatory Mechanisms: Lack of standards, the absence of suitable regulatory criteria and mechanisms. Where control and regulation exist, they are generally not enforced.
- Technical: The overall technical capacity is still low, particularly at the field level, with varying levels between countries. From the sustainability standpoint, most wastewater treatment plants in the region are suffering from operational control problems, and lack of routine maintenance. As a result the effluent in most cases does not comply with the recommended guidelines.
- Institutional: Responsibility is diluted among several institutions, with a lack of clear responsibility and cooperation mechanisms among the various authorities involved in the overall scheme of collection, treatment and reuse of wastewater. At present, this is the most critical issue for the countries of the Near East Region.

1.5 FAO future plans

It is now widely recognized that wastewater reuse constitutes an important and integral component of the comprehensive water management programme of each country, more so in “Water scare” countries such as the great majority of the countries in the Near East Region. Although wastewater reuse for agriculture is widely practiced in the Near East Region, FAO has identified that this practice, while highly desirable, is often poorly regulated and suffer from a lack of standards, policy deficiencies, and the absence of suitable regulatory criteria and enforcement. This leads to economic inefficiency, public health problems, and environmental degradation. Within the region, there is also a wide range of experience that can be beneficially shared among the countries of the region.

At the request of its member countries, FAO plans for the near future include the establishment of a Regional Network to coordinate between the various stakeholders and assist countries in several ways to build lift the prevailing constraints.

1.5.1 A regional network on wastewater

Following a joint collaboration effort of the Regional Inter-Agency Task Force on Land and Water Resources (IATF), FAORNE and WHO/EMRO convened an “Expert Consultation on Low-Quality Water Reuse for Sustainable Agriculture”, which was held in Amman, Jordan, during the period 15-18 December 1997. In order to strengthen regional co-operation in the field of treatment of wastewater and its use for irrigation, three alternatives were considered: 1) strengthening the existing relevant institutions; 2) formation of a regional network; and 3) establishment of a specialized center. After considering these alternatives, the Consultation concluded that the first step for strengthening co-operation among the countries of the region is to establish a “Network on Wastewater Reuse”. The consultation further recommended that:

Priority action for the establishment of the Network is to collect information on existing institutions, activities, projects, and key professionals in the field of wastewater reuse. The experiences and resources of existing networks at some institutions such as WHO/CEHA, ACSAD and others should be utilized.

At its 5th meeting in 1998, the IATF members proceeded with further discussions on the establishment of the proposed Regional Network. They felt that since there are few available and accurate data on this subject, it would be necessary to prepare an assessment report, regarding the status of wastewater treatment and reuse in the countries of the region. This suggestion was unanimously endorsed and the meeting recommended that:

A status report on wastewater reuse in the region will have to be prepared as a first step towards establishing the Network.

In fulfillment of the above, FAO Regional Office for the Near East prepared a detailed questionnaire " Wastewater Information Sheets" to be filled in at the country level. The collected Wastewater Information Sheets for the 29 countries of the region constituted a preliminary "Status Report" on Wastewater. The sheets will be continuously updated and validated in order to include the latest information on the status of wastewater and its use in agriculture.

For twelve countries, information gathered could be considered as fairly acceptable (Bahrain, Cyprus, Egypt, Iran, Jordan, Kuwait, Libya, Malta, Saudi Arabia, Tunisia, United Arab Emirates, and Yemen). For six countries (Lebanon, Morocco, Oman, Qatar, Syria, and Turkey), more information is needed. For eleven countries (Afghanistan, Algeria, Djibouti, Kyrgyzstan, Mauritania, Pakistan, Somalia, Sudan, Tajikistan, and Turkmenistan), almost all information is missing. In general, very little information are available on sludge production, treatment and use.

1.6 General conclusions

The available conventional water resources in a great part of the Near East Region are already being exploited and water availability will in the near future be a limiting factor for further development. The expected population growth, the development of towns, industries and tourism, as well as the necessary increase in the production of energy and food, will all require a sensible management of the available water resources and the development of additional sources. Apart from that, the increased water consumption will provoke a greater sea and coast pollution.

To overcome these limitations, there is a need to manage adequately the existing resources for their efficient use and to increase supply where possible. A means for doing so is to develop, thoroughly and in time, new unconventional water resources, such as wastewater, along with the implementation of necessary measures for its reuse, sanitary protection and control.

The potential of wastewater reuse in agriculture and for other purposes in the Near East Region is high. The cost benefit of such uses is well demonstrated and so are the environmental impacts when the use is adequately planned and managed.

Recent experience in the Near East Region has shown that the practice of wastewater reuse in agriculture can be greatly improved, with limited costs and substantial outputs in terms crop production and environmental control. The experience has also created a great deal of knowledge and capacity in the Region. In all countries where the experience was initiated, it resulted in building a background, which in certain cases became solid, on wastewater reuse for restricted irrigation. Nevertheless, several constraints still persist and countries of the region are at different capacity levels on the subject of wastewater reuse.

The basis and momentum created through recent programmes and activities in cooperation with FAO and other parties, can be improved substantially. This can be achieved through the sensitization of decision-makers to take appropriate actions and catalyze change, the setting of standards, the promotion of better technologies, and the provision of technical assistance and training. The role of FAO and all concerned stakeholders in this regard is essential.

1.7 Recommendations

POLICY

Due to limited surface and groundwater resources, national water policies need to recognize the importance of wastewater treatment, reuse, and the application of low cost approaches to water resources protection and management.

National water policies need to be regularly reviewed and updated. A comprehensive strategy is required for water resources management and protection, including standards and the need for explicit provisions for water quality planning, management and enforcement. This should include provision for clear identification of problems, achievable targets, programme monitoring and review procedures.

Better economic analysis is needed to establish the benefits of wastewater treatment in order to promote expanded use of treatment technologies. More generally, the economic value of water should be recognized, and the tools of environmental economics used to integrate the effects and costs of water quality degradation and pollution into the national macro-economic and national accounts structure.

Policies and guidelines need to be established that deal with use of sludge in agricultural applications.

ENVIRONMENTAL ASPECTS

An appropriate use of treated wastewater is for the prevention of seawater intrusion in coastal areas through the recharge of aquifers. Appropriate standards are required.

All uses of wastewater in agriculture must take into account the larger issues of preservation of the natural resource base (soils, groundwater, etc.).

HEALTH ASPECTS

Untreated wastewater should not be used to produce food, however it may be used for non-edible applications.

Concerning the health hazards of wastewater reuse, the objective should not be only one of irrigation but must also include public health consequences.

Health effects on farm workers and the general public need to be taken into account in the development and application of wastewater.

LEGISLATION AND CODES OF PRACTICE

Treatment standards for wastewater reuse need to be established or adopted from FAO and WHO guidelines, and provision made for enforcement of these standards.

Enforcement of water quality standards is essential to achieve progress in water quality management. Good examples exist in some countries of strict law enforcement of wastewater reuse regulations.

Enforcement of the law should include the provision for taxation of companies or individuals that pollute water; these taxes should be used for treatment.

Legislation is required that provides for in-plant treatment of industrial wastewater at the design stage, and provision for monitoring and enforcement of its implementing using health and environmental standards.

INSTITUTIONAL ASPECTS AND HUMAN RESOURCES DEVELOPMENT

Institutional duplication and overlap is a major barrier to efficient and effective management of water quality and wastewater reuse, and needs to be resolved.

Although many countries have Water Resources Planning and Management Authorities, specialized boards are required for water quality management and control.

A national water quality authority should be established as a service-oriented authority that consolidates the activities of data collection, processing and dissemination.

Water planning should be accompanied by land use planning in order to optimize space and costs for wastewater treatment and use.

DATA

Optimization and modernization of water quality monitoring programmes is needed; new methodologies of measurement and assessment, source identification and quantification, etc., will lead to greater programme efficiencies and better decision-making.

Improvements are needed in national water quality monitoring programmes so that these become more responsive to User's needs and more efficient in their application through use of modern approaches such as toxicity assessment, data standards, etc.

Monitoring programmes should lead to public information so that the public are better informed about the state of water quality.

TECHNOLOGY AND TECHNOLOGY TRANSFER

Guidelines and codes of practice need to be developed or adapted for crop selection, methods of irrigation and water management when using wastewater.

Alternative technologies need to be identified and utilized for wastewater treatment that reduce usage of chemicals such as chlorine, reduces maintenance costs, requires less energy, and increases availability of high quality water.

Wastewater treatment needs to be appropriate and sustainable. It also needs to be least cost, easy to operate and maintain, and very efficient. In many (but obviously not all) situations in the near East Region, waste stabilization ponds are the most suitable method of wastewater treatment.

Exchange experience in methods, practices, legislation, etc. is needed between countries of the Near East.

EDUCATION AND PUBLIC AWARENESS

A continuing education programme needs to be implemented for the use of treated wastewater. This can be directed to small farmers through leaflets or simple manuals.

Public awareness needs to be raised including the environmental awareness of agricultural extension workers.

Capacity of householders needs developing, especially rural women.

FOLLOW-UP

International organizations should play a stronger role in urging governments to take effective measures for water pollution control, including the provision for penalties for non-compliance and the Polluter Pays Principle.

International organizations should assist member countries in project identification and to assist in the approach to potential donors for priority activities.

A regional network should be established as a vehicle to share experience in use of wastewater in agriculture.

FAO is encouraged to continue its effort in assisting countries of the Near East Region in order to reuse treated wastewater in appropriate and sustainable manner.

FAO is also encouraged to promote the development of decision support systems that integrate fully the topic of wastewater treatment and reuse. Such systems should be designed to bring knowledge and experience into the hands of Users.

Donors and investors are requested to provide more means of financial support to assist in achieving the proposed recommendations and plans for the near future.

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• Table 1-1 Water withdrawals in the Near East Region

Country	Year	Annual water withdrawal: Agricultural Mm³	%	Domestic Mm³ (2)	100 (2)/(4)	Industrial Mm³ (3)	100 (3)/(4)	Total Mm³ (4)=(1) +(2)+(3)	M³ per ** inhabitant (5)	% internal renewable water res.	% total actual renewable water res.
AFGHANISTAN	1987	25 849.0	99	261.0	1	0.0	0	26 110.0	1 702	47	40
ALGERIA	1990	2 700.0	60	1 120.0	25	680.0	15	4 500.0	180	32	31
BAHRAIN	1991	135.1	56	94.3	39	9.9	4	239.2	465	5980	206
CYPRUS *	1993	156.0	74	50.0	24	5.0	2	211.0	331	(23)	(23)
DJIBOUTI	1985	6.5	87	1.0	13	0.0	0	7.5	20	3	3
EGYPT	1993	74 400.0	86	3 100.0	6	4 600.0	8	55 100.0	913	3061	95
IRAN	1993	64 155.0	92	4 395.0	6	1 484.0	2	70 034.0	1 091	55	51
IRAQ	1990	39 380.0	92	1 280.0	3	2 140.0	5	42 800.0	2 367	122	57
JORDAN	1993	737.0	75	214.0	22	33.0	3	984.0	246	145	122
KUWAIT	1994	324.0	60	201.0	37	13.0	2	538.0	348	IRWR	2690
KYRGYZSTAN	1990	10 465.0	95	259.02	2	312.0	3	11 036.0	2 527	23	95
LEBANON	1994	875.0	68	368.0	28	50.0	4	1 293.0	444	27	29
LIBYA	1994	4 000.0	87	500.0	11	100.0	2	4 600.0	880	767	767
MALTA	1995	6.6	12	48.6	87	0.5	1	55.7	152	348	359
MAURITANIA	1985	1 499.6	92	101.0	6	29.3	2	1 630.0	923	408	14
MOROCCO	1991	10 180.0	92	543.0	5	322.0	3	11 045.0	436	37	37
OMAN	1991	1 148.0	94	56.0	5	19.0	2	1 223.0	728	124	124
PAKISTAN	1991	150 600.0	97	2 500.0	2	2 500.0	2	155 600.0	1 277	63	37
QATAR	1994	210.6	74	65.9	23	8.4	3	284.9	528	559	538
SAUDI ARABIA	1992	15 308.0	90	1 517.0	9	193.0	1	17 018.0	1 040	709	709
SOMALIA	1987	785.7	97	24.3	3	0.0	0	810.0	99	14	5
SUDAN	1995	16 800.0	94	800.0	4	200.0	1	17 800.0	633	51	20
SYRIA	1993	13 600.0	94	530.0	4	280.0	2	14 410.0	1 017	206	55
TAJIKISTAN	1989	11 088.0	88	630.0	5	882.0	7	12 600.0	2 065	20	32
TUNISIA	1990	2 727.5	8	261.4	9	86.1	3	3 075.0	382	87	75
TURKEY	1992	22 900.0	7	5 200.0	16	3 500.0	11	31 600.0	541	16	17

TURKMENISTA	1989	20 748.0	9	228.0	1	1 824.0	8	22 800.0	6 346	2280	32
U. A. EMIRATES	1995	1 408.0	6	500.0	24	200.0	9	2 108.0	1 107	1405	1405
YEMEN	1990	2 700.0	9	201.0	7	31.0	1	2 932.0	251	72	72
NEAR EAST REGION		467 892.6	9	25 049.6	5	19 502.1	4	512 444.3	964	58	

* : Cyprus: Figures for water withdrawal refer to government controlled area; figures for water resources refer to whole island.

** : Annual water withdrawal per inhabitant : Figure for the whole region refers to population of 1993. Source: FAO, 2000

• Table 1-2 Sources of water in the Near East Region

Country	Total water		Desalinated		Reused treated		Use of desalinated water		Country
	Year	Mm^3 per year	Year	Mm^3 per year	Year	Mm^3 per year	Mm^3 per year	% total withdrawal	
		(1)		(2)		(3)	(4) = (2) + (3)	100 (4)/(1)	
AFGHANISTAN	1987	26 110.0		-		-	-	-	AFGHANISTAN
ALGERIA	1990	4 500.0	1990	64.00		-	64.00	1.422	ALGERIA
BAHRAIN	1991	239.2	1991	44.10	1991	8.03	52.13	21.793	BAHRAIN
CYPRUS *	1993	211.0		-	1995	11.00	11.00	5.213	CYPRUS *
DJIBOUTI	1985	7.5	1990	0.10		-	0.10	1.333	DJIBOUTI
EGYPT	1993	55 100.0	1990	25.00	1993	200.00	225.00	0.408	EGYPT
IRAN	1993	70 034.0	1991	2.90		-	2.90	0.004	IRAN
IRAQ	1990	42 800.0		-		-	-	-	IRAQ
JORDAN	1993	984.0	1993	2.00	1991	50.30	52.30	5.315	JORDAN
KUWAIT	1994	538.0	1993	231.00	1994	52.00	283.00	52.602	KUWAIT
KYRGYZSTAN	1990	11 036.0		-	1990	9.00	9.00	0.082	KYRGYZSTAN
LEBANON	1994	1 293.0		-	1991	2.00	2.00	0.155	LEBANON
LIBYA	1994	4 600.0	1994	70.00	1990	100.00	170.00	3.696	LIBYA
MALTA	1995	55.7	1995	31.40	1993	1.56	32.96	59.174	MALTA
MAURITANIA	1985	1 630.0	1990	1.70		-	1.70	0.104	MAURITANIA
MOROCCO	1991	11 045.0	1992	3.40		-	3.40	0.031	MOROCCO
OMAN	1991	1 223.0	1995	34.00	1991	26.00	60.00	4.906	OMAN
PAKISTAN	1991	155 600.0		-		-	-	-	PAKISTAN
QATAR	1994	284.9	1995	98.60	1994	25.20	123.80	43.454	QATAR
SAUDI ARABIA	1992	17 018.0	1995	714.00	1992	217.00	931.00	5.471	SAUDI ARABIA
SOMALIA	1987	810.0	1990	0.10		-	0.10	0.012	SOMALIA
SUDAN	1995	17 800.0	1990	0.40		-	0.40	0.002	SUDAN
SYRIA	1993	14 410.0		-	1993	370.00	370.00	2.568	SYRIA
TAJIKISTAN	1989	12 600.0		-		-	-	-	TAJIKISTAN
TUNISIA	1990	3 075.0	1990	8.30	1993	20.00	28.30	0.920	TUNISIA
YURKEY	1992	31 600.0	1990	0.50		-	0.50	0.002	YURKEY

TURKMENISTAT	1989	22 800.0		-		-	-	-	TURKMENISTAT
U. A. EMIRATES	1995	2 108.0	1995	385.00	1995	108.00	493.00	23.387	UNITED ARAB
YEMEN	1990	2 932.0	1989	10.00	1992	-	10.00	0.341	YEMEN
NEAR EAST REGION		512 444.3		1 726.50		1 200.09	2 926.59	0.571	NEAR EAST REGION

* : Cyprus : Figure for total water withdrawal refers to government controlled area; other figures refer to whole island. Source: FAO, 2000.

• Table 1-3 Wastewater Information on selected Countries in the Near East

	Egypt	Jordan	Saudi Arabia	Tunisia	Turkey
Percentage of total population served with piped water supply .					
Urban	90 (93)	100 (93)	100 (90)	91 (92)	98 (94)
	45 (93)	97 (93)	74 (90)	65 (92)	85 (94)
Total					
Average per capita water supply demand (m^3/yr)	913	246	1040 (92)	382 (92)	541 (92)
Percentage of total population served by sewage schemes :					
Urban	50	70	99	78	85
Rural	15	17	35	18	15
Total		55		42 (94)	
Wastewater production					
Existing average per capita wastewater flow (1/day)	149 (93)	150 (97)	77 (91)	73	106 (94)
	149 (00)		90 (00)		118 (00)
Produced wastewater : Annual quantity of wastewater (no	3430 (93) :	232 (93)	504 (91)	237 (94) Tot.	2400 (94)
drainage water from agriculture) produced in the country	3800 (00)	300 (97)	720 (00)	Dom. 82%	2840 (00)
if possible with a break down of domestic, industrial and other (Mm^3/ yr)	4930 (00)			Ind. 12% / Tour. 6%	
Number of existing treatment plants and their capacities per day / year	10 in operation 22(82)	17	22 (91) : 27	49 : 52	60
Treated wastewater : Annual quantity of wastewater which is	437 Primary	50 (91)	454 (91)	96 (93)	100 (94)
treated and the different degrees of treatment : preliminary, primary, secondary, tertiary and / or advanced (Mm3/yr)	263 Secondary	69 (95)	Sec: Tert.	116 (96) 123 (98)	Sec: Tert.
Reuse					
Annual quantity of treated wastewater in irrigation (Mm^3)	200 (93)	50 (93)	217 (91)	20 (93)	50 (treated)
	700 (95) > 600 (00)	69 (95)		28 (98)	400 untreated

Irrigated areas with raw and treated wastewater (percent)	0.15	5.7	1.2	1.7 (98)	< 0.1
Irrigation methods used with wastewater	Surface	Sur. Spr. Drip	Piv. Spr. Drip.Sur.	Sur., Spr. 57 percent	Surface
Any report on adverse health and / or environment impacts due to reuse of wastewater and associated with the kind of treatment	No	No	No	No	Yeas
Sludge					
Annual quantity of sludge produced in the country (Thousand Tons)			60	30	
Sludge treatment if any: thickening, stabilization (aerobic/ anaerobic		Lagoon sludge	Dry beds :	Aaerobic stab.	
Digestion, (lime) dewatering (dry beds. Dry lagoons) ect			Composting	Dry bed	
Ultimate disposal of sludge: land application, incineration		Land	Land	Land fills 45 percent	
Composting land filling including any national guidelines for sludge disposal		Application as Soil Conditioner	Application Landscaping	Agric. 55 percent	

2 Wastewater reuse for agriculture - Regional health perspective

DR SAQER S. AL-SALEM[2] AND DR HOUSSAIN ABOUZAID[2]

2.1 The crisis and the response

The Eastern Mediterranean Region (EMR) is the driest region in the world. The region is poorly endowed; rainfall is low and poorly distributed. The drought and desert define the region. Water demand in the region is growing fast and water availability is falling to crisis levels. [Al Salem S. Saqer 1996 a]

As population has grown against a background of finite freshwater resources, so the water available to individuals has fallen dramatically. Annual per-capita availability, about 3,300m^3 in 1960 fallen, has by 60 percent to about 1,250m^3 and is predicted to fall by another 50 percent to about 650m^3 by 2025. This average covers all human activities, domestic, industrial and agricultural. For example, in Yemen and the West Bank and Gaza per-capita availability today is less than 180m^3 already far below the projected regional average 30 years from now. [PAI, 2000]

Fortunately, solutions are available which reduce water consumption and peak demand in an environmentally acceptable manner. A number of technologies/devices can help water users to reduce the consumption and the demand without any appreciable impact on lifestyles. Typical of these are wastewater reclamation and reuse and water conservation through low-flow toilets; low-flow showers heads, and faucet flow restrictors. Generally speaking, these technologies have been well received in the Region and have become steadily more popular as the cost of municipal water has risen.

Significant reductions could be achieved through the use of on-site wastewater treatment and recycling systems that permit the reuse of greywater for landscape irrigation and toilet and urinal flushing. As an example, in the typical household, approximately 34 percent of water consumed is used in flushing of toilets. The remaining 66 percent of the water for the most part is available for on-site recovery and reuse. On-site wastewater treatment and recycling systems can be used in all types of residential and commercial buildings and most types of institutional and industrial buildings.

A significant water cutback could be achieved by using modern irrigation systems and by maximizing plantations of high-value crops and minimizing plantation of the crops using high-water consumption, with low-economic value. Long-term plans in this context will be shifting the economy from an agriculture-based to industrial/service-based economy. Other methods to mitigate the water crisis are industrial water conservation, economic incentives, and maximizing recycling and reusing of industrial wastewater.

2.2 Regional potential of wastewater reuse

Depending on how it is practiced, the wastewater reuse in the Region could widely contribute to solving the problem of quality and quantity. The reuse will have major influence on the agricultural economy, the well-being, and the health of the society. Wastewater reuse will continue to be the first feasible option to augment the water resources for the coming years in the Region (Table 2-1).

- Table 2-1 Cost and options for enhancing water resources

Cost of option for enhancing water resources	Estimated costs in US cent/m^3
Reducing end-user demand (recirculation, low-water use technology and leakage repair)	5-50
Rain water harvesting and cloud harvesting	Variable
Secondary treatment of wastewater for irrigation	16-60

[2] Technology Transfer Adviser. WHO/Regional Centre for Environmental Health Activities; Amman-Jordan

Tertiary treatment of wastewater for irrigation	32-100
Grey water reuse for toilet flushing and landscape irrigation	11[1]
Desalination of brackish water	45-70
Development of marginal resources	55-85
Desalination of sea water	100-150
Water conveyance by pipelines	10-1500[2]
Transporting the water by marine vessels	0.50-1500[2]
Transporting giant floating bags by sea do not include the costs of terminals, inland transport, or purification	15-35[2]

1. Initial cost for combined wastewater treatment and recycling systems in larger commercial and industrial facilities per gross square meter; [National Association of Plumbing-heating-cooling Contactors; 2001]

2 The price of the water itself is not included. The cost depends mainly on the distance. [World Bank 1997]

The quantity of effluent produced in Egypt in 1999 was about 4.96Mm^3, 3.77Mm^3 of which were from secondary treatment plants, whereas 1.20Mm^3 resulted from primary treatment plants [Seham M. Hussein, et al., 1999]. In Tunisia, 135Mm^3 of wastewater were produced in 1999 through 55 treatment plants, and were irrigating 3,000ha with 35Mm^3 of treated wastewater in 35 irrigated areas. Seventy percent of the reused water was for fodder crops and 15 percent was for arboriculture and the other 15 percent for golf courses and public parks [Fadhel Ghariani, et al., 2001].

Jordan produced 71Mm^3 in 1998. The amount of wastewater treated constitutes 12 percent of the water used for irrigating. 15,700 dunums (1 dunum equals .1 ha) have been irrigated with 15.7Mm^3 of treated effluent for restricted irrigation and the rest blended with surface water and was used to irrigate 91,100 dunums for unrestricted use mostly in the Middle and Southern Jordan Valley [Mohammed Al Najjar, 1999.]. The total quantity of reused treated wastewater in EMR is estimated at 1200Mm^3 year. Syria, Saudi Arabia and Egypt are the largest users of treated wastewater in absolute terms, accounting for almost 66 percent of all the wastewater reused in the region, with Syria alone accounting for almost 31 percent [FAO, 1999].

At present, GCC countries recycle no more than 43 percent of their total treated wastewater, which contributes 1.8 percent of their total water supply, being used mainly in landscaping, fodder crop irrigation, and some industrial uses. It is estimated that if only 50 percent of domestic water supplies are treated and recycled in agriculture, recycled waters will have the potential to meet more than 11 percent of the GCC countries total water demand, and satisfy more than 14 percent of the agricultural sector demand. This could reduce fossil groundwater withdrawal by more than 15 percent by the year 2020 [Waleed K. Al-Zubai, 2000].

However, major reuse in the Region is mostly haphazard and presents significant health risks, especially where untreated wastewater is used to irrigate vegetables. To avoid the spread of disease, wastewater should be suitably treated for the type of the irrigated crops and to match with the adapted health protection measures.

2.3 Treatment from a health point of view

It is unfortunate, and yet not a coincidence, that most of the treatment plants in the EMR use activated sludge process followed in some cases by rapid sand filtration [Al Salem S. Saqer, 1993]. These techniques were developed to reduce suspended matter load and oxygen demand of the discharged reclaimed waters and to reduce eutrophication of the water bodies. These technologies are not efficient in removing excreted pathogens, while they may reduce substantially the required nutrients for the soil. Their use in EMR, where the excreted infections are endemic and where wastewater reuse is mostly for agriculture irrigation, is justifiable only in specific circumstances.

The above situation has the following environmental and health impacts:

- Soil, surface water, and groundwater pollution as a result of discharge of untreated or partially treated wastewater to the environment. This can raise the nitrate concentration in the water and subsequently will affect children and pregnant women,
- Potential farms' workers infections due to direct /indirect contact with reclaimed effluent and contaminated soil.
- Direct and indirect human health risks with especial impact on the vulnerable groups of pregnant women and children as a result of consumption of polluted crops and fish.
- Contamination of the coastal zone seawater, threatening swimmers, the fishery, as well as the marine ecosystems,
- Indirect human health risks as a result of consumption of polluted crops and fish.

However, alternative treatment processes that are superior in achieving low survival/acceptable risk of excreted pathogens in the effluent are available [WHO 1989]. There are five wastewater treatment processes that can achieve complete removal of helminth eggs and an overall excreted pathogen reduction suitable for unrestricted irrigation. These are:

- Waste stabilization ponds with detention time of more than 14 days;
- Combination of treatment and effluent storage to replace the required detention time;
- Conventional secondary sewage treatment followed by polishing ponds;
- Conventional secondary treatment followed by slow sand filtration; and
- Conventional secondary sewage treatment with effluent disinfected/ upgraded by Beta or Gamma Ray radiation.

2.4 Health effect of inappropriate wastewater treatment

The main constraint in wastewater treatment and reuse continues to be the control of spreading the diseases due to inappropriate treatment and uncontrolled reuse of the reclaimed water in the Region.

Significant occurrence of diseases are associated with wastewater irrigation and caused by pathogens, particularly helminthes, that are neither detected by the techniques used in conventional microbiological monitoring of effluent quality nor removed completely by conventional wastewater treatment process. In fact, helminths infections (intestinal nematodes) pose the greatest risk to the farms' workers as well as to consumers of farms' products. Intestinal parasitic diseases are quite widespread and endemic in the most of the countries of the Region. These are the challenges that Ministries of Health are trying to face with the cooperation of WHO.

2.5 Microbiological pollutant prevalence and intensity

FAIZABAD CITY, AFGHANISTAN

It was found that the prevalence rate of *Ascariasis* for male students (7-12 years old) had reached a level of 96.6 percent, whereas the prevalence rate for female schoolchildren of the same age group was 79.5 percent. The highest prevalence was within the female age seven years (87.05 percent) and the lowest prevalence was within the girls age twelve which was 55.5 percent. [Saqer Al Salem 1996 b]

MOROCCO

A study [K. Habbari et. al 1999] showed that the prevalence of intestinal helminthic infections caused by five parasites (*Ascaris lumbricoides, Trichuris trichiura, Enterobius vermicularis, Hymenolepis nana and Taenia saginata*), in the areas of wastewater use, 30.8 percent of the children were infected with helminthic parasites, as compared to only 5.6 percent among children living in the control areas. Children in the study sample suffered low-intensity infection with *A. lumbricoides* and *T. trichiura*. The parasite load of *Ascaris* infection, as expressed by number of eggs per gram of faeces (epg), was much higher among children living in wastewater-exposed areas (18.3 epg) versus unexposed areas (2.3 epg.).

A study [Ali-Shtayeh et. al.1989] summarizes six years of accumulated data on 22,970 specimens in Nablus, West Bank, Palestine: Infection with Ascaris was 17.7 percent and by trichuris 1.3 percent.

AMMAN CITY, JORDAN

The concentration of intestinal nematodes in 1988 was 297 eggs per litter at the inlet of the wastewater treatment plant, of which 245 eggs per litter were *A. lumbricoides* [S. Al Salem et. al. 1989.] While the Ascaris eggs concentration in the Amman Waste Stabilization ponds influent in 1998 was undetectable, this can be attributed to the enforcement of the law on reuse of the reclaimed wastewater and the appropriateness of the technology used. The health records showed that the average of intestinal nematodes infections was 1.33 percent among schoolchildren during the period of 1995-1999. [Ministry of Health of Jordan Annual Reports, 1995-1999]

GAZA STRIP

A study [Chris Smith 1990] showed that more than 50 percent of the children under the age of 10 are infected by Ascaris.

SYRIA

A study of parasitic infestation and the use of untreated sewage for irrigation of vegetables [Bradley, R. M. et. al, 1981] shows that the domestic sewage of Aleppo contained 3340 *Ascaris* eggs/liter, with an *Ascaris* infestation rate of 42 percent of the total Aleppo population, daily excreting an average of 800,000 eggs per person. The irrigation of vegetables with sewage completes the cycle by returning the parasites back to the community. On the other hand, a sample of untreated sewage from the Syrian coastal town of Lattakia contained 460 *Ascaris* eggs/litre. Untreated sewage is not used for irrigation in Lattakia and this is reflected in the lower parasite count of Lattakia sewage. A study titled "Epidemiology of Gastrointestinal Diseases Related to Microbiological Pollution of Barada River" carried out by Mohammed Maher Gatlan in 1999 showed that in Barada river basin there were 11.4 percent of the people that were infested by *Ascaris* worms.

EGYPT

A survey for prevalence of some diseases related to wastewater from records of the health offices in Helwan, Egypt during the years 1991-995 showed that people infested by Ascaris in 1994 were 0.55 percent and in 1995 3 percent. People infected by *Taenia* in 1994 were 0.7 percent and in 1995 0.3 percent. The concentration of viable *Ascaris* eggs at the inlet of the wastewater treatment plant in Helwan (activated sludge) was 70/litre, while at the outlet (secondary effluent followed by chlorination) the viable Ascaris eggs were 15/liter and the concentration of *Ascaris* eggs at the river Nile water at Faroque corner was 60/liter. The result of clinical examination for Helwan sewage plants workers and some of sewage farm workers showed that 38.2 percent had parasitic infections (*Ascaris, Entamoeba histolytica* and *Giardia*) [Academy of Science & Technology Cooperation; 1995]

OMAN

In South Batinah Region epidemiological study of intestinal parasitic infestation among schoolchildren showed that 19 percent of the examined schoolchildren were infected with *Hymonolepis nana*. The percentage of *Ascaris lumbricoides* was relatively low (0.1 percent) and the infestation of *Strongyloides* was 5 per 1000 of examined schoolchildren [Saqer Al Salem, 1998].

2.6 Waster reuse constraints

The Region's low sanitation coverage and high infestation in sanitation-based disease could be explained by the following factors:

- Institutional inefficiency is one of the major constraints in managing the sector: insufficient national professionals in the field of wastewater treatment design, operation, and reuse, lack of bylaws or their enforcement, lack of transparency of the decision-making, short-term planning, seepage of brackish or saline groundwater to sewer system, which limits the use of reclaimed wastewater,

- The high influence of donors in promoting unsustainable/unaffordable technologies and projects, which are not within the long term integrated planning or within the communities' affordability,
- Data and information availability. Trustworthiness, validity, and reliability are common shortages in most of the countries in the Region. The information is scarce regarding quality, coverage, use and cost. The inadequacy and insufficiency of the information can lead to inadequate planning and decisions. This situation does not permit the right decision making in all of its aspects either for the politicians or the professionals,
- Inadequacy/insufficiency of researches and local experiences prevails. The region mostly relies on the North countries regarding research. There are few surveys or investigations carried out in the Region to solve the Region's problems, while there are Region's specific problems that need to be deeply investigated by the resource institutions and universities located in the Region. More funds are needed to be allocated for the research and development in field of wastewater treatment and reuse,
- Inadequate financing system in most countries of the Region. There is a need to reform the sector to balance the sector capability of self sustaining and health and social benefits,
- Lack of beneficiaries' participation in the decision-making and absence of consideration of communities' affordability to pay in the sector planning and investments,
- Low coverage in adequate sanitation and inadequacy of the technology used for wastewater treatment, which is usually not designed to be compatible with the end use,
- Week enforcement or inadequacy of the laws and regulations governing the wastewater reuse,
- The main health protection measures in wastewater reuse is the treatment option, which usually is an expensive and unreliable one,
- Underused potentials of reclaimed water and grey water reuse and the reuse to irrigate low-value agriculture crops; and
- High cost of the conventional sewer system due to the unusual terrains and topography of the Region, and sewers' construction, which predominantly take place post urbanization.

2.7 Health regulations and guidelines

Most of the standards and government regulations in EMR were set as country effluent standard to control the quality of discharge. The major issues of such standards have been that the application of uniform effluent standard could be uneconomical and inappropriate. Moreover, the effluent standard is usually too stringent and environmentally unjustified. This is due to the great variation in the end uses covered by one uniform standard.

It is suggested that standard discharge to stream be imposed only in case of indirect reuse and to be based on using the assimilative capacity of the rivers or watercourses and on the water quality level for the predominant water reuse downstream. Ultimately, water reuse standards must protect the public health and the environment, and must match with end reuse objectives and the methods of application. Most of the EMR standards are based on either USEPA or WHO guidelines regardless of the type of the end use or the country diseases' profile. Nevertheless, most of the time these standards are not reinforced. Some countries with high prevalence of sanitation-based disease lack the proper standards for reuse of the wastewater.

2.8 Specific health issue

In 1989, WHO published new guidelines for wastewater use in agriculture and aquaculture (WHO, 1989). The guidelines included a new dimension, which was not considered in the previous WHO reports on reuse (WHO 1973). The new guidelines set microbiological quality criteria for wastewater use in irrigation of crops to be eaten cooked or eaten raw, sport fields, public parks, cereal crops, industrial crops, fodders, and trees. The new dimension in the guidelines required that wastewater should contain less than 1 nematode egg per liter. In addition to nematode eggs the faecal coliform criteria has been revised and required that wastewater should contain less than 1000 faecal coliforms per 100ml for vegetables eaten raw.

The WHO Guidelines for Use of Wastewater in Agriculture Aquaculture (WHO 1989) state that:

The presence of free-living nematode larvae stages, sometimes in large numbers, in stabilization pond effluents IS OF NO PUBLIC HEALTH SIGNIFICANCE because they are not pathogenic to human beings (emphasis added).

This statement is valid for all helminthic pathogens excreted in faeces except for *Strongyloides stercoralis* (threadworm) and *Enterobius vermicularis* (pinworm), since their eggs are NOT normally excreted in the faeces. The pinworm is of minor public health importance because it is an infection that does not commonly cause serious illness.

Strongyloides is potentially serious, particularly in malnourished or immune-suppressed individuals. When the body's immune responses are deficient, disseminated *strongyloidiasis* may occur, with larvae attacking most organs of the body; such cases are usually fatal (Feachem 1983).

The mode of transmission of *strongyloidiasis* infective *filariform* larvae, which develop in most soils, contaminated with faeces is by penetrating the skin (usually through the foot), entering the venous circulation. They are then carried to the lungs. They hatch and liberate non-infective, *rhabditiform* larvae, which migrate into the lumen of the intestine, leaving the host in the faeces and develop wither into infective *filariform* larvae, which may infect the same or a new host, or into free-living adults after reaching the soil (Benenson 1985).

The eggs are ovoid and measure 50-60 by 30-35 micrometers but are seldom seen because larvae hatch out and are passed in the faeces. *S. Stercoralis* exists in night soil and sludge as a delicate larva, not as a robust egg. A new infection can be initiated by the penetration of single larvae. Since *Strongyloides* represent a high actual risk, it is recommended to eliminate or remove 100 percent of its concentration. This would mean to have zero *S. stercoralis* larva/liter, because infection can be initiated by skin penetration of a single *S. stercoralis* larva. The period of communicability is as long as there are living worms in the intestine, which may extend up to 35 years (Benenson, 1985). Concerning inactivation of *Strongyloides* in sewage treatment processes, there are no studies reported (Feachem, 1983).

However, it is suggested that sludge pasteurization as currently applied in Switzerland and Germany (at 70ºC for 30minutes) may offer considerable safety. Pathogens may be reduced in rapid sand filtration but not substantially and probably insufficiently to justify investment in this filtration method by the health benefits it yields and most helminth eggs will be totally unharmed by effluent chlorination (Feachem, 1983).

This was confirmed by a study carried out in Jordan and by the performance of the Bahrain tertiary treatment plant operating on dual media filtration, chlorination, and ozonation. (Al Salem, Saqer, 1992 c)

So far, there is no guaranteed feasible method of inactivation of S. stercoralis larva neither in sewage or sludge treatment processes. It is recommended to take protection measures by wearing shoes and gloves, burying the sludge at least 0.5m below ground surface, and stopping irrigation of crops at least 3 weeks before harvesting. (Al Salem Saqer 1992)

It is worth mentioning here that WHO is considering now updating the 1989 "Health guidelines for the use of wastewater in agriculture and aquaculture." Background documents are being prepared and will be circulated soon for comments.

2.9 Work of WHO/EMRO

Dissemination of the appropriate technology transfer in wastewater treatment and reuse in EMR, during the period from September 1999 till April 2001 where nine training courses in various aspects of wastewater reuse and treatment were carried out. 297 professionals attended the training courses.

A regional training course was convened during 20-25 november1999. 12 professionals from ten countries attended the course; The main objectives of the course were to:

- Disseminate knowledge on the regionally recommended procedure for testing of nematodes eggs (*Ascaris*, and *trichuris* species and hookworms) in raw sludge and treated wastewater and introduce periodic programmes regarding the frequency of sampling, times, days, and numbers of samples to ensure better safety and foster community health during wastewater reuse in agriculture,
- Disseminate knowledge on the mentoring and surveillance of reclaimed water and sludge for agriculture.

Publication of a manual in Arabic language for wastewater superintendents that deals with operation and maintenance prepared by CEHA is now in the process to be printed.

A resource person was contracted to write up “Guidance for Design, Operation, and Maintenance of Wastewater Treatment Plants” in Arabic language. The reference book is now in the final technical editing phase.

A resource person from Royal Scientific Society/Jordan was contracted to write up “Sanitary Parasitology; Theoretical and Practical Guide”. The guide would be the first of its kind dealing with nematodes eggs screening and enumeration in the wastewater, final effluent and sludge. The subject has a Regional and even International relevance, The Guide is a comprehensive and multidisciplinary type.

Resource persons were contracted during 2001 to write up the country profile on wastewater management and reuse. The following countries’ profiles are either completed or in final draft: Jordan, Oman, Syria, Egypt, Sudan, Tunisia, and Morocco. The following profiles will be written during 2002: United Arab Emirates, Saudi Arabia, Kuwait and Yemen.

During 2002-2003, nine training courses were budgeted, to be carried out on appropriate wastewater treatment for agriculture and health aspects of wastewater reuse in 7 countries. (Yemen, Saudi Arabia, United Arab Emirates, Morocco, Oman, Tunisia, Egypt.)

A series of applied researches are budgeted to be carried out during 2002-2003 to assess the efficiency of wastewater treatment plant in removal of helminth eggs and to find the most visible methods for removal or inactivation of helminth eggs from reclaimed wastewater innovative approaches that will be investigated.

Arabization of the first Volume of the US Environmental Protection Agency publication titled “ Operation and Maintenance of Wastewater Collection Systems” started and it is anticipated to be ready in the first quarter of 2002.

Translation to Arabic of the WB/UNDP publication titled “Reuse of Wastewater in Agriculture: A guide for Planners “ will be completed in 2001.

In 2002 some countries of the region will be provided with required laboratory equipments necessary to carry out the identification and enumeration of the nematode eggs in wastewater and sludge (Egypt, Syria, Yemen, Sudan, Morocco, Tunisia)

2.10 Key suggestions

The policy-makers and high-ranking professionals in each country should review the above-mentioned stress factors related to their country and to decide how to overcome them,

Plan to treat the whole generated wastewater and to use the whole amount in environmental/healthy-based programmes,

Irrigate only high-value agriculture production and allocate the water for the highest-value uses and pollution preventions,

Provide incentive for conservation and sanction/penalties for irrational use. Impose cost for the economic water value; this will prevent uneconomical use/reuse of water,

Coordinate water use activities, set water plans, strategies and investments on long-terms according to the priorities to be decided with beneficiaries' participation,

Stop wasting the valuable water resources by discharging the reclaimed water to the sea,

Update the wastewater reuse guidelines to match the newly gained knowledge and use comprehensive approach of health protection measures and not to depend on treatment measure as sole method for health protection, and

Design the wastewater reuse/greywater projects as an integral part of the wastewater network and water resources plans.

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3 Institutional aspects of wastewater reuse

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3.1 Introduction

In many arid and semi-arid countries, water is becoming an increasingly scarce source, caused by the limited available water resources and at the same time an increase in water demand caused by the increase of population at a high rate and the rise of standard of living. This situation prompted planners to consider any source of water which might be used economically and effectively to promote further development. The potential for irrigation to raise both agricultural productivity and the living standards of the rural poor has long been recognized. Irrigated agriculture occupies approximately 17 percent of the world's total arable land, but the production from this sector comprises about 34 percent of the world total. This potential is even more pronounced in arid areas, such as the Near East Region, where only 30 percent of the cultivated area is under irrigation, but it produces about 75 percent of the total value of agricultural production. In this same region more than 50 percent of the food requirements are imported and the rate of increase in demand for food exceeds the rate of increase in agriculture production. Hence irrigation development is badly needed to mitigate this problem.

Irrigation development during the last fifty years in the Near East Region has utilized most of the conventional water resources, surface and groundwater, which are economically feasible. In large parts of this region no crops can be grown without irrigation water and only by further irrigation development agricultural production could be increased. This situation has given cause for concern in formulating national development plans in these countries. It is gratifying to report that decision makers are being increasingly involved in devising ways to optimize the use of the available water supplies as well as augmenting the available water resources, both conventional and non-conventional sources. The latter includes two programmes, one is desalination of brackish and seawater and the other is the treatment of sewage effluent and its reuse, mainly for irrigation. The latter source will be the subject of this paper.

3.2 Justification for the reuse of treated wastewater

Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater. With the current emphasis on environmental, health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially. Use of wastewater for agriculture could be an important consideration when its disposal is being planned in arid and semi-arid areas. Wastewater is now being considered as a new nutrient-rich source that can be used for food production and thus help alleviate food shortages in many countries with reduced use of fertilizers.

Treated wastewater can be used for irrigation of agricultural crops, public parks and recreation centers, landscape areas and golf courses. It could also be used for industrial purposes and groundwater recharge. Furthermore, as various industrial and agricultural demands are met by treated wastewater, more freshwater could be made available for municipal use. It is reported by FAO (1997) that the total reused treated wastewater in FAO Near East Region amounted to about 1200Mm^3 in the year. Recent reports from several countries in the region indicate that the above figure is on the low side.

Several Arab countries, have already initiated ambitious programmes in this field, such as Saudi Arabia, and other Gulf States, Syria, Egypt and Jordan. The following are some examples from the Region on the amount of treated wastewater the amount used and area irrigated, and the planning for the future.

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3.2.1 Jordan

The policy is to treat and use all wastewater, mainly for irrigation and to a lesser extent for industrial purposes. Table 3-1 below summarizes the projected water supply for irrigation from fresh and treated sewage water.

- Table 3-1 Projected water supply from fresh and treated sewage water

Figures are in Mm^3					
Year	**2000**	**2005**	**2010**	**2015**	**2020**
Fresh water	462	586	608	511	425
Treated wastewater	72	93	156	182	202
Total	534	679	764	699	627
Percentage of treated effluent	13	14	20	26	32
Area Irrigated by Treated (ha)	7,200	9,300	15,600	18,200	20,200

3.2.2 GCC Countries

GCC Countries include Bahrain, Kuwait, Qatar, Oman, Saudi Arabian and UAE. The total capacity of the wastewater treatment facilities is more than 1,100Mm^3/yr and most of the treatment facilities have advanced tertiary treatment. The total treated effluent is about 915Mm^3/yr, out of which 390Mm^3/yr (49 percent of the treated effluent) is used mainly in urban areas (irrigating gardens) fodder, agricultural crops, and road highway landscaping. The remaining treated volumes (secondary treatment) are discharged to the sea or into wadis. Treated wastewater provides an additional source, which allows reserving limited fresh water resources for potable supply and other priority uses. The marginal cost of providing additional good quality water of the same volume as that of wastewater produced, will be generally higher than the wastewater. For example, in Bahrain cost of tertiary treated effluent in about US$ 0.317/m^3 while the cost of desalinated water is about US$ 0.794/m^3.

3.2.3 Egypt

In the year 2000, the total capacity of all installed treatment plants was about 4.8Mm^3/day or about 1,752Mm^3/yr. The presently used treated volume is about 940Mm^3/yr, reused for irrigating about 40,000ha.

The future projection for the year 2020 the total treated sewage will reach about 5,000Mm^3/yr, which can irrigate about 500,000 feddans or 210,000 ha. Development of irrigation using treated effluent is carried out in the desert areas in Sinai, the Northwest Coast, and on both sides of the Nile Valley, from Aswan to Cairo.

3.2.4 Syria

The constructed treatment plants all over the country have a capacity of 1,157,000m^3/day or 422 Mm^3/yr. At present Damascus treatment plant produces about 785,000m^3/day and provides irrigation water to 18,000ha in El-Ghotta region of Damascus. The amount of treated effluent in the whole country is expected to irrigate about 40,000 ha.

It should be realized that the quantities of treated effluent available in most countries will account for only small fractions of the total irrigation requirements. However, the contribution of treated wastewater to the total irrigation water, in some Arab countries, as mentioned above, is important. Furthermore, the wastewater use will result in the conservation of higher quality water and its use for purposes other than irrigation. Also the availability of this additional water near population centers, can provide supplementary irrigation to rainfed crops, which will not only increase the yield and quality of the produce, but it will enable farmers to grow more varieties of crops, with a higher economic value.

It in generally accepted that wastewater use in agriculture is justified on agronomic and economic grounds, but care must be taken to minimize adverse health and environmental impacts.

3.3 Pre-requisites for wastewater reuse in irrigation

Any successful reuse of wastewater for irrigation development must consider the overall perceptions of and attitudes to such projects, both by people in the area being considered, and by the officials in appropriate institutions and regulatory agencies. This is an essential requirement in the countries where wastewater reuse does not exist at present and those where its practice is of pilot and demonstration nature, in limited areas. The prerequisites for successful wastewater reuse irrigation projects can be listed as follows:

- Presence of interested farmers and agricultural infrastructure,
- Land availability,
- Environmental safety including avoiding the risk of ground water pollution,
- Public health safety,
- Social acceptance,
- Manpower availability,
- Appropriate institutional framework.

In most cases, the institutional framework and social acceptance may prove to be the most important issues to be solved in order to ensure success of the reuse projects. In the case of social acceptance, there may be deep-rooted socio-cultural barriers to wastewater reuse; their removal can be achieved by pilot small-scale projects, over a few seasons, to demonstrate that the use of wastewater for irrigation is economically attractive for farmers and that such projects do not have any health risks. The process should also include an objective information campaign, through extension agents, radio, television and the press, addressed to the population, especially farmers, and indicating that there are no documented cases of health hazards found anywhere in the world stemming from restricted irrigation by treated effluents. The initial reservations are likely to be overcome, within a period of one to five years. If the pilot projects and public awareness campaign persuade some progressive farmers to use treated wastewater as a supplementary source of water for irrigation, their success will spread to the initial doubters to use the available wastewater.

The institutional framework mentioned above will be the main subject of this presentation. With the existence of a government policy to reuse wastewater, this policy must be backed up by adequate legislation governing the collection, treatment and distribution systems of treated effluent as well as by definition of responsibilities and mandate of the different concerned agencies. A training programme to train personnel at different levels, to be competent in operating and maintaining the reuse project at an efferent level, must be established and implemented. This is a prerequisite for the success of such projects by maintaining safe and economical operations. In parallel to this, a multidisciplinary research programme, for finding solutions to the existing issues and improving management techniques, should also be initiated and well supported.

3.4 Planning considerations

The planning considerations associated with treating and delivering wastewater to potential users include the following specific elements: design; economics; public health; institutions, environment and energy.

Institutional considerations play an important role in determining the feasibility of a wastewater reuse programme. A reuse project that is economically and technically feasible may be impossible to implement because of institutional constraints. Implementation of a viable wastewater reuse programme may, in some cases, require more efforts and resources for solving institutional problems than for addressing engineering problems. Institutional considerations include, among other things, the following:

- Lines of responsibility and co-ordination of activities of the various sectors involved: local authorities responsible for wastewater treatment and disposal; farmers who will benefit from the use scheme and the State which is concerned with the provision of adequate water supply, protection of the environment and the promotion of public health. Sufficient attention must be given to the social, institutional and organizational aspects of effluent use in agriculture to ensure long-term sustainability:
- Water rights of present downstream users of the treated wastewater,
- Establishment of an agency to manage wastewater and may be responsible for the distribution of water to individual farmers,
- Identification and co-ordination with present water supplier serving the same users,
- Gaining public and regulatory agency acceptance.

Economic considerations should take all relevant cost elements into account in evaluating the economics of a reuse project. These elements include reclaimed wastewater supply, storage and conveyance system, on-site distribution and maintenance requirements. In addition, those elements are imposed on users, as a result of the general poorer water quality. However, in areas of water shortage, the economic evaluation may not have to show a favorable ratio of reclaimed wastewater cost to potable water cost. Rather the economics of reclaimed wastewater usage need only to appear reasonable in terms of the user's ability to pay versus the consequences of not having enough water.

The cost of existing storage facilities should be included in the total economic evaluations. These facilities are constructed, owned and maintained by the supplier since they are tied up with the operation of the treatment plant.

Conveyance facilities for transporting reclaimed wastewater to the use site are usually constructed and owned and maintained by the user. Numerous other cost elements should be included, such as sludge disposal and periodic cleaning of the irrigation sprinklers and drippers, because of a high level of suspended solids. An offsetting cost element for irrigation reuse is the fertilizers value of the wastewater.

Although the responsibility for collecting, treating and disposing of urban wastewater will normally lie with a local water or sewerage authority or municipality, farmers wishing to use the treated effluent are often able and willing to pay for what they use but are not prepared to subsidize, in general the disposal costs. The local sewage authorities should acknowledge their financial responsibility for the basic system to achieve environmental protection objectives and only incremental costs associated with additional treatment or distribution required, specifically for effluent use in agriculture. In practice, if the effluent use scheme is considered at the time the sewerage project is being planned, treatment costs might well be reduced over those normally required for environmental protection.

Since wastewater treatment is a major cost in effluent use systems; it is essential that treatment process selection is made in conjunction with decisions on crop and irrigation system. Only in this way can a minimal investment in treatment be achieved without compromising the health risks of an effluent use scheme.

Other elements are to be taken into consideration, in the planning process are: public health, environmental consideration and energy considerations.

3.5 Policy and institutional issues

3.5.1 General principles

While wastewater treatment and reuse are becoming an increasingly important issue in arid and semi-arid developing countries, it is necessary to consider them within an overall water development and management framework. Currently many of the reuse projects are not properly conceived, which means that they could fall into one or more of the following categories:

a) Lack of national policies and strategies in this area.

- Inadequate commitment from decision makers.
- Results are sub-optimal due to ad hoc planning and management.
- Long-term sustainability is in doubt.
- Unnecessary expensive for the objectives to be achieved.
- Major constraints exist in terms of lack of adequate funds for operation and maintenance; inadequate monitoring and evaluation; lack of trained manpower.
- Health and environmentally related issues are not being properly considered.

The problems are undoubtedly serious, but given proper management and appropriate commitments from decision-makers, they are surmountable within a limited time period. This requires a national policy for wastewater use in agriculture.

3.5.2 Policy issues

The legislative framework for effluent use in agriculture can have a significant influence on project feasibility. A coherent national policy for wastewater use in agriculture is essential. This must define the division of responsibilities among involved ministries and authorities and non-government organizations, such as the water users associations, if they exist, and/or the individual users. Institutional mechanisms for implementing the national policy must be established and legal backing provided for enforcement of regulations. Realistic standards must be adopted to safeguard public health and protect against adverse environmental impacts. Provision should be made to adequately staff and provide financial resource to organizations charged with the responsibility for assessing, implementing, operating and monitoring effluent use schemes and enforcing compliance with regulations.

A distinction between the upgrading of existing wastewater use schemes and the development of new schemes should be kept in mind. In addressing the former, it is stressed that attention should be paid not only to the technical improvements required or feasible but also to the need for better management of existing schemes and to their improved operation and maintenance.

A national and/or regional consultative committee will often be of value in developing policy guidelines. Serving on this committee should be a representative of all the main interested groups, including: water resource planning, public health, public works (municipalities), irrigation, agriculture and commercial interest (including farmers' representatives). Policies emanating from such a committee should be free of local or partisan influences but, nevertheless, should be pragmatic. In particular, enforcement legislation must be unequivocal, unambiguous and address the main problem areas. The committee should also be charged with assessing the agricultural and epidemiological (health) impacts of effluents use schemes.

3.5.3 Institutional issues

The scope and success of any effluent scheme will depend to a large extent on the administrative skills applied. Wastewater collection and treatment and effluent use in agriculture span a wide range of both urban-based and rural-based interests, at both local and regional levels and institutional responsibilities must be clearly defined. Decisions will have to be taken on:

- Allocation of effluent among competing uses,
- Maintenance of quality standards and system reliability,
- Investment in supporting resources, especially managerial and technical staff, required to administer each component of an effluent use scheme.

Policy decisions should normally be taken by a national or regional body, with executive responsibilities in the hands of a regional organization. Such a regional organization would be responsible for project implementation and operation and would provide the criteria, framework and administrative mechanisms necessary for effective effluent utilization. However, they would also be responsible for effective monitoring and control of the crops irrigated, the quality of the effluent and associated health and environmental impacts.

One of the most important features of a successful effluent use scheme is the supervision provided at all stages of the system. Strict control must be applied from the wastewater treatment plant, through the conveyance and irrigation systems to the quality of the resulting products, whether they are of commercial or environmental value. The management, monitoring and public relations procedures are as important as the technological hardware involved in the system and the managers of regional organizations set up to administer effluent use projects, in a firm manner, if the schemes are to realize their full potential. Managerial and technical staff must be properly qualified and suitably trained to carry out their functions effectively. Treated effluent use in agriculture is a major source development activity and requires an appropriate institutional structure, provided with adequate recourses, to be successful.

3.6 Examples of policy and management of wastewater reuse

3.6.1 Tunisia

The Tunisian law, enacted in 1975 provides the legal framework for treated wastewater use. This code prohibits the use of raw sewage in agriculture. In 1989 an act regulating the use of treated wastewater in agriculture was introduced. The implementation and enforcement of the decree is the responsibility of the ministries of Public Works, Agriculture, Economy and Public Health. The 1989 Act requires that treated wastewater use in agriculture be authorized by the Ministry of Agriculture, after making preliminary inquiries with the Ministry of Public Health and notification from the National Environmental Protection Agency. The document also specifies the frequency of chemical and biological analyses to be undertaken. Irrigation of vegetables and of any crop that might be consumed raw is forbidden. It also stipulates that crops irrigated with treated wastewater must be tested by the Ministry of Public Health. Quality standards have been issued in a separate document, in which the crops that might be irrigated with treated wastewater are specified (forage and industrial crops, cereals, trees) and the precaution that must be taken to prevent contamination of workers, residential areas and consumers, are detailed.

The volume of treated wastewater available in Tunisia in 1988 was $78Mm^3$ and in the year 2000 was planned to exceed $125Mm^3$. A regional department for agriculture development (CRDA) supervises all irrigation water distribution systems and enforces the water codes. In the early 1990s, about 1,700ha was irrigated with treated wastewater, and another 5,300ha were under implementation. Many other projects are planned and the total area to be irrigated with treated effluent will reach 30,000ha in the coming few years. An institutional and legal framework has been set up to organize the treatment, distribution and quality control of recycled water. Since Tunisia has adopted a firm national reuse policy; reclaimed water is expected to reach 10 percent of the total water demand within the next few years.

3.6.2 Brisbane-Australia

The Department of Natural Resources in Queens Land, Australia is presently carrying out a comprehensive strategy called the Queensland Water Recycling Strategy (QWRS) to determine future government directions in the whole area of water recycling. This strategy is considering the beneficial use of all waste streams such as domestic sewage, industrial and agricultural wastes, as well as urban rainstorm water. Following a workshop held during the initial phase of the strategy it was determined that a high priority must be given to the demonstration of recycling practices. Three separate types of recycling projects are being carried out, the first being based on demonstrating recycling on a large new urban development close to Brisbane, the second associated with demonstrating the complex treatment process associated with the higher levels of recycling, and the third associated with demonstrating community based recycling schemes.

This overall project is aimed at joining together state and local governments and land developers to come up with acceptable reuse practices. The community will be involved from the initial planning stages to the final operation and monitoring stages. A comprehensive education programme will be developed in collaboration with the community, addressing both the existing residents needs and that of future inhabitants.

The QWRS initiative has now been underway for two years and it has now been acknowledged as a successful model for progressing water recycling. One of the main reasons for this is the community involvement approach in all levels of decision-making. This shows well in the area of demonstration projects where the community has major inputs into which projects are chosen and how the information is delivered to the community on the performance of the projects. This is done with the backup of suitably qualified technical advice where necessary. The community will no longer trust the technocrats to make decisions on issues that will directly affect their local environment unless they are involved in the decision-making.

3.6.3 Saudi Arabia

The country has adopted a firm national policy for the reuse of treated effluent. The Royal Order No. M/34 dated 24/08/1400 (about 1980) forms the legislative framework for the protection of water resources including wastewater. A draft law was prepared indicating the government agencies that should participate in the treatment and use of wastewater. They include:

- Ministry of Agriculture and Water,
- Ministry of Municipalities and Rural Affairs,
- Ministry of Health,
- Ministry of Industry and Electricity,
- Meteorology and Environment Protection Agency,
- The National Directorates of Water and Sewerage established in the main cities of the kingdom,

The law contains instructions concerning:

- How to dispose of wastewater, including collection and transport, supervision and inspection and the conditions required for this purpose,
- Conditions required for the use of effluents, including licences for use, treatment conditions, protection of public health and the environment, with a high level of care for not polluting groundwater,
- The Ministry of Agriculture and Water is the government agency that leads the action for the establishment of irrigation projects depending on treated wastewater,
- The National Directorates for Water Supply and Sewerage are responsible for the municipal water supply and for the collection and treatment of wastewater.

The Ministry of Agriculture and Water conveys the water from the treatment plant to the use site. The tertiary treatment is adopted at all treatment plants in the country. The Ministry distributes water to the farms that are accessible, so as to minimize costs. Some farmers are permitted to convey the treated effluent to their farms after obtaining a licence and conforming to acceptable standards, including not growing vegetables that are eaten un-cooked. Beside irrigation, treated wastewater is used for industrial purposes, in landscaping and for aforestation inside towns.

It is estimated that the total treated and used wastewater in the Kingdom amounts to about 610Mm^3/yr (representing about 46 percent of municipal water). About 460Mm^3 is used to irrigate about 16,000ha. In addition, about 92Mm^3 support the irrigation project in Al-Ehsaa' and 58Mm^3/yr for landscaping in the cities of the Eastern Provinces.

3.6.4 Jordan

The main interested parties that are involved in wastewater management and reuse are:

- The Ministry of Water and Irrigation (MOWI), which includes the Water Authority of Jordan [WAJ] and Jordan Valley Authority [JVA] who are responsible for the management of water resources, including the assessment, development, collection and allocation of wastewater for treatment and reuse,
- The Ministry of Health is responsible for the water and wastewater from the health point of view,
- The Ministry of Agriculture is involved in reuse, mainly for reforestation so far,
- The National Center for Agricultural Research and Technology Transfer is responsible for the research related to the use of treated wastewater,
- Institutions, industries, and establishments which deal with the wastewater treatment on their own,
- The Ministry of Municipality and Rural Affairs and Environment,
- The Department of Standards and Measurements,
- Some NGOs such as the Jordan Society for the Protection of Environment; and
- The private sector, which deals with the use of treated effluent.

IMPORTANCE OF THE ISSUE

Due to a lack of experience and weak planning, the development of this sector has faced many problems. One of these is the safe disposal of treated effluent without causing health and environmental hazards. This was partially solved by agreements signed between the Water Authority of Jordan and other public agencies to use the effluent for irrigating fodder crops, close to the treatment plant, as it is the case in Madaba, Aqaba, Mafraq, Kufrenjah and Ramtha. The price charged for such water is about 10fills/m^3 (US cents 1.43/m^3). The indirect reuse of treated effluent from other wastewater treatment plants, as is the case with Khirbet Al-Samra (about 170,000m^3/day) is used after storage in King Talal Dam for unrestricted irrigation in the Jordan Valley. The dilution of this water in the dam reservoir was on average of about one to one during the last three years.

Reuse of treated wastewater amounted to about 72Mm^3 in the year 2000, which is about 13 percent of the total water used for irrigation. It is estimated that this will increase to reach about 200Mm^3 in the year 2020, which will constitute 32 percent of the total water used for irrigation. This considerable contribution will play a significant role in the sustainability of irrigated agriculture. In 1994, about 630ha were directly irrigated with treated sewage and about 3,000ha indirectly irrigated by treated effluent in the Jordan Valley.

CURRENT POLICY FRAMEWORK

The present policy of the MOWI is to treat and use wastewater mainly for irrigation. Treatment plants are to produce effluents (tertiary treatment) suitable for unrestricted irrigation, but the effluent is to be used only for restricted irrigation. To encourage reuse schemes the MOWI has made it mandatory for all new sewerage treatment plant projects to include fully designed and operable reuse schemes. Legislation was effected in 1991 on industrial effluent quality and in 1994 the legislation on treatment of municipal wastewater was introduced, providing standards for the quality, which are more stringent than those of WHO. These measures reflect a tightening of standards in response to continuing problems with pollution of water sources and a general desire to harness valuable and scarce resources.

POLICY GAPS

The policy of wastewater management and reuse must be backed up by adequate legislation dealing with site selection; collection, treatment and distribution systems, as well as responsibilities of reuse. The legislation must define the responsibilities and scope of various government agencies. The following are existing gaps:

- The institutional set-up for wastewater reuse is not adequate. The responsibility for developing and operating wastewater treatment facilities and reuse in irrigation project is not clearly defined,

- There is a need to establish standards for treated effluents for different uses and in harmony with local conditions,
- More research is needed to develop improved management techniques and on ways to reduce the cost of treatment process and increase their efficiency,
- More trained personnel are needed at various levels,
- There is an absence of data and documentation on the environmental impacts of wastewater treatment and reuse projects,
- Public participation in the selection of the location of the treatment plants and site of use should be encouraged,
- Criteria need to be established for a fair pricing of treated wastewater according to quality and type of use,
- There is an absence of regulations that define the areas to be served by wastewater.

CONSTRAINTS TO RESOLVING THE ISSUE

These included:

- Financial limitations,
- Social aspects including acceptance of the principle of treated effluent reuse for irrigation purposes and the consumption of agricultural products,
- Lack of highly trained personnel in the field of wastewater treatment and effluent reuse for irrigation and other uses,
- Limited co-ordination between concerned government agencies; and
- Limited public awareness.

STRATEGY

To implement the policy mentioned before, the MOWI shall peruse the following strategy:

- Establish a unit with well qualified staff to be responsible for the planning, design, construction and management of sewerage system projects and for the reuse of treated effluent;
- Separate the wastewater section from the water supply section because of the differing needs and functions of these two units,
- Put in place an institutional framework capable to provide for wastewater allocation, quality, and health and safety aspects of wastewater collection, treatment and reuse.

3.6.5 Mexico and Chile

Through legislation the authorities in Mexico, responsible for the supply of treated wastewater are able to impose crop restriction measures in irrigation districts because they are empowered to withhold treated effluent from farmers not observing the regulations.

In Mexico, six irrigation districts currently make use of wastewater and surface runoff from urban areas. Four of these districts receive wastewater and runoff from Mexico City, which on average amounts to $55m^3/s$ and irrigates about 43,000ha. The concentrations of chemicals constituents and pathogenic organisms in the irrigation water will vary spatially and temporally. No treatment of sewage is provided but some treatment is made through the transportation of the sewage 60 kilometers from Mexico City to the irrigation sites. Clearly, little improvement in faecal coliform levels occurs before it is applied as irrigation water. In general faecal coliform levels in the irrigation water are 106 to 108/100ml.

In trying to achieve public health protection, reliance is placed on the application of crop restrictions rather than on wastewater treatment. Every year, each farmer specifies the crops he is going to grow and irrigate with water allocated by the irrigation district. The Ministry of Health sets the basic rules for crop restriction and the District's Directing Committee specifies in detail the crops that may not to be cultivated under its jurisdiction. In this area banned crops are: lettuce, cabbage, beet, coriander, radish, carrot, spinach and parsley. Adherence to this restriction is monitored mainly by the district's canal and gates operators, who are in close contact with farmers. Maize, beans, chili and green tomatoes, which form the staple food for the majority of the population, do not fall under these restrictions, and neither does alfalfa, an important fodder crop in the area. The high content of organic matter and plant nutrients in the wastewater have improved the physical and chemical properties of the soils, thus their productivity has increased. As a result, farmers are producing high yields (greater than those 10 years ago).

The Mexican experience with raw wastewater irrigation suggests that successful enforcement of crop restriction has provided health protection for the general public, including crop consumers.

On the other hand, in Chile the Sanitary Authorities have little leverage. Chilean law vests water rights in the hands of farmers (landowners) and the authorities have never been successful in imposing crop restrictions. Even lettuce and other vegetables are being irrigated with raw sewage, and this has been implicated in annual typhoid epidemics in the capital Santiago.

3.7 Conclusions

In most countries of the Region the institutional set-up for wastewater is inadequate. The responsibility for developing and operating wastewater treatment facilities and reuse in irrigation projects is not clearly defined. There is a need for the establishment of a unit with well-qualified staff to be responsible for the planning, design, construction and management of sewerage system projects and for the reuse of treated effluent. In most cases it will be the Department or the Authority of Water and Sewerage. This action should be accompanied by the followings:

- Strong co-ordination between concerned government agencies should be established. The establishment of a national consultative committee, with representatives from the main interested groups, will help to ensure this required co-ordination. Such committee will be also of value, in developing policy guidelines and providing guidance for improvement in different fields,
- Develop a wastewater master plan that will establish targets for providing wastewater collection systems and treatment facilities to served areas throughout the country,
- Wastewater should be included as a surface water source in the water master plan studies and elsewhere,
- Establish detailed legislation governing the use of treated effluent in agriculture and for other uses,
- Establish quality standards for treated effluent that should ensure there are no hazards for public health and the environment, taking into considerations the socio-economic conditions in the country,
- Establish the institutional capability for monitoring, regulating and enforcing wastewater regulations,
- Rules and laws related to wastewater should be unified in the different government agencies,
- Implement a training programme for up-grading staff skills of the above mentioned unit,
- Carry out research to improve treatment processes as well as improve reuse practices,
- Develop and carry out plans to strengthen and improve management efficiency, including improving the performance of wastewater collection and treatment facilities,
- Launch public awareness programmes on the treatment and reuse aspects of sewage effluent. Encourage members of the public and concerned agencies to participate in project studies and the environmental assessment of wastewater projects,
- Require industries to recycle part of their wastewater and to treat the rest to acceptable standards before it is discharged into the sewerage systems or elsewhere. This should be monitored regularly to make sure that the regulations are strictly adhered to,

- Involve the community concerned with the reuse project at all levels of decision making, from the planning stages to the final operation and monitoring stages. This approach has proved to be successful in Australia,
- Some reuse projects provide a good opportunity to organize Water User Associations (WUAs) who in their part take the responsibility of the operation and management of the reuse scheme.

3.8 Recommendations

TO GOVERNMENTS

- A policy for the reuse of treated effluent should be established, but it should be revised later according to new circumstances. At the beginning, the policy must spell out the uses, the conditions governing the uses and users and it must establish the required standards to be met. It should define the division of responsibilities among all those involved,
- The necessary legislation and institutional framework for wastewater reuse must be established,
- Wherever treated wastewater is used, the standards and strict regulations should be followed from the beginning and if necessary these standards should be revised after long-term monitoring of activities,
- Industry should be encouraged, if necessary, forced, to recycle part of its wastewater and to treat the rest to acceptable standards, before it is allowed to be discharged to the sewerage system,
- The institutional set-up mentioned above, should be adequate to provide a framework for the allocation use, quality and health and safety aspect and there should be continuous co-ordination and cooperation between the concerned agencies,
- A training programme to train personnel at different levels must be established to ensure that reuse projects will be a success by maintaining safe and economic operation,
- A research programme for finding solutions to improved management techniques as well as technical should be initiated.

TO INTERNATIONAL REGIONAL ORGANIZATIONS

To provide assistance to the member countries in the following fields:

- To give due support to the establishment of a regional network on wastewater reuse,
- Upgrading of national skills through technical meetings study tours and fellowships,
- Legislation relating to the treatment development and management of treated wastewater for irrigation and other uses,
- Monitoring and evaluation of on-going programmes and wastewater reuse,
- Capacity development including institutions and human resources,
- Exchange of information and experiences between member countries,
- Initiation of a joint regional project on wastewater reuse.

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4 Adding a 'loop': use of treated wastewater in Jordan

ANDREAS J KUCK[4]

Summary

Water issues in the Middle East have become a source of conflict between regional states as well as a mask for underlying tensions. Competition for fresh water factors into many regional political controversies, especially as populations continue to grow and renewable water resources available per capita decline. At the same time no major transboundary conveyance of water is to be expected in the region in the near future because of the prevailing political situation and the general state of water scarcity affecting all countries.

Therefore the countries of the Middle East are left with the task of adequate internal distribution of scarce water sources and with the resolution of the increasing conflict of water allocation to the competing sectors of their economies.

The paper draws evidence from the Jordanian case: On the one hand there is the intensively cultivated area of the Jordan Valley. The particular climatic conditions allow growing off-season fruits and vegetables, with the potential of high productivity provided sufficient irrigation water being available. On the other hand increasing population in the highland, industrial growth and further touristic development are demanding additional water allocations.

In this situation first of all an overall concept is required which integrates the particular interests of the competing sectors on a national level. At the same time water use and distribution within the agricultural sector and on the farm has to be optimized in terms of allocating water adequate in quantity and quality for different crops and their irrigation requirements.

Food security is a legitimate concern of all countries. However, self-sufficiency requires of the order of 1,000m^3/capita/yr of water, far in excess of the resources available in areas like Jordan or the Palestinian territories having less than one fifth of this quantity. The solution is seen by many to be 'virtual water': Therefore food security is expected to be more likely through strong and diversified trading than by relying on the vagaries of climate and shrinking water resources to grow needed crops.

Competition over water has emerged with demands to reallocate water used in agriculture to rapidly growing urban centers. This is especially the case, since agriculture now contributes but a few percent to national GDP in countries like Israel and Jordan. Therefore, within the countries of the region it cannot be expected, that major additional freshwater resources will be available in future for agriculture because of the pressing demand of the M&I sector.

Complementary use of resources is also possible as shown by reusing the effluent from wastewater treatment plants. At the same time it has to be pointed out that the prospects of water reuse are less than one might expect at first thought. Some countries like Tunisia and Israel have quite extensive wastewater use programmes. However, the potential quantities available are limited. Due to partly consumptive use by M&I, restrictions in sewerage services and losses in transit and treatment, usually only some 25 percent of supply to M&I is left as discharge for reuse in agriculture. Although, as economies grow and sewerage coverage expands, the respective figure may reach nearly 50 percent of M&I effluent being available for water reuse in irrigation.

What on first sight might look as a competition between economic sectors in their struggle for scarce water resources is practically more a challenge calling for close cooperation. The different sectors of economy have different characteristics with respect to their *water use vis a vis* their *water consumption*. In most cases M&I are *using* rather than *consuming* the supplied water. A significant portion of the supplied water to these sectors can - after proper treatment - be directly applied in agriculture.

[4] Brackish Water Project, c/o GTZ

Therefore in the near future a new role is coming up for agriculture. With increased water consumption of M&I, extended sewer networks and improved treatment of wastewater the increased effluent and sludge quantities from treatment plants have to be disposed of safely. Agricultural water reuse and application of bio-solids on fields provide an excellent, ecologically suitable and economically feasible disposal option.

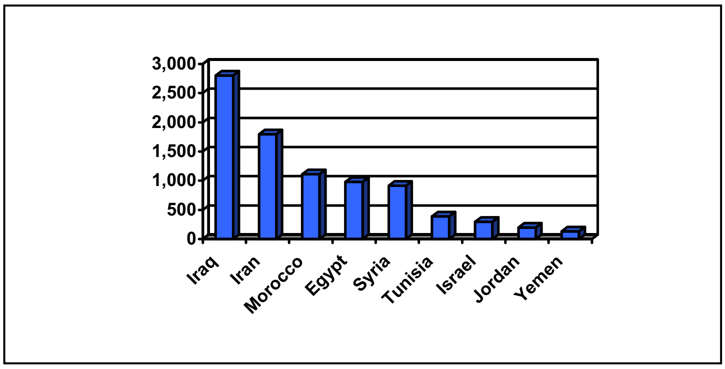
What is needed for the region's permanent water scarcity is a holistic approach which takes into account the needs of both, water *users* (M&I) and water *consumers* (agriculture). Properly treated wastewater and slightly saline water can provide a major share of the irrigation water demand on the farms.

So the decision is not necessarily an 'either-or'. The solution lies in an organizational, legal, and technical framework which allows to serve the major water needs of all economic sectors. Therefore, instead of blaming the agricultural sector for consuming some 70 percent of water resources as it is frequently done, the leading question is how to achieve cooperation between the different economic sectors?

The example of the Middle East and the current attempts to find solutions for the growing conflicts over available water resources may also be instructive with respect to future developments expected elsewhere in the world.

4.1 Introduction

Water issues in the Middle East have become a source of conflict between regional states as well as a mask for underlying tensions. Competition for fresh water factors into many regional political controversies, especially as populations continue to grow and renewable water resources available per capita decline. At the same time no major transboundary conveyance of water is to be expected in the region in the near future because of the prevailing political situation and the general state of water scarcity effecting all countries.



• Figure 4-1 Water resources in MENA (m^3/capita/yr)

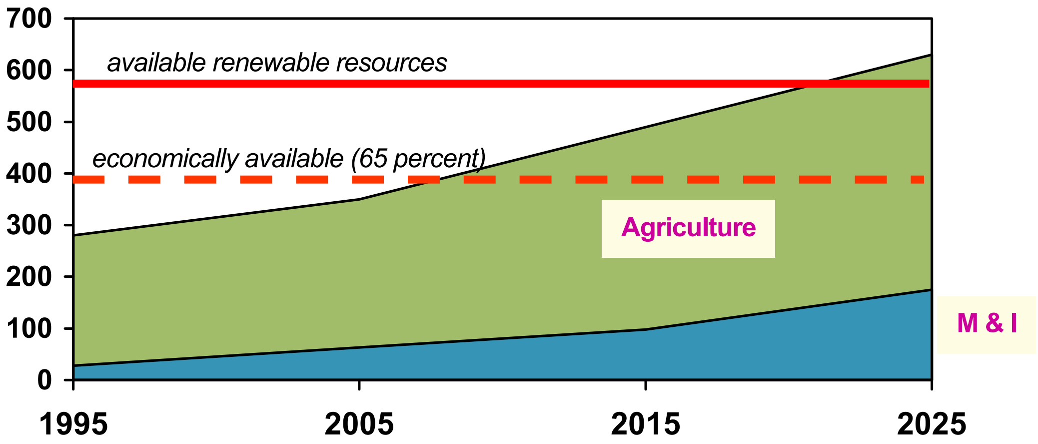
Therefore the countries of the Middle East are left with the task of adequate internal distribution of scarce water sources and with the resolution of the increasing conflict of water allocation to the competing sectors of their economies.

4.2 Scope

The paper draws evidence from the Jordanian case. On the one hand there is the intensively cultivated area of the Jordan Valley. The particular climatic conditions allow growing off-season fruits and vegetables, with the potential of high productivity provided sufficient irrigation water being available. On the other hand increasing population in the highland, industrial growth and further touristic development are demanding additional water allocations.

In this situation first of all an overall concept is required which integrates the particular interests of the competing sectors on a national level. At the same time water use and distribution within the agricultural sector and on farm level has to be optimized in terms of allocating water adequate in quantity and quality for different crops and their irrigation requirements.

- Figure 4-2 Growing competition for water supply in MENA (m^3/capita/yr)



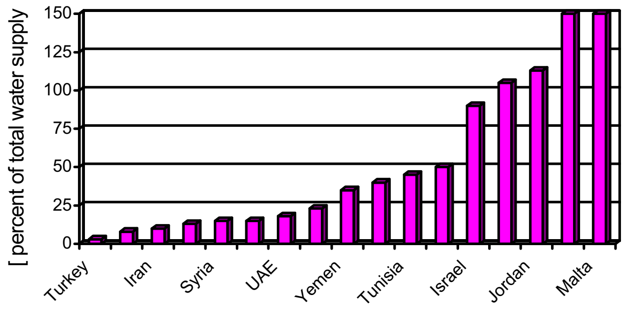
All efforts on the three particular levels, i.e. national concept, agricultural sector water allocation and farm management are directly linked and interdependent. Therefore justification and effectiveness of decisions and measures taken are to be evaluated with a common parameter, i.e. the achieved social and economic benefit for the involved individuals and the national economy.

4.3 Background

Food security is a legitimate concern of all countries. However, self-sufficiency requires in the order of 1,000m^3/capita/yr, far in excess of the resources available in areas like Jordan or the Palestinian territories having less than one fifth of this quantity. The solution is seen by many to be ‘virtual water': Importing one ton of cereals effectively also imports the 1000m^3 of water that was needed to grow it. Therefore food security is expected to be more likely through strong and diversified trading than by relying on the vagaries of climate and shrinking water resources to grow needed crops.

Besides the desire for food self-sufficiency the perceived need to create rural employment have driven governments to promote agriculture with all sorts of subsidies and other incentives. As populations have grown however, and economies become less agrarian, the demand for municipal and industrial water has rapidly exceeded available supplies. Consequently, competition over water has emerged with demands to reallocate water used in agriculture to rapidly growing urban centers. This is especially the case, since agriculture now contributes but a few percent to national GDP in countries like Israel and Jordan. Therefore, within the countries of the region it cannot be expected, that major additional freshwater resources will be available in future for agriculture because of the pressing demand of the M&I sector.

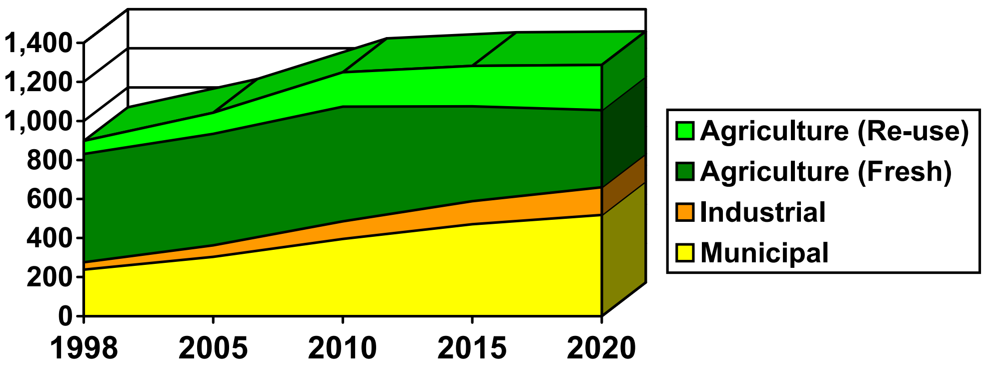
• Figure 4-3 Import of virtual water



4.4 Searching for new sources of irrigation water

Agriculture in the countries of the Middle East is facing the fading out of direct or indirect subsidies. With a growing scarcity of freshwater available for irrigation, other sources of lower quality like brackish water, saline water, and treated wastewater become more important as additional or substituting input for the agricultural sector. At the same time it is clear that sophisticated treatment like desalination or nano-filtration under current conditions is still far too expensive to be a major solution to future irrigation water needs. Hence adaptation of farming and irrigation practices to the particular water qualities constitutes a more viable approach.

• Figure 4-4 Projected water supply in Jordan



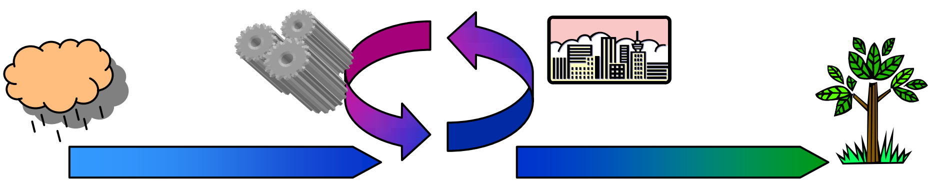
Resulting from the experience drawn from several countries of the region special emphasis has to be given to the practical approaches that have been successful in the past. Success, viability and acceptance of marginal water use in agriculture depend on locally adapted water and soil management with appropriate selection of cropping pattern and farming practices. Furthermore the following aspects have to be considered:

- Adjustment of the infrastructure (e.g. parallel conveyor system),
- Adapted operation and management of irrigation systems (quantity, quality, frequency),
- Appropriate agricultural, irrigation and drainage management on the farms,
- Involvement of water users, quality related water tariffs, tradable water rights,

- Provision of advisory services to farmers.

Complementary use of resources is also possible as shown by reusing the effluent from wastewater treatment plants. At the same time it has to be pointed out that the prospects of water reuse are less than one might expect at first thought. Some countries like Tunisia and Israel have quite extensive wastewater use programmes. However, the potential quantities available are limited. Due partly to consumptive use by M&I, restrictions in sewerage services and losses in transit and treatment, usually only some 25 percent of supply to M&I is left as discharge for reuse in agriculture. Although, as economies grow and sewerage coverage expands, the respective figure may reach nearly 50 percent of M&I effluent being available for water reuse in irrigation.

- Figure 4-5 Adding a "Loop" – Non-consumptive use of M&I



4.5 Imperative of cooperation between economic sectors

What on first sight might look like competition between economic sectors in their struggle for scarce water resources is more practically a challenge calling for close cooperation. The different sectors of the economy have different characteristics with respect to their water use *vis a vis* water consumption. In most cases M&I are *using* rather than *consuming* the supplied water. A significant portion of the supplied water to these sectors can - after proper treatment - be directly applied in agriculture.

Apparently the availability of water is not necessarily the most serious limiting factor for economic growth of industry and tourism in the region. But it is definitely the major restriction for irrigated agriculture. Therefore it seems to be less a political discussion whether more water can be diverted from agriculture to other sectors, but rather a question of willingness and technical ability to collect, treat and convey the return flow from M&I in a proper way for further reuse in agriculture.

Therefore in the near future a new role is coming up for agriculture. With increased water consumption of M&I, extended sewer networks and improved treatment of wastewater the increased effluent and sludge quantities from treatment plants have to be disposed of safely. Agricultural water reuse and application of bio-solids on fields provide an excellent, ecologically suitable and economically feasible disposal option.

Eventually the trade-off between agriculture and M&I has to be assessed by the achieved social and especially economic consequences and benefits. In this context it is necessary to reach a consensus concerning the relevant parameters that are to be studied and compared across the borders of individual sectors. Once this is agreed upon further work can be supported by suitable tools allowing modeling and forecasting of particular economic factors (e.g. agricultural gross-margin, contribution to GDP, etc.).

- Table 4-1 Area irrigated with treated wastewater in Jordan

	Area (ha)	Cereal,Fodder	Forest Trees	Fruit Trees	Vegetable
Restricted near WWTP	664	177	318	169	-
Restricted below WWTP	900	200	50	650	-
Un-Restricted after Blending	9,100	650	100	2,500	5,850
Total	10,664	1,027	468	3,319	5,850

4.6 Conclusions

What is needed for the region's permanent water scarcity is a holistic approach which takes into account the needs of both, water *users* (M&I) and water *consumers* (agriculture). Properly treated wastewater and slightly saline water can provide a major share of the irrigation water demand on the farms. It is obvious that handling of these water qualities requires some preparation of the farmers and eventually also assistance in developing appropriate irrigation management practices.

So the decision is not necessarily an 'either-or'. The solution lies in an organizational, legal, and technical framework that serves all the major water needs of all economic sectors. Therefore, instead of blaming the agricultural sector for consuming some 70 percent of water resources as it is frequently done, the leading question is how to achieve cooperation between the different economic sectors? And even more particular - How can the technical and institutional dialogue encourage cooperation between the stakeholders and support sound, acceptable and sustainable political decisions concerning water distribution on the national and eventually also on the regional level?

The example of the Middle East and the current attempts to find solutions for the growing conflicts over available water resources may also be instructive with respect to future developments expected elsewhere in the world.

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5 Cyprus country paper

CHRISTODOULOS PHOTIOU[5]

Summary

Today, 180Mm^3 of water representing 75 percent of the mean annual available water is used for agricultural purposes and 60Mm^3, i.e. 25 percent, for domestic water supply industry and commerce. Also, 6Mm^3 of sewage water is collected, treated and used mainly for irrigation purposes. It is expected that with the completion of central collection and treatment plants in the cities and villages (by 2012) 30Mm^3 of treated wastewater will be available for use.

Due to the scarcity and the high cost of land, only conventional treatment plants are used. Only 12 secondary and 20 tertiary treatment plants are operating in the villages(2000). From the central treatment plants of the cities, Nicosia, Limassol and Larnaka treatment plants are in operation, Paralimni – Ay. Napa treatment plant will commence its operation by the end of 2001 and Paphos treatment plant is under construction.

Concerning the treatment plants in the villages, the Council of Ministers decided that they represent a basic instrument for agricultural, social and environmental policy of the government, so they contributed to the total cost by 75 percent. The cost of the construction and operation of the tertiary treatment plants in the cities, as well as for the distribution of treated wastewater to the farm level, are covered by the government.

The problems related to the current practices of wastewater reuse are mainly related to the following aspects: environment, health, regulation, legal, social acceptability and public information, and training.

There are three institutions principally involved in the production, treatment and reuse of treated wastewater. The Water Development Department, which is responsible for the implementation of the water policy, has been appointed by the government as the responsible body for the tertiary treatment as well as the allocation and distribution of this water to farm level. The Department of Agriculture is responsible for the education of farmers in all matters related to agricultural production with the use of treated wastewater as well as to follow up the code of practice at farm level. The sewerage boards have the responsibility of the concentration operation and maintenance of the main sewer system, which includes the pipes, the pumping stations and the treatment plants.

The reuse of treated wastewater is an activity, which involves the responsibilities of different organizations. Thus, the institutional framework should be well defined and the distribution of responsibilities should be clearly specified. Especially for the farmers, it is very important to be aware of the responsibilities of each institution in order to address these problems accordingly.

In conclusion, treated wastewater and reusing it is considered a realistic new source of water to meet shortage and cover water needs. Also, it is a means to meet wastewater disposal regulations aiming at protecting environment and public health. From the environmental point of view, treatment and reuse of wastewater for irrigation could probably present the most safe, easy and useful disposal approach.

5.1 Water resources

Cyprus is situated at the northeastern part of the Mediterranean basin with an area of 9,251km^2 out of which 47 percent is arable land, 19 percent is forest and the remaining 34 percent is uncultivated land. It is dominated by two mountain ranges, the Troodos range in the central part of the island and the Pentadaktylos range in the north of the island. Between the two ranges lie the Morphou and Mesaoria plains that together, with the narrow alluvial plains along the coast, make up the bulk of the agricultural land.

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Most of the rivers, which flow only in winter, have their sources in the Troodos Mountains and only one substantial river has its source in Pentadaktylos. All the water resources of Cyprus result from rainfall. The average annual rainfall is about 500mm and ranges from 300mm in the central plain and the southeastern parts of the island up to 1,100mm in the Troodos range and 550mm at the top of Pentadaktylos. The variation in rainfall is not only regional but annual and often two or even three years consecutive droughts have been observed.

The volume of water that corresponds to the total surface area of the island is 4,600Mm^3 but only 20 percent or 900Mm^3 are offered for development. The remaining 80 percent returns to the atmosphere as loss by evapotranspiration. The mean annual water crop of 900Mm^3 is distributed between surface and ground water in the ratio 2:1 i.e. 600Mm^3 to 300Mm^3, respectively.

The main aquifers are found along the coast of the island and in coastal valleys where the sedimentary rocks and the alluvial soils of the rivers, which have high permeability, allow the percolation and storage of surface water. Out of the 300 Mm^3 of water that recharge the aquifers about 270 Mm^3 are pumped or over pumped from boreholes or come up naturally from the ground as springs. It is estimated that about 70 Mm^3 of groundwater is lost into the sea through the aquifers, especially during the winter months.

From the surface runoff of 600Mm^3 about 150Mm^3 are diverted from rivers in winter and spring and used for irrigation. The present storage capacity of the dams and ponds is 300Mm^3 but annually the available or safe yield of these dams hardly reaches 190Mm^3. The remaining 260Mm^3 of surface runoff flow to the sea.

If a balance of water resources of Cyprus was to be carried out, then the inflows would include the mean annual water crop of 900Mm^3 which is analyzed into 67 percent surface water and 33 percent groundwater, while the outflow is analyzed into 37 percent losses, 30 percent pumping and flow from springs, 21 percent mean annual supply and 17 percent river diversion for irrigation. These outflows create a small deficit of the order of 5 percent which is caused by the over pumping of certain aquifers.

Records indicate a significant reduction in rainfall over the past 25 years. Especially during the last decade we suffered from consecutive severed droughts. As a result, 180Mm^3 of water, representing 75 percent of the mean annual available water, is used for agricultural purposes and 60Mm^3, i.e. 25 percent, for domestic water supply, industry and commerce.

Recently two desalination treatment plants have been launched producing 30Mm^3/yr for domestic purposes. It is expected that in two years time the desalinated water will increased to 50 Mm^3/yr.

Another source of water, which is continuously increasing, is the treated wastewater. Nowadays about 6Mm^3 is treated and used mainly for irrigation purposes. With the completion of the central collection and treatment plants in the cities and villages it is expected that 30Mm^3 of treated wastewater will be available.

In view of this situation, the Ministry of Agriculture, Natural Resources and Environment has formed a long-term integrated policy for a satisfactory solution of water problem. This policy includes, amongst others, the proper use and conservation of water with integrated development projects and water management programmes, the use of marginal quality water, the construction of sewerage treatment plants and the reuse of treated wastewater.

5.2 Wastewater treatment and reuse

Due to the scarcity and high cost of land, only conventional treatment plants are used. The treatment plants for the villages are usually tertiary, when the treated wastewater will be used for irrigation or secondary when the treated wastewater for specific reasons cannot be used for irrigation. All treatment plants for the cities are tertiary and the water produced is used mainly for irrigation. The tertiary treatment plants are of the activated sludge type and consist mainly of:

- Preliminary treatment: where the removal of coarse solids or other large material often found in raw wastewaters is taken place,
- Primary treatment where the removal of settleable organic and inorganic solids by sedimentation and the removal of floating materials by skimming is taken place,
- Secondary treatment: where the removal of residual organics and suspended solids is taken place,
- Tertiary treatment: where the removal of specific water constituents (N, P, BOD5, SS, heavy metals) which cannot be removed by the secondary treatment is taken place.

According to data from the year 2000, 12 secondary and 20 tertiary treatment plants in the villages were in operation. In the meantime another 10 treatment plants were either in design or a construction phase.

From the central treatment plants of the cities, Nicosia treatment plant is in operation since 1980 and its treated wastewater is deposited in the river, Limassol and Larnaca (first phase) treatment plants are in operation and the treated wastewater is used mainly for irrigation, Paralimni-Ayia Napa treatment plant will commence its operation by the end of 2001 and Paphos treatment plant is under construction.

The tertiary treated wastewater from the cities accounts for $6Mm^3$ and is used mainly in irrigation. With the completion of the central collection and treatment plants in the cities and the villages it is expected that about $30Mm^3$ of treated wastewater will be available in the near future, thus covering about 15 percent of the total irrigated area.

5.3 National policy strategy and on-going programmes

Until the late 1980s, sewage was totally disposed of underground in septic tanks – absorption pits. The increase in population density and water consumption created conditions, especially in areas with low ground permeability, where the quantities of sewage for disposal are beyond the absorptive capacity of the ground. The problems that followed this development, together with tourist expansion in the coastal areas, were behind the initiation for planning and construction of treatment plants. The establishment of central treatment plants was too slow to cope with the rapid tourism development. This created the need for adoption by the authorities of intermediate measures for protection of coastal waters from sewage pollution. As a result of this policy, a great number of private sewage treatment plants came into operation in a short time. Every effort was made by the authorities to ensure proper disposal of wasted but was felt that the correct solution was the central sewerage system. In the meantime the design and construction of treatment plants in villages was initiated. A list of the villages facing sewerage problems was prepared, priorities were set and constructions were initiated.

In order to facilitate the design and construction of treatment plants in the villages the Council of Ministers with its Act dated 28/5/1997 decided the following:

- The construction of treatment plants in the villages constitutes the basic instrument for the agricultural, social and environmental policy of the Government,
- For each treatment plant there should be a programme for the use of the treated effluent,
- The village will contribute 25 percent of the total cost and the Government will cover the remaining 75 percent,
- Each household will not pay more than US$130/yr. (this figure will be re-evaluated every three years),
- In the case of tertiary treatment, the Government may even cover a higher percentage of the construction cost.

For the central sewage treatment plants of the big cities, the sewerage board is responsible for covering the full cost up to the secondary treatment. The cost for the construction and operation of the tertiary treatment is covered by the Government, which is also responsible for the proper use of the treated wastewater.

During negotiations with the European Union (EU), it was decided that all communities with population equivalent of more than 2000 would be served with treatment plants by the year 2012. This was the result of a comprehensive study made by the Government of Cyprus and accepted by the EU.

The multifaceted experimental work of the Agricultural Research Institute was continued as well as the establishment and operation of demonstration plots, at farmers' level, from the Department of Agriculture.

5.4 Problems and issues related to current practices

The use of treated wastewater for agriculture is not only a beneficial source of water, which contains a lot of nutrients, but also the best solution for the disposal problem. In addition, using the treated wastewater for irrigation purposes has the advantage to turn an effluent into an asset. Unfortunately, irrigation with treated wastewater is generally associated with a number of problems and constraints that have to be considered. The use of such water as a consequence is subject to certain limitations and special attention must be given to its physical, chemical, microbiological and biological constituents.

The problems associated with the use of treated wastewater can be categorized in health (presence of pathogenic organisms, bioaccumulation of toxic elements to crops) and agronomic hazards (presence of inorganic pollutants or toxic substances which accumulates in the soil or crops affecting them and their yield). The main constituents of concern are restricted to:

- Suspended solids since filtration may be needed particularly with micro-irrigation systems,
- Nutrients in order to adjust fertilization,
- Salinity in order to estimate the leaching fraction and select appropriate cropping patterns,
- Pathogens for precautionary measures.

Attention should be given to wastewater constituents causing clogging in the irrigation systems. Clogging problems with sprinkler, mini sprinkler and drip irrigation systems might be a serious problem. Growths (slimes, bacteria) in the emitter orifice cause clogging, as do heavy concentrations of algae and suspended solids. The most serious clogging problems occur with drip irrigation systems. Microbiological water quality is most important when field workers and the public are exposed to treated wastewater directly or indirectly.

Treated wastewater used for irrigation may also have negative effects on the environment. The main environmental hazards associated with wastewater are the introduction of chemicals into soil and water. The main soil problems are salinity, alkalinity and water permeability, accumulation of potentially toxic elements and accumulation of nutrients. The main water problems, which under certain conditions are more important than the effects on soil, are the pollution of groundwater with the constituents present in the wastewater. Furthermore, there are additional issues related to practices of wastewater reuse. These issues can be summarized as follows:

- Social acceptability,
- Public information,
- Training,
- Legal issues,
- Regulatory considerations.

5.5 Institutions

There are three institutions principally involved in the production, treatment and reuse of wastewater. The Water Development Department is responsible for implementing the water policy of the Ministry of Agricultural, Natural Resources and Environment, with the objective of national development and management of the water resources of the country. As treated wastewater is part of the water resources, the Government appointed the Water Development Department as the responsible body for the tertiary treatment as well as the allocation and distribution of this water to the farm level.

The Department of Agriculture, which also belongs to Ministry of Agriculture, Natural Resources and Environment, is responsible for the education of farmers in all matters related to agricultural production with the use of treated wastewater. The selection of crops and irrigation systems to be used as well as preparation of irrigation schedules are amongst the responsibilities of the Department. Implementation of the guidelines and the code of practice is also the responsibility of the Department of Agriculture.

The Sewerage Boards is a public sector organization and has the responsibility of concentration, operation and maintenance of the main sewerage system, which includes the pipes, the pumping stations and the treatment plants. Its main target is to produce treated effluent that can be used for irrigation purposes. Sewerage boards treat the wastewater up to the secondary level while the Government undertakes tertiary treatment. The board is under the control of the ministry of Interior and its president is the mayor of the city.

5.6 Problems of an institutional nature

Treated wastewater and reuse is a reliable source of water even in drought years. However, its use is associated with environmental and health risks. Considering the risks associated with wastewater reuse, an adequate institutional framework should always be created to control, supervise and advise on reuse schemes, in order to ensure safe reuse. At the national level, reuse of treated wastewater is an activity that involves the responsibilities of several ministries, agencies and semi-government organizations.

The institutional framework should be well defined and the distribution of responsibilities clearly specified. Considering that usually a great number of institutions are involved, smooth operation of interactions is not always easy to achieve. The form and operational characteristics of the institutional framework should be designed to suit local conditions. It is important, especially for farmers, to be aware about the responsibilities of each institution in order to address the problems faced. Without this background general confusion can develop.

5.7 Conclusions and recommendations

Treated wastewater and reuse is a realistic option for new sources of water to meet shortage and to cover water needs. It is also a means to meet wastewater disposal regulations aimed at protecting the environment and public health. In addition, from the environmental point of view, treatment and reuse of wastewater for irrigation could probably present the safest, easiest and most useful disposal approach. Generally, health and environment can be protected through four groups of measures:

- Waste treatment,
- Restrictions of the crops grown,
- Irrigation methods and
- Control of human exposure to the waste and hygiene.

Tertiary treatment prevents excreted pathogens from even reaching the field. This is the responsibility of the sewage treatment boards. For farmers, selection of the appropriate crops, irrigation systems and human exposure control are more important.

To overcome the problem of salinity, the following approaches should be considered:

- Select crops tolerant to wastewater salinity,
- Select irrigation system,
- Follow a schedule of irrigation,
- Follow a leaching programme.

To overcome the alkalinity–permeability problem, the following solutions are recommended:

- Use of chemical amendments,
- Use of appropriate irrigation systems.

To overcome specific ion toxicity, the following measures are recommended:

- Selection of tolerant crops,
- Use of appropriate irrigation systems,
- Follow a leaching programme.

To overcome trace elements and heavy metals problems, the following are recommended:

- Select crops tolerant to certain heavy metals,
- Avoid acid fertilizers,
- Use of lime (calcium carbonate).

The problem of clogging of micro-irrigation systems, which is mainly of organic origin, can be solved with the selection of the irrigation system, in combination with the installation of central filtration or self-cleaning filters at the farm gate.

Contamination of groundwater with the constituents present in the treated wastewater can be avoided with the proper installation and use of micro-irrigation systems. To follow, an irrigation schedule is also a necessity.

To overcome the problem of social acceptability and public information the education of all participants in the process of reuse (personnel managing and maintaining treatment facilities and the farmers using the treated wastewater) is a necessity. Furthermore special attention should be given to providing information and education programmes that will involve people from all community levels. Also a well-organized public information campaign should be planned to make the public aware of the issue.

Training programmes, including technical, environmental, health and socio-economic aspects, should be introduced. This is a necessity because lack of skills and knowledge can potentially increase environmental and public health risks.

Regulatory considerations with the establishment of guidelines and code of practices are intended to protect the health of consumers and workers.

6 Egypt country paper

DR SHALAAN NASR SHALAAN[6]

Summary

Egypt's main water resource is the River Nile, which contributed about 82 percent of the available water from different resources in the year 2000. It is expected that by the year 2017, the River Nile will contribute about 62 percent although the amount of water from the Nile is expected to increase. One exception is the small area of irrigated land in several depressions in the western desert where fossil groundwater is the source of irrigation water. Rainfall is so negligible as a source of water for agriculture except for a small area along the Mediterranean coast with less than 200mm/yr.

Egypt is a unique country in the region that depends mainly on irrigation. The environment conditions controlling agriculture, e.g. clay soil, arid climate and intensive agriculture, need an intensive efficient drainage system. This results in huge amounts of agricultural drainage water, which is not to be considered as wastewater. Wastewater includes treated municipal sewage and industrial effluents, in addition to agricultural drainage, water which are considered as non-conventional water resources.

There are many laws and decrees that control the discharge of industrial wastewater. They include guidelines and standards for treated industrial wastewater to be discharged into water bodies. The strategy for the reuse of treated effluents in Egypt is based on the fact that adequately treated wastewater effluents are a precious resource. The policy for the time being is to use the wastewater effluents for irrigation producing timber trees planted in the desert and never to use it for irrigating any other crops like vegetables and field crops.

It could be concluded that there is an urgent need to launch a programme for strengthening national capabilities including provision for technical assistance and training programmes in water quality management with emphasis on:

- Dissemination of information on water quality;
- Wastewater management and reuse,
- Communities and private sector participation in water quality management,
- Economic measures, and
- Public awareness.

6.1 Introduction

Egyptian agriculture is wholly dependent on irrigation from the Nile River. One exception is the small areas of irrigated land in several depressions in the Western Desert where fossil groundwater is the source of irrigation water. Rainfall is very negligible as a source of water for agriculture except for a small area along the Mediterranean Coast with less than 200mm/yr. Outside the Nile Valley and Delta and the Mediterranean Coast, the bulk of Egypt (about 97 percent of the total area) is arid desert. Consequently, the agricultural development has always been, and still is today, closely associated with the Nile water. Almost more than 84 percent of Nile water is consumed by the agricultural sector. The rest is allocated for industrial, municipal and navigation uses.

6.2 Water resources

The main water resource in Egypt is the Nile River, which contributed about 82 percent of the available water from different resources in the year 2000. The other different resources are ground water, effective precipitation and non-conventional water. It is expected that by the year 2017 the Nile River will

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contribute about 62 percent, and that the amount of water from the Nile River will increase. Table 6-1 shows the water resources of Egypt in the year 2000 and the expected amounts by the year 2017.

- Table 6-1 Water resources of Egypt

Source	Current water resources for 2000 (Bm^3)	Projected water resources for 2017 (Bm^3)
Nile River	55.50	57.50
Rainfall and Floods	1.00	1.50
Ground water in the Deserts and Sinai	0.57	3.50
Groundwater in the Valley and the Delta	4.80	7.50
Agricultural Drainage water Reuse in Delta	5.20	8.40
Treated Wastewater	0.70	2.50
Cropping Patterns and Irrigation Improvement	-	7.00
Total	**67.77**	**87.90**

Source: NWRC (MWRI), 2001

Regarding wastewater, Egypt is considered a unique country in the region, as it is depending mainly on irrigation. The environmental conditions controlling agriculture, e.g. clay soil, arid climate and intensive agriculture, need an intensive efficient drainage system. Irrigation results in huge amounts of agricultural drainage water, which could be considered as wastewater. Treated wastewater includes the treated municipal water (sewage) and industrial effluents, in addition to the agricultural drainage water, which are considered as non-conventional water resources.

It is worth-mentioning that the per-capita water is presently 1,005m^3/yr (water scarcity level starts at 1,000m^3/yr) and it is expected to drop to 645m^3/yr by the year 2025.

6.3 Water quality status

- The Nile River water is generally of good quality,
- Shallow ground water in some areas is suffering from pollution with pathogens,
- Deep ground water pollution sources could be high salinity or the relative high content of heavy metals or both,
- Agricultural drains are polluted with untreated wastewater,
- Some canals have poor quality water due to wastewater discharges or mixing with drains.

6.4 Policy of water use

The present government policy is to utilize the available conventional and non-conventional water resources to meet the socio–economic and environmental needs of the country with focus on:

- Demand management,
- Resource development,
- Environmental Protection.

The major use of water is agriculture. The amount of water allocated for agriculture is presently about 88 percent, while the rest (12 percent) is allocated for municipal, industrial and navigational uses.

6.5 Wastewater

The government is working on the regulation of wastewater and agricultural drainage within an integrated water resources plan. As presented in Table 6-1, the current amounts of wastewater (agricultural drainage water and treated wastewater) were 5.90Bm^3 in the year 2000. It is planned to double these amounts, to reach 11.9Bm^3, by the year 2017.

Regarding agricultural drainage water, there is only one treatment, that is diluting its content of salts by mixing it with fresh (Nile) water. This is an old traditional treatment practised in Egyptian agriculture, especially in the north Nile Delta, for a long time. The current plans are to use the mixed agricultural drainage water for adding new areas to the cultivated land in Egypt. This area is estimated at about 445,000ha. Out of this area, 277,000ha located east of the Nile Delta, including part of Sinai, are already under reclamation. The rest, 168,000ha, is located west of the Nile Delta.

There are many laws and decrees that control the discharge of industrial wastewater from industrial firms. These include guidelines and standards for treated industrial wastewater to be discharged into water bodies, i.e. fresh surface waters (such as the River Nile and feeder canals), non-fresh surface waters and subsoil aquifers.

Sewage water receives either primary or secondary treatment. The total production of Sewage Treatment Plants in the country is presently about 7.0Mm^3/day (2.5 Bm^3/yr). Table 6-2 shows the capacity distribution of the existing Sewage Treatment Plants in the year 2000.

- Table 6-2 Treatment capacity of existing sewage treatment plants in 2000

Region	**Flow (1000m^3/day)**
Greater Cairo	3,280
Alexandria	970
Giza	900
Nile Delta	955
Upper Egypt	270
Sinai, Matrouh and New Valley	130
Suez Canal	419
TOTAL	**6,915**

A number of Laws and Decrees have been issued for the control of water pollution from municipal and industrial effluents, among the most important of which are:

- Law No. 48/1982 for the protection of the Nile River,
- Law No.12/1984 on irrigation and drainage,
- Law No. 4/1994 on environmental protection.

6.5.1 National strategy and policy

The Strategy for the Re-use of Treated Effluents in Egypt is based on the fact that adequately treated wastewater effluent is a precious resource of water. The present policy is to use wastewater effluents for irrigating and producing timber trees planted in the desert, but not for any other crops like fruits, vegetables and field crops.

POTENTIAL USES OF TREATED WASTEWATER (DOMESTIC SEWAGE AND INDUSTRIAL EFFLUENTS)

Based on Egypt's water policy the following are the potential uses of treated wastewater:

- Irrigation of agricultural fields and farms: water is needed to fulfill the country's obligation to reclaim 3.4 Mfeddans by 2017. The target is to increase the inhabited area to 25 percent compared with about 4 percent nowadays,
- Irrigation of forestry and green belts, jojoba, flowers, aromatics, industrial crops (cotton, flax, jut, etc.),
- Artificial recharge of groundwater reservoirs,
- Artificial and engineered wetlands,

- City parks, street, islands and other non-potable urban uses (such as fire fighting, flushing tanks, golf courts, etc.),
- Industry (cooling systems industrial processes: cement, paper mills, bricks, steel, etc.),
- Soil and sand dune stabilization.

6.5.2 Problems and issues related to current use

The following are the major problems and issues related to the current use of treated sewage water in Egypt:

- There is not enough infrastructure (treatment plants) to treat the amounts of wastewater produced in the country,
- About 50 percent of the urban population is connected to sewerage systems, while only 3 percent of the rural population is served by sewerage systems,
- Significant volume of wastewater enters directly into water bodies without any treatment,
- Many wastewater treatment facilities are overloaded and/or not operating properly,
- Some industries still discharge their wastewater with limited or without any treatment into natural water bodies,
- Municipal and industrial solid wastes are mainly deposited at uncontrolled sites and/or dumped into water bodies (especially outside greater Cairo),
- The quality of treated wastewater differs from one treatment station to another, depending on inflow quality, treatment level, plant operation efficiency, and other factors,
- There are negative impacts of the above problems on both health and environment,
- The potential environment impacts with respect to reuse in agricultural are numerous, including:
    - Soil contamination, including salt deposition,
    - Soil clogging resulting in poor infiltration,
    - Crop contamination,
    - Livestock infection,
    - Ground water contamination,
    - Raising of water table,
    - Surface water contamination,
    - Public health deterioration, and
    - Natural habitat and ecosystem deterioration.

6.5.3 Institutions

Several ministries are involved in water quality, for planning, operation, research, and monitoring and regulation activities. Among the major ones are:

- Ministry of Water Resource and irrigation,
- Ministry of Environment,
- Ministry of Health and Population,
- Ministry of Agriculture and Land Reclamation,
- Ministry of Industry,
- Ministry of Scientific Research,
- Ministry of Housing, Utilities and New Communities,

6.5.4 Problems of institutional nature

Many institutional problems are faced with the use of treated wastewater in Egypt. The following are considered the most critical ones:

- The conduct of water quality monitoring by several ministries and institutes,
- Absence of a clear policy and action plan for wastewater management,
- Need for the development of a water quality monitoring coordinated approach that is policy driven and takes into account agreed priorities,
- Unclear delineation of responsibilities and limited coordination among the involved institutions,
- Strict present standards, practically leading to impossible enforcement, limit the effectiveness of pollution abatement efforts,
- Limited dissemination of information among the various organizations and to the public,
- Need to increase awareness and strengthen capacity regarding water quality management issues.

6.6 Conclusion and recommendations

The key environmental concerns constitute the risks to public health. Therefore, wastewater of a standard quality should be used in groundwater and soils where the public is exposed to it, directly or indirectly, in order to minimize any undo risk. In this respect, wastewater should be conveyed out of reach from the general public, or otherwise with a clear indication that the water is not safe to use or drink, as stated in the guidelines under the issued Laws and Decrees.

The fate of contaminants is an important consideration for projects using wastewater. Most contaminants are removed in the top 2m of the soil by various biological, physical and chemical processes. However, these processes are not all able to function effectively in saturated soils, since they require that the water table be at a level deeper than 2m otherwise, direct contamination of the aquifer is likely to occur.

Plants also take up certain toxic elements from the depth of the rooting zone. These may be retained in plant tissue, including the edible parts, presenting a health risk over to consumers.

It could be concluded that there is an urgent need to launch a programme for strengthening national capacities, including provision for technical assistance and training programmes in water quality management with emphasis on:

- Dissemination of information on water quality,
- Wastewater management and reuse,
- Communities and private sector participation in water quality management,
- Economic measures such as polluters-pay incentives, etc,
- Industrial pollution abatement,
- Public awareness.

7 Iran country paper

SYED ALI MAHMOODIAN[7]

7.1 Introduction

For the past two decades, and particularly during the last years of the twentieth century, water has become the focal point of international discussions and negotiations, and there are no international gatherings on the future administration of the world in the third millennium, in which water and its management is not the salient feature on the agenda. Although in the past water issues were only national concerns, in the future these problems will have national, regional and even global dimensions, causing great international anxiety about peace, food security and sustainable development.

Water is the most important life-sustaining substance, but unfortunately it is not distributed equitably throughout the world. Its abundance has caused problems in some areas, whereas in most places, especially the arid and semi-arid regions, its scarcity, coupled with insufficiency of resources and the huge costs of long distance water transfers or desalination of seawater on one hand, and the existence of large volumes of wastewater around cities and their suitability for agricultural use on the other, have turned recycling treated wastewater into a very attractive option. In the last decade, scientists have paid special attention to this matter and recommend it as a source of water supply for agricultural and industrial uses.

Like many other countries, which are counted as arid and semi arid due to their climatic conditions and are afflicted with water tension, in Iran also water scarcity has become a critical issue. Under such conditions, the reuse of effluents is one way to alleviate the problems of water shortage. However, it should be considered very carefully. In territories where access to water is very difficult and new supply systems are highly expensive, water consumption should entirely conform with economic principles.

Moreover, the water, which has been transferred at great expense from long distances, through employment of all facilities for urban supply should not be wasted after urban consumption, without any further utility. Put in another way, one can say that unconventional water resources are the only reliable source of supply for future generations.

The mentioned realities have forced officials, planning organizations and international bodies to take notice of the value and importance of recycling this rare and vital substance, placing this issue high on their agenda for developing plans, to the extent that while respecting all the special conditions of each urban area, the reuse of water has become the central theme in any urban water supply plan.

A very good example of this concept is the present conference, jointly organized by FAO and WHO in the great country of Jordan. It has provided a good opportunity for the exchange of views and finding practical solutions for reuse of the limited water resources in the region. This article is a general review of the facilities and measures taken in the Islamic Republic of Iran in its plans and programmes for collection, treatment and safe reuse of wastewaters.

7.2 Overview of water resources

7.2.1 Water resources

Covering a surface area of 1,648,000km^2, Iran is divided from a hydrological point of view into 6 main and 31 secondary catchments areas. The annual average rainfall equals 251mm or the equivalent of 413Bm^3. This figure is one quarter of the global average (land and sea), and one third of the average rainfall on land. Occupying 1.1 percent of the land surfaces of the world, Iran has access to only 0.34 percent of the world's inland waters. The annual rainfall fluctuations in different parts of Iran vary from 1400mm (in the north) to less than 50mm (Central Desert). Each year, 72 percent of the rainfall, or the

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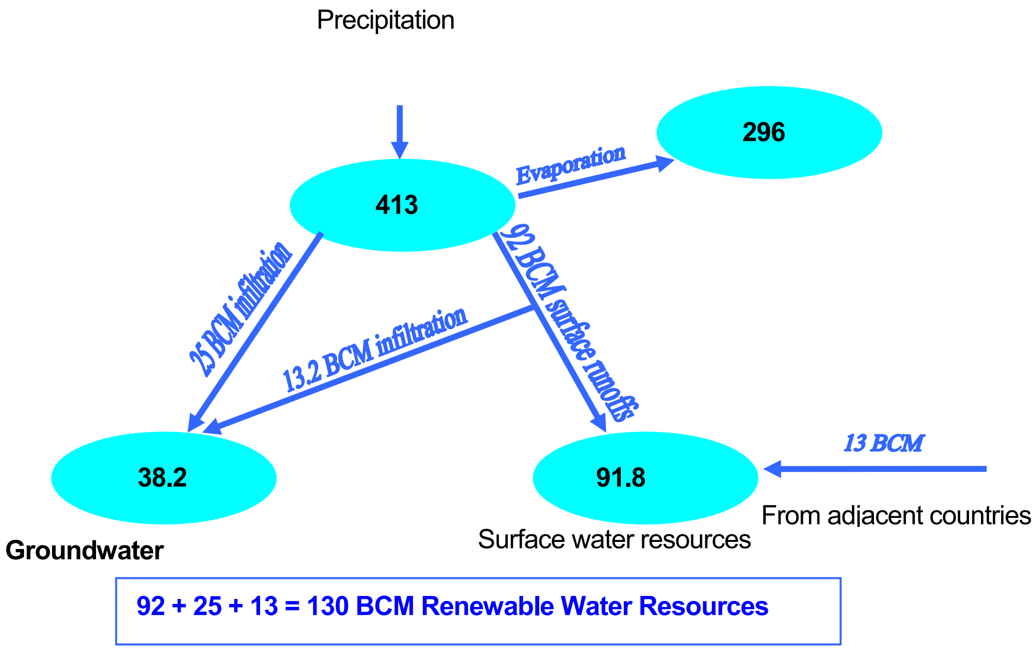
equivalent of 296Bm^3 of water, is evaporated and cannot be used. Therefore, the efficient precipitation in the country is only 28 percent of the total, equivalent to 70mm.

From the total of 413Bm^3 of precipitations in the country, around 92Bm^3 flow as surface run-off, 25Bm^3 feed directly the alluvial aquifers and the rest are lost through evapotranspiration (Figure 7-1). In addition to rainfall, around 13Bm^3 of water enter the country from cross border rivers and, by joining the surface flows, increase the potential of renewable water resources of the country to a figure of 130Bm^3. From a total of 105Bm^3 of surface flows in the country (including from borders), around 13.2Bm^3 feed the alluvial aquifers and 41Bm^3 are used; and from this figure around 18.3Bm^3 also infiltrate to ground aquifers. Considering the above, the ground resources are replenished by 56.6Bm^3 of water, whereas the withdrawal volume reaches a figure of 61.3Bm^3, of which 46Bm^3 are used, 5.5Bm^3 are lost through evapotranspiration, and 9.7Bm^3 flow out to seas, marshes and lowlands in the form of runoff and surface and underground drainage water.

Studies and reviews show that, currently, from the total of renewable resources, around 88.5Bm^3 are drawn for agriculture, mines and industries, and drinking purposes, and from this figure in turn, around 83 Bm^3 (93.5 percent) is allotted to agriculture, 4.5Bm^3 (5 percent) to drinking and sanitation and the rest to industries, mines and miscellaneous uses.

The Changes in consumption pattern during the period between the years1960 to 2020 are represented in Table 7-1.

- Figure 7-1 Simplified water balance in Iran



- Table 7-1 Changes in consumption pattern from 1960 to 2020

Type of consumption	1960	1995	2020
Agriculture	98.6	93.3	87
Rural and Urban Drinking	1.3	5.2	7.4
Mines and Industries	0.1	1	2.7
Marine life	-	0.5	2.9
Total	100	100	100

7.2.2 Changes in population

The total population of Iran has more than tripled from 18.9 million in 1956 to almost 60million in 1996. In the past 40 years, urban population has increased 6.18 times, while rural population has grown only by 1.79 fold. The ratio of urban population in the year 1955 was around 31.4 percent, while the number of towns amounted to 199. This index increased during the years 1965, 1975, 1985, and 1995 to 38.7 percent (272 towns), 47.03 percent (373 towns), 54.3 percent (496 towns) and 61.3 percent (614 towns), respectively.

In view of this increasing trend, it is expected that by 2020, the ratio of urban population will reach almost 70 percent and the number of towns 1,932. The number of cities with more than one million inhabitants in the years 2010 and 2020 will increase to 11 and 19 respectively. By 2020 there will be 19 mega cities and 13 large cities with a population of 500,000 to 999,000 people and 143 medium towns of 100,000 to 499,000 inhabitants. Furthermore, in the same year, there will be 171 small towns with a population of 50,000 to 99,000 and 1586 communal towns with less than 50,000 inhabitants, which will be home to 70 percent of all the country's estimated population of 98 million, while the urban population of the country will be 67.5 million (Table 7-1 and Table 7-2).

- Table 7-2 Ratio of urban population to the country's total during 1955 to 2020

Year	Ratio percent	The number of towns
1955	31.4	199
1965	38.7	272
1975	47.03	373
1985	54.3	496
1995	61.3	614
2000	63.3	734
2020	69.1	1932

- Table 7-3 Number of towns in 2020

Type of town	Population (X 1000)	Number of towns
Mega-city	> 1000	19
Large city	500 - 999	13
Medium town	100 – 499	143
Small town	50 – 99	171
Communal towns	< 50	1586
Total		1932

However, the establishment of populated poles without due consideration to the capacity of water supply and planning beyond the potential of natural water resources have aggravated the problem of water scarcity.

7.2.3 Per capita renewable water

Despite having more than 130Bm^3 of renewable water, due to economic, technical and environmental limitations, we have not been able to fully exploit this potential. By the year 2020 we shall not be able to use more that 112Bm^3 of either surface or ground water resources. Based on the trend of population growth, the per capita renewable water has been reduced from 5,800m^3 in 1956 to 1,830m^3 in 1996, dropping further to 1,200m^3 by the year 2020. This means that the per capita renewable water has decreased 5 folds during the last 65 years. So new generations will have to live with a limited amount of water, despite an increase in their demands.

7.2.4 Water quality and environmental issues

As mentioned earlier, the volume of 4.8Bm^3 of water is drawn annually from permanent aquifers. According to estimates, the accumulative surplus water drawn is between 60 and 80Bm^3. The negative impacts of this process on the environment and the advance of brackish basins towards freshwater resources in various parts of the country are quite clear.

Currently around 19Bm^3 of agricultural, industrial and urban effluents are discharged to surface and around 10Bm^3 to groundwater resources. The total of these two figures corresponds to around 23 percent of the potential of renewable water resources in the country, whereas the total of treated effluents and returned waters is quite negligible (0.26Bm^3/yr).

7.2.5 Water crisis and the need for recycling water

Notwithstanding the demand from harvestable resources, the severe decrease of per capita renewable water resources is the most distinct index for the occurrence of a water crisis in any country. In Iran the potential of renewable water resources is between 130 and 135Bm^3 a portion of which is unusable due to pollution. Therefore, even with the most optimistic evaluation, the demand rate will surpass the rate of harvestable water by the year 2010, and Iran will be faced with a serious water crisis. However, due to delays and holdups in new water projects, the amount of available water is much less than the yearly demands, and so, one can claim that the country is already on the threshold of a water crisis. A measure to counter this crisis is the use of unconventional water resources, including wastewater, which is among the most valuable and considerable resources of the country.

7.2.6 Freshwater consumption and the volume of wastewater

Another reason for higher per capita water consumption apart from population growth is the improved living standards. In Tehran, the per capita water use in 1986 averaged 247 l/d. A decade later, this rate had increased to 353 l/day. Consequently, water supply to the city increased from 98.43Mm^3 in 1966 to 870Mm^3 in 1996, reaching the figure of 980Mm^3 in the year 2000. The nationwide per capita demand is 242 l/day and the volume of water supply has increased from 200Mm^3 in 1956 to the current figure of 4.16Bm^3. The total urban population is presently (2001) 41.60million, 97 percent of whom benefit from urban water supply. The total of the country's urban and rural water consumption is expected to reach 7.8Bm^3 by 2020. Assuming that 75 percent of the total water consumed is discharged, the volume of household wastewater would be equivalent to 3.1Bm^3. According to predictions mentioned in the Report of the Comprehensive National Water Study, by the year 2020, the volume of urban and rural returned waters will be 5.9Bm^3 and the volume of industrial effluents will be 1.4Bm^3, making a total of 7.3Bm^3 of wastewater. Adding the 25.97Bm^3 of agricultural effluents, the total of returned waters in the country will reach the figure of 33.6Bm^3. In view of this considerable volume of water, it is necessary to implement management programmes as soon as possible.

7.3 Overview of sewage and wastewater treatment and reuse

7.3.1 Existing condition of urban wastewater discharge

Although by the end of year 2000, there were many wastewater projects either being planned or implemented in over 228 towns, still in most urban areas (with the exception of Isfahan and some others) wastewater was discharged to ground basins through absorption wells. The traditional wastewater collection systems are also available in around 75 towns and cities, but the raw wastewater is either discharged directly to water courses, or used for irrigation. Based on the efficiency of these systems, and according to the conditions of wastewater discharge, the urban areas of the country are divided into two groups. The first group comprises the towns where suitability of soil and climate make the traditional wastewater discharge currently tolerable. Their number is around 250 and they are mainly small towns (with 24 percent of the country's population). The second group consists of towns, where due to either high level of water in ground basins or the impermeability of soil, discharging wastewater to the ground is not possible. In view of health hazards and environment protection, serious measures should be taken immediately in this group to implement wastewater plans. This situation prevails in around 350 towns, which are mostly large and home to 74 percent of the country's population. Considering the increasing population, relatively quick development of urban areas and higher water consumption, the traditional wastewater discharge system has heightened the problems and inadequacies in these towns. The most important problems are sanitation and a threat to the environment, which have resulted in outbreaks of infectious diseases, disruption of natural water balance, rising levels of ground water tables and pollution of water resources.

7.3.2 Performance and execution of wastewater plans

There are currently 228 wastewater collection and treatment plans either under study or being implemented by Water and Wastewater companies. From this total, 86 projects are in the study phase and the rest are being executed in 142 towns.

Establishment and expansion of urban wastewater networks until the end of 1999 (the target year for the Second Plan), reached the figure of 14,528km including 3,500km of traditional systems, providing service to 5.76 million people. By reaching the target of 15,000km of wastewater collection network set in the Third Five Year Economic, Social and Cultural Plan, around 7.7 million people will benefit from wastewater services, and in this case the situation in the last year of the Plan (2004) shall be as indicated in Table 7-4.

- Table 7-4 Situation of wastewater services

	Unit	2001	2004
Population coverage of wastewater collection network	Million	7.250	13.5
Percent of population covered in relation to the country's total	Percent	15	30
Length of wastewater collection network	Km	16,700	29,528
Number of wastewater connections	Connection	1,035,000	2,284,000
Volume of produced wastewater	M3/day	712,000	2,379,000

7.3.3 Wastewater treatment

To protect the environment and water resources form pollution and to reuse effluents, it is imperative to treat wastewater in the country. According to national standards, wastewater should be treated to reduce the levels of BOD and SS to 30mg/l and 40mg/l, respectively.

Currently, 39 treatment plants with a total capacity of 0.7Mm^3/day are operating throughout the country, treating the wastewater produced by a population of 3.8 million. There are also 79 treatment plants with a total capacity of 1.9Mm^3/day under construction, ready for operation by the year 2005. Furthermore, there are 112 treatment plants with a total capacity of 1.6Mm^3/day being studied for completion by the year 2010. It is also planned, to build second modules of the above plants during the period between the years 2010 and 2025. Accordingly, by 2025, the volume of treated urban wastewater will reach a figure of 10.5Mm^3/day or 3.8 Bm^3/yr, which is a very considerable potential for reuse.

7.3.4 Reuse of wastewaters

Using treated effluent to augment existing water supplies is an option that is becoming increasingly attractive. The advantages of wastewater reuse can be identified as follows:

- Water pollution abatement (not discharging into receiving waters),
- Reliability of water supply,
- Water demand and drought management,
- Encouragement for conserving resources,

- Availability of highly treated effluent for various beneficial uses.

The reuse of wastewater has a long history throughout the world. Wastewater has been used for irrigation either through direct transfer by aqueducts to agricultural fields, or indirectly by discharging it into rivers and conducting the water downstream to farms. As mentioned earlier, in Iran there are currently 39 wastewater treatment plants with a nominal capacity of 712,000m^3/day, but still operating below their capacity with a total outflow of 356,600m^3/day (130Mm^3/yr), 64 percent of which from the city of Isfahan alone. This city of 1,374 million people is the second largest one of the country and the first to have a full wastewater collection system from nearly 30 years ago. The other 36 percent belong to the rest of the country. Wastewater in Isfahan is discharged into Zayanderood River (the second largest of the country). In the other urban areas, wastewater is disposed of in a similar fashion. Therefore it can be claimed that at the moment all the treated wastewater is indirectly used in agriculture. Of course in some towns, albeit in a limited form, raw wastewater is used directly for irrigation, resulting in some health related problems.

As mentioned before, around 70 towns, which are mostly situated in the west, north- west and north of the country, due to their rocky ground or high level of water table, have a traditional wastewater collection system (like Rasht and Ahvaz). Here also the wastewater is often discharged untreated to existing floodways, a part of it infiltrates the ground and the rest is used for irrigation downstream. The volume of this wastewater is estimated to reach 116Mm^3/yr.

In other places, despite ongoing projects for wastewater collection, the main method for wastewater discharge is through absorption wells, and a part or all of the discharged wastewater reaches the underground water basins to be drawn and used for irrigation later on. As a result there is a kind of artificial replenishment of ground basins in these towns; however in some areas there are signs of pollution threatening freshwater resources. For example, tests have shown that the nitrate content in groundwater resources of the city of Mashad is 180mg/l and that of Arak reaches up to 220mg/l, which is many times more than the allowed limit. The volume of wastewater in this urban group is estimated to be around 2.83Mm^3/yr, and as wastewater collection and treatment plans are implemented, the indirect and unsafe use of wastewater changes into direct and safe reuse.

7.4 National policies, strategies and ongoing programmes

As observed previously, Iran is on the brink of a water crisis. The country experienced the severity of drought-instigated water shortage during the past two years. To counter the crisis, the Government has included these four essential actions in the national water management programmes:

- Efficient and optimal use of available water resources,
- Continuing effort to find new resources in the water cycle and maximum use of unconventional water,
- Deep and far-reaching actions to conserve freshwater resources and prevent the pollution and destruction of water quality,
- Expanding public awareness and implementing demand management programmes.

The on-going water crisis in the country has also forced many decision-making bodies to consider the reuse of effluent as an appealing option. Among the recent decisions taken by the Expediency Council, were the adoption and implementation of general plans for recycling water nationwide. The proposed policies and strategies are as follows:

- Fully satisfying the drinking water demand potential from freshwater, prior to any other use. To achieve this, it will be necessary for new urban water supply plans to pass freshwater, either from surface or ground resources, through cities, for drinking purposes, and then the produced wastewater will be allotted to the agriculture sector after treatment,
- Guaranteeing future urban water demands by replacing the agricultural water rights (from brooks, rivers, springs well, etc., which are of potable quality) with treated effluents. It is now time for those towns which are faced with shortage of freshwater resources, to negotiate with

farmers first hand appropriation of freshwater and the allotment of treated wastewater instead. According to estimates, during the next ten years, around 100Mm^3, and in twenty years time around 180Mm^3, have to be added annually to the existing resources of Mashad, which is the third largest city of Iran, with a population of 2.4 million. To guarantee such a supply, the option is either to transfer water from northern frontier rivers at a distance of 200 to 250km, or to replace agricultural water (from dams or wells) with treated urban effluents. With the completion of Mashad Wastewater project, the second option is more attractive than long distance transfer (requiring construction of a dam on Tajan River and creation of a 250km supply line), as far as economy and initial investment are concerned. Currently both options are being studied. In Tehran also, the more urban wastewater is allotted for Varamin agricultural fields, the more Jajrood River water (which is currently used for irrigating Varamin fields) can be supplied to Tehran for drinking purposes,

- Avoiding the use of high quality urban water to create green spaces, and instead allotting low quality water for this purpose. Each year in Tehran, over 50Mm^3 of raw (but potable) water is used to irrigate the forests northeast and west of the city. A considerable portion of this demand can be alleviated by treated wastewater and, instead, the water used for forestation can be added to Tehran's freshwater potential. Through expansion of Tehran Wastewater Plan and the use of effluent for greeneries and industries, the stressful situation of freshwater resources will be abated,
- Cutting off water supply to industries that have not taken practical measures to treat and reuse their wastewater. The most important related legal status, proposed in the Third Five Year Economic, Social and Cultural Development Plan, and approved by the Parliament, is Article 134, according to which issuing new licenses or renewing old ones for exploiting surface or ground resources or for obtaining a connection to the urban supply network by large production units, industries, animal husbandries, or services, which produce a large amount of wastewater, will be subject to the construction of wastewater treatment and recycling facilities by the said units,
- Expansion of research projects towards establishment of reasonable standards for safe and reliable reuse of wastewater. Replacing freshwater with treated effluents in agriculture necessitates introducing farmers to the positive and economic advantages of using wastewater, and consequently convincing them to exchange freshwater with effluents. This in itself requires research and study on the sanitary, economic and environmental impacts of using wastewater for agriculture and artificial recharge of ground resources. There were two related projects in Mashad, undertaken by the Ferdowsi University with very beneficial outcomes. The research, lasting for a full growth cycle, yielded to the following results, among others, but still a generalization will not be possible without consecutive studies over several years:
    - For producing carrots, the use of wastewater resulted in an increase in yield of 4T/ha, which is equivalent to the yield obtained from 25 tons of manure. The crop irrigated with effluents carry sanitary pollutants such as parasite roes and feces Coliforms, but the quality of the product itself is in no way affected. Moreover, irrigation using effluents had changed neither the physical nor the chemical characteristics of the soil,
    - In tomato farms, there was a considerable increase in yield (28T/ha) as compared with reference crops. There were no signs of sanitary pollution and the quality of the product was not affected,
    - In cucumber, the use of effluent resulted in an increase of 14T/ha, a value comparable with the productivity of 25T/ha of manure. The cultivation method, in which the bushes did not come into contact with wastewater, caused no sanitary pollution,
    - In sugar beet farms, in comparison to those irrigated with normal water, the use of wastewater increased considerably most of the quantity and quality parameters of the crop, to the extent that during tests, the sugar yield of beets was 2.36 times more than the samples irrigated with well water.

Other policies and strategies related to the reuse of wastewater are summarized below:

- Focusing on public health as the most important consideration in wastewater reclamation and reuse,

- Including the programme for safe reuse of wastewater among the objectives of every urban wastewater plan, be it at the study or design stages,
- Abandoning the culture of "single use of water" and by replacing it with the concept of "water is not a single use commodity", urban and industrial wastewater should be thought of as a valuable and considerable water resource amongst others in the country,
- Preparing a general programme for the study and implementation of water recycling plans and the use of unconventional waters,
- Halting new water allocation from national resources to towns, which do not have an approved plan for reuse of their wastewaters,
- Preparing and implementing regulations and tariffs related to water consumption and its reuse and recycling,
- Teaching farmers the positive advantages of using effluent in agriculture as well as its safe method of application.

7.5 Institutions

According to the law, numerous ministries are involved in various aspects of water, with activities running parallel to each other, sometimes interfering and sometimes facing a lack of guidelines and directives. This multiplicity, at times, not only causes a gap in control of quality and quantity and pollution abatement, but is also an impeding factor. The Ministry of Energy is responsible for supplying freshwater and discharging wastewater form urban areas, whereas the responsibility for rural water supply and wastewater collection is handed over to the Ministry of Agriculture and Jihad, and the supreme monitoring of water quality from drawing point to consumption, as well as the improvement of freshwater resources in rural areas, which do not have piped water, have become the charges of Ministry of Health, Medicine and Medical Education. The Environment Protection Organization is in charge of protecting and preserving water from pollution, and has to take action to prevent water pollution by industrial, household and agricultural units. Within the Ministry of Energy, the Regional Water Boards (Government concerns) are responsible for water supply to cities, and the water and wastewater companies (NGOs), are in charge of distribution of water, as well as the collection and treatment of wastewaters. Moreover, the treated urban wastewater is delivered to Regional Water Boards, to be distributed among farmers.

7.6 Problems and issues related to current practices

Some of the problems and issues of wastewater recycling management in Iran are listed as follows:

- Delays in plans for collection and treatment of wastewater, in relation to the society's demand,
- Legal inadequacy for bringing action against polluting industries and the users of raw wastewater in agriculture,
- Excessive decision making centres and divided management of water supply and consumption, which ultimately results in futility of responsibilities,
- Inability of city and village dwellers to pay for costs, investments and operations of wastewater plans,
- Reluctance of people to pay for wastewater connection fees in towns or areas where the traditional system is relatively efficient,
- Shortage of information and insufficient research related to water recycling and reuse in different parts of the country,
- Farmer's limited awareness of advantages of wastewater reuse in agriculture and its methods of application.

7.7 Conclusions

In Iran and other arid and semi arid regions of the world, water shortage is an increasingly critical issue. The exponential growth of population and inclination towards industry and technology, in parallel with agricultural development, mean more demand for water and, under such conditions, the safe and reliable reuse of wastewater is an important option for solving water shortage in urban areas. On the other hand, due to many valuable compounds, the benefits of using treated effluents and resulting sludge for soil and water ecosystems cannot be ignored.

Farmers consider only the irrigation and economy of using effluents and neglect its health, biological and environmental aspects. However, the impacts of using wastewater should be generally evaluated from three different outlooks:

- Preventing health hazards and the spread of diseases,
- Guaranteeing the society's security and welfare, and preserving natural beauty and the environment,
- Preserving the balance of ecosystems and natural resources.

With these objectives in mind, many research activities have been conducted throughout the world and consequently many proposals have been compiled and published on reuse of wastewater. The WHO recommendation is one such achievement. However, they are all just general guidelines and if the reuse of wastewater is to be considered seriously and on a long-term basis, it will be necessary to conduct separate and repeated field research for every climatic, soil and social conditions as well as for any type of cultivation, to analyze results and to propose practical recommendations.

The launch of the Near East Network on Reuse of Treated Wastewater, which is to be jointly managed by WHO and FAO, will provide a suitable opportunity for research on the above objectives and Iran warmly welcomes the move. Through the efforts and activities of this Network, it will certainly be possible to cooperate and conduct joint studies to compile a "Source Book" in which the proper methods and procedures for efficient use of wastewater, as well as realistic and practical regulations and standards under different climatic, farming and environmental aspects of regional countries, with due consideration for their economic, social and living conditions, are explained.

We should all be aware that the period of considering water as a single use commodity is over and well behind us, and that it is time for a new concept in planning at every level of water management in the region, towards increasing water production, reuse and closing the water cycle.

8 Iraq country paper

HAMMAD M. SALIH[8]

Summary

The limitation of river water during the past decade has become the most important factor that limits agriculture production in Iraq. Therefore, non-conventional wastewater has to be taken into consideration as an additional resource for the expansion of irrigated agriculture and the saving of fresh water for other social and industrial purposes. Preliminary studies indicate that treated wastewater could be used as an integral part of a water management strategy. However, intensive studies are needed to avoid environmental difficulties due to the moderately high level of some harmful ions and salinity. In addition to this wastewater must meet the standard level of pathogen microbes before reuse.

8.1 Introduction

The limitation of river water during the past decade has become the most important factor that limits agricultural production in Iraq. Therefore, considerable efforts have been given to use other resources of water such as drainage and groundwater. These water resources are used by farmers for the production of cereal and vegetable crops in the desert and in regions where no fresh water is available. Due to expanding agriculture and growing population in Iraq, non-conventional wastewater has been taken into the consideration, as an additional resource, for expansion of irrigated agriculture and the saving of fresh water for other social and industrial purposes.

8.2 Sanitation practices

Many sanitary sewage plants have been built up in several counties and cities of Iraq. The biggest two were built in Baghdad County. The first one “Al-Rustumia treatment plant” was designed to handle an average flow of 204Mm^3/yr, and the second one “Al-Karkh treatment plant” which handles an average flow of 150Mm^3/yr. Most of the plants consist of a conventional activated sludge process. The unit processes are:

- Preliminary treatment (screening, grit removal and preparation),
- Primary sedimentation,
- Secondary treatment (air-activated sludge),
- Final sedimentation,
- Effluent chlorination (treated wastewater),
- Sludge drying.

Until now, the majority of wastewater after treatment has been discharged into rivers and drainage canals by gravity and no definite canal network for wastewater collection is available.

8.3 Chemical properties of wastewater

Baghdad city is generally supplied by less saline drinking water (0.8 – 1.2 dS/m) and this salinity increases almost 2–3 times in the wastewater (Table 8-1 and Table 8-2). Therefore, it can be used without creating any salinity and alkalinity problems except for very sensitive crops. The sodium concentration is rather low resulting in sodium adsorption ratio (SAR) ranging between 2.68 and 3.12 for Al-Rustumia station and between 4.38 and 5.24 for Al-Karkh station. With such values of problems for crops and soil are expected.

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Chloride content of wastewater of Al-Karkh station is relatively high for surface irrigation and not recommended for sprinkler irrigation, while chloride content of Al-Rustumia station is appropriate for surface irrigation but relatively inadequate for sprinkler irrigation. Bicarbonate content of wastewater from both stations is adequate for surface irrigation but relatively inappropriate for sprinkler irrigation. Phosphorus and potassium contents of wastewater from both stations are relatively low. Contents of iron, manganese, chromium, zinc, cobalt and boron in wastewater of both stations are generally within acceptable limits.

- Table 8-1 Chemical characteristics of treated wastewater of Al-Rustumia sewage station during different sampling periods.

Parameters	**Months (1994 – 1995)**				
	October	**December**	**February**	**April**	**July**
PH	7.4	7.38	7.38	8.15	7.74
EC dS/m	1.75	1.8	2.2	2.0	1.8
SAR	2.98	2.68	3.09	3.06	3.12
Ca ppm	118	131	160	133	114
Mg ppm	66	62	81	69	68
Na ppm	164	149	193	175	171
K ppm	17.0	18.8	21.6	21.0	17.3
Cl ppm	197	149	231	196	214
SO_4 ppm	553	454	667	534	386
HCO_3 ppm	253	337	318	214	329
CO_3 ppm	0.0	0.0	0.0	56.4	0.0
NO_3 ppm	62.0	0.0	4.3	0.0	20
NO_2 ppm	43	0.0	62.0	42.0	0.0
NH_4 ppm	0.36	28.2	25.7	1.46	31.2
P ppm	6.09	3.75	4.76	5.05	5.3
Fe ppm	0.0	0.0	0.0	0.2	0.0
Cr ppm	0.0	0.0	0.0	0.1	0.0
Zn ppm	nil	0.0	0.0	0.0	nil
Mn ppm	0.5	0.0	0.0	0.0	nil
Co ppm	0.5	0.0	0.0	0.0	nil
B ppm	0.55	0.59	0.36	1.15	1.35

- Table 8-2 Chemical characteristics of treated wastewater of Al-Karkh sewage station during different sampling periods

Parameters	**Months (1994 – 1995)**				
	October	**January**	**February**	**April**	**July**
PH	7.77	7.46	7.33	8.4	7.46
EC dS/m	2.85	2.75	2.85	3.1	2.4
SAR	5.06	4.38	4.7	5.24	4.52
Ca ppm	125	138	142	142	110
Mg ppm	124	111	118	132	91
Na ppm	335	286	321	363	266
K ppm	9.5	11.4	13.5	11.1	11.7
Cl ppm	415	351	397	441	320
SO_4 ppm	788	643	796	443	432
HCO_3 ppm	246	293	336	246	303
CO_3 ppm	0.0	0.0	0.0	46	22.8
NO_3 ppm	34.0	26.5	0.0	0.0	0.95
NO_2 ppm	7.8	3.9	49.2	47.6	0.0
NH_4 ppm	0.54	5.18	15.9	16.2	18.7
P ppm	2.24	1.62	2.55	2.59	3.54
Fe ppm	0.0	0.0	0.0	0.0	0.0

Cr ppm	0.0	0.0	0.0	0.0	0.0
Zn ppm	nil	0.0	0.0	0.0	nil
Mn ppm	nil	0.0	0.0	0.0	nil
Co ppm	0.5	0.0	0.0	0.0	nil
B ppm	0.88	0.81	0.64	1.13	1.12

Nitrate content of wastewater of both stations is significantly fluctuating with time, the level of nitrate ranges from 0–62 ppm and from 0–34 ppm, in Al-Rustumia and Al-Karkh stations respectively. Therefore, the amount of nitrogen fertilizer in wastewater should be taken into the consideration before adding the required amounts for crops.

8.4 Future plans

Until now, neither guidelines nor a code of practice for the use of wastewater in irrigation have been adopted. However, the increasing demand for food production and the limitation of high quality water will definitely lead decision-makers to initiate programmes for the use wastewater in irrigation. The programmes should focus on the following points:

- Management of soils irrigated with wastewater (physical and chemical characteristics, dynamics of organic matter, and fertility potential),
- Optimization of the use of fertilizers with wastewater,
- Selection of appropriate cropping systems,
- Minimizing long terms effects of wastewater on soil-water-plant systems,
- Selection of appropriate wastewater irrigation schemes,
- Economic evaluation of wastewater use.

8.5 Conclusions and recommendations

Preliminary studies indicate that treated wastewater could be used as an integral part of water management strategy in Iraq. However intensive studies are needed to avoid environmental difficulties due to high levels of nitrate, chloride and salinity in wastewater. The high nitrate level could be overcome by achieving adequate balance between the nitrogen of wastewater and the nitrogen requirements of crops. Growing salt tolerant crops could solve the problem of high salinity level. The high chloride content suggests that the wastewater can be used under surface irrigation only.

9 Jordan country paper

SALEH MALKAWI[9]

Summary

The report summarizes the status of water and wastewater in Jordan. It was intended to provide an overview of the water resources in the country and to describe the various wastewater treatment techniques that are employed locally. The main topics discussed are:

- Water resources in country,
- Water supply,
- Wastewater treatment plants,
- Treated wastewater quality,
- Wastewater management policy.

9.1 Background

The Hashemite Kingdom of Jordan (HKJ) covers a land area of about 90.000km^2. In 2000, the population of Jordan was 5.039 million. The average population growth rate stands at about 3.5 percent; a fact that is due to natural and non-voluntary migration.

It has been noted that 78 percent of the population are located in urban areas concentrated in four governorates, namely Amman, Zarqa, Irbid and Balqa.

The Jordan climate is known to be an arid to semi-arid one with rainfall ranging between 50mm in the desert region to 600mm in the eastern mountains adjacent to the Jordan Valley.

9.2 Water resources

The Renewable water resources in Jordan are estimated at about 780Mm^3/yr, of which 505Mm^3/yr are surface water and the remaining 275Mm^3/yr are ground water. The non-renewable water resources are estimated at about 140Mm^3/yr. The average per capita per year share of existing renewable water is 155 m^3. The volumes of water supplied to each of the Governorates are indicated in Table 9-1.

- Table 9-1 Water supply by governorate

Governorates	L/C/D	Population	Supply Quantity (MCM)
Amman	130.7	1917340	91.343
Balqa	135.4	330555	16.338
Zarqa	119.8	792635	31.760
Madaba	119	128495	5.583
Irbid	92.3	898955	30.288
Al-Mafraq	218.4	232300	18.513
Jarash	78.5	148145	4.242
Ajloun	77.4	111865	3.161
Karak	124.6	202570	9.214
Tafileh	86.3	76595	2.412
Ma'an	210.5	98260	7.549
Aqaba	410	101285	15.161
Total		5039000	235.566

[9] Director of Environment, Water Authority of Jordan. P.O. Box 2412, Amman, Ministry of Water and Irrigation

9.3 Wastewater services

63 percent of the total population of Jordan has access to wastewater collection and treatment systems. Currently, there are 18 treatment plants that are serving most of the major cities in the country and treating about 82Mm^3/yr. In 2000, the quantity of treated wastewater was 72Mm^3/yr (Table 9-2 and Table 9-3).

- Table 9-2 Treatment plants and their annual influent and effluent in 2000 (Mm^3)

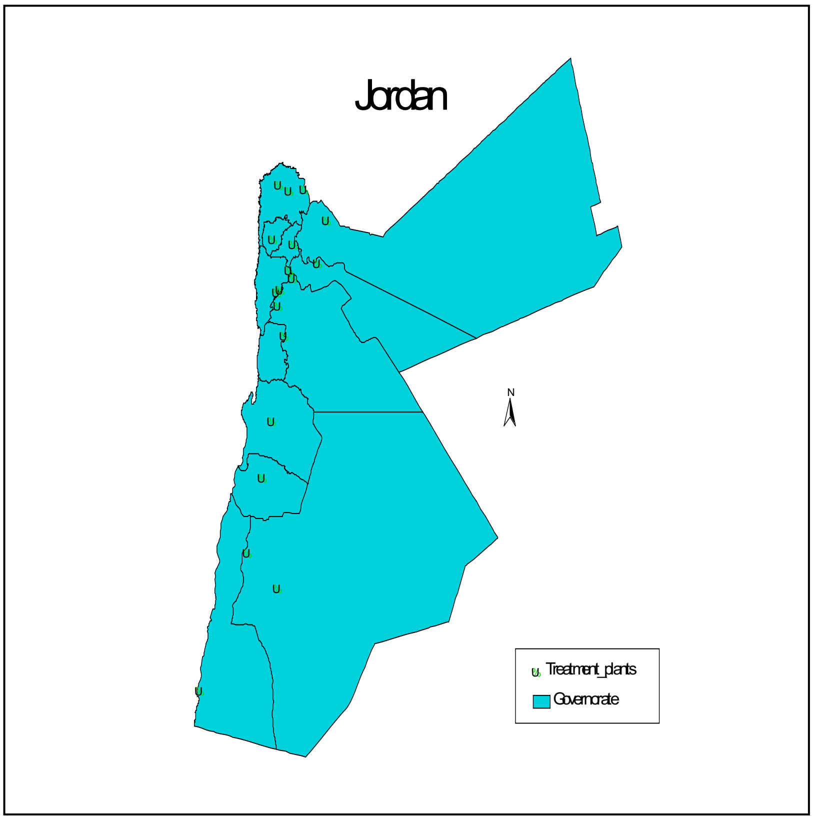
No.	WWTP	Operation	Governorate	Influent	Effluent
1	As samra	1985	Amman-Zarqa	62.37	54.64
2	Abu Nuseir	1988	Amman	0.59	0.58
3	Wadi Essir	1996	Amman	0.41	0.26
4	Wadi Arab	1999	Irbid	2.19	2.05
5	Irbid	1987	Irbid	1.68	1.65
6	Ramtha	1988	Irbid	0.85	0.68
7	Salt	1981	Balqa	1.24	1.20
8	Baqa'	1988	Balqa	4.09	3.88
9	Fuhais	1996	Balqa	0.44	0.38
10	Ma'an	1989	Ma'an	0.69	0.62
11	Wadi Mousa	2001	Ma'an	***	***
12	Mafraq	1988	Mafraq	0.67	0.54
13	Jarash	1983	Jarash	0.76	0.72
14	Kufranja	1989	Ajloun	0.69	0.59
15	Madaba	1989	Madaba	1.56	1.20
16	Karak	1988	Karak	0.45	0.44
17	Tafila	1988	Tafila	0.26	0.25
18	Aqaba	1987	Aqaba	3.21	2.44
	Total			82.15	72.12

- Table 9-3 Population served and wastewater production in 2000

Plant	Inflow m^3/d	BOD_5 g/m^3	Population	Average L/C/d
As Samra	170750	698	1833590	95
Irbid	4610	1262	8955	52
Aqaba	8804	359	48625	180
Salt	3400	888	46450	73
Jarash	2072	1178	37550	55
Mafraq	1850	620	17650	105
Baqa'a	11200	1155	199015	56
Karak	1230	760	14380	85
Abu Nuseir	1620	580	14455	111
Tafila	700	650	7000	100
Ramtha	2430	883	31788	76
Ma'an	1892	684	19909	95
Madaba	4265	1079	70800	60
Kufranja	1890	1165	33875	56
Wadi Al-Sir	1120	550	9477	118
Wadi Arab	6000	675	62300	96
Fuheis	1220	745	13984	87
TOTAL	225053		2,469803	88

Source: WAJ Wastewater Sector Report 2000

• Figure 9-1 Location of the treatment plants in the different Governorates of Jordan



• Table 9-4 Characteristics of WW treatment plants used in Jordan

WWTP	Treatment Type	Design Load		Actual Load		Efficiency %	Degree of Use percent	
		Hydraulic m^3/d	Organic mg/L	Hydraulic m^3/d	Organic mg/L		Hydraulic	Organic
As Samra	WSP	68000	526	170752	698	80	250	333
AbuNuseir	AS+RBC	4000	1100	1617	579	95	40	21
WadiEssir	AP	4000	780	1113	550	93	28	20
Wadi Arab	EA	22000	995	5985	475	98	27	13
Irbid	TF+AS	11000	800	4610	1262	96	42	66
Ramtha	WSP	1920	820	2340	817	71	122	121
Salt	EA+MP	7700	1090	3403	888	98	44	36
Baqa’	TF+MP	14900	800	11185	1155	92	75	108
Fuhais	EA+MP	2400	995	1218	745	97	51	38
Ma’an	WSP	1600	970	1892	684	81	118	83
WadiMousa	AS	3400	***	700	***	***	***	***
Mafraq	WSP	1800	825	1847	620	62	103	77
Jarash	EA+MP	3500	1155	2072	1176	96	59	60
Kufranja	TF+MP	1906	850	1889	1165	96	99	136
Madaba	WSP	2000	850	4266	1079	69	213	270
Karak	TF+MP	785	1080	1231	760	92	166	110
Tafila	TF+MP	1600	1050	707	650	96	44	27
Aqaba	WSP	9000	900	8804	359	73	98	43

• Table 9-5 Treated wastewater effluent quality in the different Governorates

WWTP	BOD_5 mg/L	COD (mg/L)	TSS (mg/L)	TDS (mg/L)
As Samra	139	497	146	1220
AbuNuseir	27	111	27	965
Wadi Essir	39	168	42	992
Wadi Arab	11	60	24	1082
Irbid	55	261	95	1053
Ramtha	254	481	324	952
Salt	18	81	18	709
Baqa'	66	223	69	1155
Fuhais	22	76	35	863
Ma'an	128	492	227	928
Wadi Mousa	***	***	***	***
Mafraq	237	490	247	948
Jarash	43	110	58	654
Kufranja	48	182	59	915
Madaba	334	861	203	1377
Karak	63	298	93	835
Tafila	28	127	32	685
Aqaba	97	345	553	886

• Table 9-6 Heavy metal concentration in the treated effluent in 2000 (mg/L)

WWTP	Ni	Zn	Cr	Pb	Mn	Cd	Fe
As Samra	0.05	0.2	0.05	0.05	0.08	0.00	0.27
AbuNuseir	0.11	0.41	0.07	0.33	0.06	0.00	0.17
Wadi Essir	0.10	0.70	0.00	0.00	0.10	0.00	0.20
Irbid	0.13	0.80	0.01	0.01	0.15	0.00	0.22
Salt	0.03	0.108	0.026	0.02	0.09	0.04	0.09
Baqa'	0.06	0.19	0.32	0.77	0.07	0.02	0.30
Fuhais	0.04	0.15	0.02	0.02	0.02	0.001	0.08
Ma'an	0.065	0.40	0.09	0.05	0.105	0.003	0.14
Mafraq	0.05	0.73	0.02	0.654	0.15	0.001	0.61
Jarash	0.01	0.25	0.04	0.04	0.06	0.001	0.28
Kufranja	0.065	0.155	0.03	0.02	0.015	0.001	0.145
Madaba	0.059	0.135	0.036	0.056	0.14	0.001	0.36
Karak	0.09	0.46	0.034	0.04	0.03	0.001	0.15
Tafila	0.13	0.74	0.04	0.09	0.12	0.002	0.34

9.4 Treated wastewater reuse

Treated wastewater reuse is considered a valuable water resource for irrigation due to the following:

- The supply-demand imbalance of drinking water,
- The arid and semi-arid climatic conditions of the country,
- The deficit in the trade of food commodities,
- The prohibition of untreated wastewater from discharge to water resources or for use in irrigation.

9.5 Actions taken by the Ministry of Water and Irrigation

The Jordanian Standards JR 893/1995 for treated domestic wastewater effluent is based on reuse categories. The Ministry of Water and Irrigation has decided that all new wastewater treatment projects must include feasibility and design aspects for wastewater reuse.

- Table 9-7 Treated effluent production and reuse in 2000 (m^3/day)

WWTP	Treated effluent (m^3/day)	Water reuse
As Samra	149589	149589
Aqaba	6683	2500
Madaba	3272	3272
Ramtha	1852	1852
Mafraq	1488	1488
Ma'an	1704	585
Wadi Essir	714	714
Wadi Arab	5611	***
Irbid	4526	***
Salt	3307	3307
Abu Nuseir	1587	***
Jarash	1959	1959
Fuhais	1036	1036
Baqa'	10626	10626
Kufranja	1629	156
Tafila	702	***
Karak	1194	750
Wadi Mousa	***	***
Wadi Hassan	***	***
	197479	177834

- Table 9-8 Treated Wastewater Storage

Reservoir	Effluent source	Effluent stored Mm^3
King Talal Reservoir	As Samra Plant Baqa'a, Jarash & Abu Nuseir Plants	53.95 3.08
Wadi Shueib Reservoir	Salt Plant	1.0
Kafrein Reservoir	Wadi Essir Plant	0.05

- Table 9-9 Restricted and unrestricted Irrigated areas using treated wastewater

Irrigation restricted	Area (Donums)	Cropping type				Remarks
		Cereal & fodder[1]	Forest trees[2]	Fruit[3]	Vegetable[4]	
Restricted Agriculture near WWTP	6654	1770	3187	1697		Under WAJ & MOH Supervision
Restricted Agriculture below WWTP	9000	2000	500	6500		Monitored by MOA, MOH & GCEP
Unrestricted Agriculture after mixing[5]	91000	6500	1000	25000	58500	Under JVA & MOA supervision
TOTAL	106654	10270	4687	33197	58500	

1 Barley, Sudan Grass, Alfalfa, Maize (forage) 2 Acasia, Cassorina, Eucaliptus, etc. 3 Olive, Citrus, Banana, 4 Other 4 different vegetables 5 Mixing takes place in Jordan Valley

Treated Wastewater was about 12 percent of the irrigation water used in the year 1998. 15700 donums have been irrigated with 15.7Mm^3 of treated effluent for restricted irrigation. The rest was blended with surface water and was used to irrigate 91000 donums for unrestricted use, mostly in the middle and the southern valley.

9.6 Wastewater management policy

The treatment of wastewater shall be targeted towards producing effluent fit for reuse in irrigation in accordance with WHO and FAO as minimum. Also the use of treated wastewater in irrigation should be given the highest priority and should be pursued with care.

It is also important that effluent quality standards be defined based on the best attainable treatment technologies calibrated to support or improve the ambient receiving conditions. Therefore, treatment technologies shall be selected with due consideration to O &m and energy savings.

The Jordanian Standards are benchmarks against which treatment and reuse were evaluated. It is, therefore, essential that they be reviewed and modified to reflect special ambient conditions or end use.

"Polluter pays" principal shall be established.

It is very important that the role of the government be fine-tuned and its involvement be reduced to be of a regulatory nature. The private sector should, however, expand with management contracts, BOT, BOO and other forms of private sector participation. An example of this is the Amman Management Contract (on-going), Samra (BOT), and the reuse near the plants (on-going).

9.7 Jordanian standard for treated domestic wastewater

- Table 9-10 Jordanian standards (893/1995) for treated domestic wastewater

Parameter	Cooked vegetable (2)	Fruit & forestry, trees, crops & industrial products	Discharge to streams, wadis & reservoirs	Ground water recharge	Fish ponds (3)	Irrigation of lawns and parks	Irrigation of folder crops
BOD_5(1)	150	150	50	50	-	50	250
COD	500	500	200	200	-	200	700
DO	>2	>2	>2	>2	>5	>2	>1
TDS	2000	2000	2000	1500	2000	2000	2000
TSS	200	200	50	50	25	50	250
PH	6.9-9.0	6.9-9.0	6.9-9.0	6.9-9.0	6.9-9.0	6.9-9.0	6.9-9.0
Color(PCU)	-	-	75	75	-	75	-
FOG	8	8	8	none	0.001	8	12
Phenol	0.002	0.002	0.002	0.002	0.2	0.002	0.002
MBAS	50	50	50	50	-	15	50
NO_3 – N	50	50	50	50	0.5	25	50
NH_4^+-N	-	-	-	-	-	50	-
Total-N	100	100	100	100	-	100	-
PO_4–P	-	-	-	-	-	15	-
Cl^-	350	350	350	350	-	350	350
SO_4^-	1000	1000	1000	1000	-	1000	1000
CO_3^-	6	6	6	6	-	6	6
HCO_3^-	520	520	520	520	-	520	520
Na^+	230	230	230	230	-	230	230
Mg^{+2}	60	60	60	60	-	60	60
Ca^{+2}	400	400	400	400	-	400	400

SAR	9	9	9	9	-	12	9
Residual Cl_2	0.5	0.5	-	-	-	0.5	-
Al	5	5	5	1	-	5	5
As	0.1	0.1	0.05	0.05	0.05	0.1	0.1
Be	0.1	0.1	0.1	0.1	1.1	0.1	0.1
Amoebae Giardia(Cyst/L)	<1	-	-	-	(3)	None	-
Nematodes (Eggs/L)	<1	-	<1	-	-	<1	<1

(-) Not Determined

(1)BOD in effluent from Waste Stabilization Pond (Filtered), and from Mechanical Treatment Plant (not filtered)

(2)Values for Trace elements and heavy metals are calculated based on the quantity of water $1000m^3/1000m^2$/Yr.; these concentrations should be reduced in case more irrigation water is used

(3)These figures depend of the type of fish, pH, TDS and temperature

(4)The most Probable Number per 100ml

(5)Salmonella per 100ml

10 Morocco country paper

AOMAR JEMALI[10]

10.1 Introduction

Within the framework of the water policy initiated by His Majesty Hassan II, the late king, Morocco has made during the last decades considerable efforts in water resource management and more specifically in resource mobilization and development of the water sector. However, fresh water resources in Morocco are limited and subject to extreme cyclic variations. In addition to its scarcity, water is subject to increasing and continuous pressure to respond to the needs resulting from the fast population growth, the improvements in the standards of living, industrial development and extension of the irrigated agriculture.

The agriculture sector consumed in 1990 nearly 88 percent of the mobilized water resources. The latter amounted to $12Bm^3$ and are expected to reach $17Bm^3$ by the year 2020. At the same time, the potential water resources use by the municipal and industrial sectors is expected to rise from 12 percent in 1990 to about 20 percent by the year 2020.

Estimations carried out lately by the World Bank triggered the alarm, by indicating that per capita renewable water resources would decrease by 50 percent, from $1058m^3$ in 1997 to $500m^3$ in 2020. This would put Morocco in the category of countries under "Chronic Water Deficit".

To face the increasing water deficit that characterize most regions, particularly those located under semi-arid and arid climate, wastewater can be considered as a significant source of water. This option becomes even more interesting as sanitation programmes of large cities integrate the possibility of using wastewater in agriculture after preliminary treatment. The arguments for protecting the environment and the receiving bodies also militate in favour of such an option.

Integration of treated wastewater in the national water programmes becomes therefore a necessary and even a priority. Its value makes it an essential component of all policies of integrated water resources management. Its actual volume is estimated at $470Mm^3$ per year and is expected to reach $900Mm^3$ in 2020. Its use after treatment would allow decreasing the present water deficit on one hand, and increasing the country's water potential on the other. In addition to saving mineral and organic fertilizers, fighting against the pollution of surface waters and protecting the environment.

The achievements of pilot experiences in wastewater treatment and reuse in Morocco remain moderate. Therefore, it becomes essential to develop, as of now, treatment methods by adapting procedures that would allow having, at any time, wastewater with the desired quality and least cost and without the need for a continuous control.

10.2 Water resources potential

10.2.1 Present situation

In Morocco, precipitation is dominated by a strong irregularity both in space and time. The annual average precipitation is less than 300mm in the basins of Moulouya, Tensift, Souss-Massa, the areas south of the Atlas and in the Sahara, and more than 1000mm/yr in the northern mountainous area (Rif, Tangérois, and the western Mediterranean coasts). Currently, the total annual precipitation is estimated at an average of $150Bm^3$ (range of 50 to 400) of which only $30Bm^3$ are considered as efficient rainfall, distributed over surface runoff ($20Bm^3$) and infiltration to groundwater ($10Bm^3$). The available water resources potential that can be mobilized in Morocco is estimated at $20Bm^3$/yr, of which $16Bm^3$ of surface water and $4Bm^3$ groundwater. However, it is worth mentioning that surface water resources represent the main source of water in Morocco. They are characterized by a big spatial irregularity

[10]Ministry of Agriculture, MADREF/AGR/DDGI/SEEN

between basins as shown in Table 10-1. In addition to this irregular spatial distribution of water resources, seasonal irregularity is also considerable.

• Table 10-1 Geographic distribution of surface water resources that can be mobilized

Basin	Total volume (Mm^3)
North Rif	2 492
North and Central Atlantic	10 307
East	1 544
South Atlas West	564
Southern Sub- Sahara – Atlas	848
Total	15 755

Source : PREM (1999)

Groundwater resources also constitute an important part of the water potential. They are distributed over 32 deep groundwater tables and more than 46 shallow groundwater tables. Table 10-2 relates their geographical distribution of which more than 50 percent are located in the central and northern regions. These groundwater tables play a strategic role in the agricultural development and provision of drinking water to populations, particularly during periods of drought.

10.2.2 Wastewater potential

The annual wastewater volume has nearly tripled during the last three decades. It increased from 48 to 423Mm^3 from 1960 to 1999; and it is foreseen to reach close to 900Mm^3 by the year 2020 (CSEC,1994).

• Table 10-2 Geographical distribution of available groundwater resources

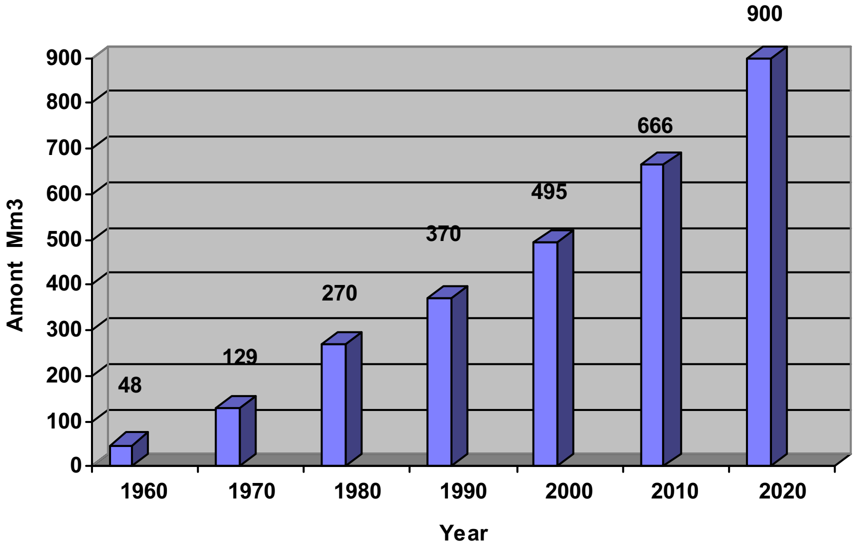
Basin	Volume (Mm^3)
Loukkos – Tangerois - Mediterranean coastal basins	226
Moulouya	779
Sebou	453
Bou Regreg - Atlantic basin coasts- Rabat - Casablanca	126
Oum Er Rbia	326
Tensift - Atlantic basin coasts- Ksob – Iguezouline	458
Souss Massa- Atlantic basin coats- Tamri - Tamraght	240
Ziz - Guir – Rhéris	306
Figuig	30
Aquifer systems of the Upper and Middle Atlas	150
Drâa	276
Sahara	16
Diffuse outflows	614
Total	4000

Source: DRH (1999)

The evolution of urban wastewater effluent is represented in Figure 10-1. The main factors that contribute to this increase are:

- Urban population growth (increase rate varying from 4,4 to 5 percent),
- Extension of drinking water networks, from 53 percent in 1972 to 79 percent in 1993 then reached 85 percent in 2000,
- Extension of sewage systems which reached 75 percent in the big cities in 1999,
- Increase of drinking water consumption from 85 to 116 l/capita/day between 1972 and 1992.

• Figure 10-1: Evolution of urban wastewater in Morocco



In 1999, wastewater volume produced by urban population was over 423Mm^3 of which more than 58 percent were disposed of in the coastline and the rest in seasonal streams and wadis, without preliminary treatment, as shown in Table 10-3.

• Table 10-3 Distribution of wastewater released in different areas

Receptor area	Volume (Mm^3)	Percent
Atlantic coast	228.36	53.95
Mediterranean coast	18.80	4.45
Rivers and wadis	176.10	41.60
Total	423.26	100

Source: DEA/DGCL (1999)

Compared to conventional water resources, wastewater will hardly exceed 4.2 percent by the year 2020. However, this ratio is not completely available for the following reasons: (i) absence of irrigated lands downstream of treatment plants in several areas, notably coastal cities, (ii) the cost of pumping and pipelines when required, and (iii) in areas with sufficient conventional waters. From the qualitative standpoint, a classification of urban wastewaters has been commissioned by the Office of Drinking Water Supply (ONEP) in 1998. The results of this study gave a precise idea of wastewater quality in the country, including evolution of ratios and the rate of restitution, in relation to the size of the cities (Table 10-4).

• Table 10-4 Classification of wastewater in Morocco

Parameters	Small cities (<2000 habitants)	Medium cities (2000-10000 habitants)	Big cities (more than 10000 habitants)	National average
BOD_5 (mg/l)	400	350	300	350
COD (mg/l)	1000	950	850	900
Suspended Solids (mg/l)	500	400	300	400
Rate of Restitution (percent)	50	75	80	65
Allocation x rate of restitution (1 hab.)	40	70	80	60

Source: ONEP (1998)

As the city gets larger, the concentration of pollutants (expressed in terms of BOD_5, COD and SS) decreases, which is due to the fact that big cities consume larger amounts of water and that results if higher dilution.

10.3 Wastewater treatment and reuse

10.3.1 Treatment

Surveys and studies carried out in the beginning of the 1990s evidenced the considerable delay accumulated in the domain of wastewater treatment and reuse, except for some pilot applied research projects. Wastewater from the main coastal cities is rejected without preliminary treatment in the coastal area (Atlantic or Mediterranean). The initial sewerage systems in these cities have been conceived relying on the self-purifying role of the sea while occasionally keeping rejection points away from bathing areas.

Continental cities are in the same situation, with their wastewater also rejected in their raw state in the environment, either through spreading on soil or release in water courses. A fraction of this water is reused directly or indirectly, notably in irrigation.

In Morocco, wastewater collection and treatment has been carried out mostly by local communities and rarely by agencies. The present situation is characterized by the following: (i) big cities are relatively well serviced in terms of sewage infrastructure; (ii) extension of these infrastructures becomes more and more expensive for the local communities to bear; and (iii) consequently, wastewater treatment is the more delayed component.

Since 1950, about 60 wastewater treatment plants have been constructed in Morocco, but not in the big cities. In 1995, an inventory led by the General Local Collectivity Directorate (DGCL) has shown that out of the existing 69 plants, 31 are out of service, 6 are not connected to sewage networks and 33 are functioning normally. Apart from the medium cities of Khouribga, Nador, Beni Mellal, Al Houceima, Benslimane and Boujâad, 14 other plants of small communities (1,500 to 3,000 equivalent inhabitants) are managed by private or semi-public enterprises and 8 other small centers are managed by their local communities. The population serviced by these plants represents less than 8 percent of the total urban population of the country. Table 10-5 shows the different treatment systems of the existing plants.

- Table 10-5 Different treatment systems of the existing plants in Morocco

Step	In function	Out of service	Not connected
Activated Sludge	13	5	2
Trickling Filters	5	6	0
Decantation – digestion	2	13	2
Dewatering	0	3	0
Infiltration – percolation	3	0	0
Lagoon	7	4	1
Lagoon High Yield	3*	0	0
Total	33	31	5

Source: DGCL (1995) and AGR/DDGI (1999)

This diagnostic brief shows that the major constraints that delay the proper operation of sewage networks remain undoubtedly: (i) the insufficiency of financial resources of local communities to cover the high costs of sewerage, and (ii) the lack of qualified staff.

10.3.2 Reuse

The reuse of raw wastewater is a current and very ancient practice in Morocco. The agricultural reuse is in fact the most generalized mode of valuing wastewater in the country. It is practiced in the suburbs of big continental cities where agricultural lands are located downstream of wastewater release points, and also in small plots along sewage outlets. Climatic constraints lead farmers to irrigate crops where water resources are available.

During the last years, wastewater reuse also has developed around certain urban areas recently equipped with sewerage networks. At present, a total area of 7,000ha is irrigated directly with raw wastewater rejected by cities, representing around 70Mm^3 of wastewater used every year in agriculture with no sanitary precaution. A wide range of crops are practiced under wastewater (fodder crops, vegetable crops, cereals, trees) without the application of any sanitary precautions, such as WHO guidelines for instance.

The irrigation of vegetable crops with untreated wastewaters is prohibited in Morocco; however, the prohibition is not respected with all the risks incurred for both by the consumers and the farmers who risk bacteriological or parasitical contamination. Globally, the volume of wastewater used represents no more than 0.5 percent of the total water use in agriculture. Table 10-6 shows the estimated areas (ha) irrigated with wastewater in certain continental cities as well as the crops practiced.

• Table 10-6 Main areas of untreated wastewater reuse in Morocco

City	Area (ha)	Speculations
Marrakech	2000	Cereals, vegetable crops, arboriculture
Meknes	1400	Cereals, vegetable crops, arboriculture
Oujda	1175	Vegetable crops, cereals, arboriculture
Fès	800	Arboriculture, vegetable crops
El Jadida	800	Vegetable crops, fodder
Khouribga	360	Cereals, vegetable crops
Agadir	310	Arboriculture, vegetable crops, soy, floriculture
Béni-Mellal	225	Cereals, vegetable crops, cotton, sugar beet,
Ben guérir	95	Vegetable crops, fodder, arboriculture
Tétouan	70	Vegetable crops, fodder
Total	7235	

Source: CSEC (1994)

This situation tends to become common in all urban areas with sewage systems where wastewater is rejected. A study carried out by SNDAL (1998), estimates that 70 areas of wastewater reuse are distributed over the whole country. This practice is not risk-free of harmful consequences on human health and the environment.

During the last decades, many multi-disciplinary research studies, of great importance and relevance to wastewater treatment and reuse in irrigation, have been launched in Morocco in order to address agronomic, sanitary and ecological issues. The outcome of these studies has provided the local communities and research institutions with reliable data and information on the studies necessary for the design and installation of water treatment stations that are adapted to the local context and to controlled reuse in agriculture.

Table 10-7 summarizes the performance results of the tested treatment systems. Concerning wastewater reuse in irrigation, the results showed that treated wastewater reuse can contribute to the economy of water and fertilizers, the increase of productivity, the improvement of farming techniques and protection of the consumer’s health and the environment. The main crops tested were alfalfa, corn, wheat, squash, bean, cucumber, peas, tomato and turnip.

Treated wastewater is very much appreciated by farmers as supplementary water resources, notably during periods of drought, as well as for its fertilizing value. It also constitutes a factor of development at the national level, through expansion of the irrigated area, reclamation of arid lands, improvement of public health and protection of renewable water resources.

• Table 10-7 Wastewater treatment plants performances: Abatement Rate in percent

Station	Ouarzazate		Ben Sergao	Drarga	Ben Slimane	Marrakech	Bouznika
Treatment System	Lagoon	Lagoon High yield	Infiltration – percolation		Lagoon aerated	Lagoon facultative	Lagoon
Sojourn time (days)	25	21.9	-	-	30 - 40	30	-
BOD5	81.7	65.3	98	97	78	97	75
COD	72	65.4	92	96	79	76	71
Suspended Solids	28	-	100	96.6	-	69	76
Nitrogen (as N)	31.5	48	85	65	75	71	14
Phosphorus (as P)	48.5	54	36	-	41	85	-
Faecal Coliforms	99.9	99.9	99.9	99	100	99.4	99.9
Helminthes Eggs	100	100	100	100	100	100	100

Source : ONEP (2001)

Other examples of wastewater reuse are described briefly below. In the cities of Nador and Khouribga, treated wastewater, through activated sludge stations, is used for irrigating the municipal nursery. In addition, in Khouribga, cistern trucks or tankers are supplied by the treatment plant and used for irrigating amenity trees of the city. In the city of Boujâad, the establishment of a treatment plant (lagoon-type) resulted in the spontaneous establishment of a vast market gardening area irrigated by quality treated water. In the city of Ben Slimane, the treated wastewater produced by a lagoon system, reinforced by light ventilation, is of “A” quality and is used for watering golf turf. The surplus is evacuated outside the station where downstream farms reuse it during the dry season.

Most projects of wastewater treatment and reuse had a purely experimental and demonstrative character, with the exception of that of Drarga. The pilot projects of Ouarzazate, Ben Sergao, Benslimane, Bouznika, and Marrakech had not associated users in their planning phase. The involvement of farmers and users associations in the process of decision-making is very important, and was a key element of success of the Drarga project.

10.4 Strategy adopted by the government

The strategy adopted by the Moroccan Government for the development of the sewerage sector is part of the decentralization policy adopted since the 1960s regarding the development and management of water resources. This strategy aimed at the following objectives: (i) improvement of the population living conditions, (ii) protection of the environment and public health, (iii) optimal utilization of water resources, and (iv) development of local financial capacities and means to manage urban facilities. This policy is actually observed in the efforts made throughout the country to develop integrated projects on sewerage – treatment - reuse.

This strategy is implemented for:

- Development of the sewerage sector: the local communities have launched an important study programme and master plans for liquid sewerage. These studies were carried out directly by the agencies in charge water and electricity distribution and by the National Office for Potable Water. They allowed the assessment of technical, operational and financial needs to fill address existing problems. The procedure comprised the following: (i) technical aspect: what is sought is optimization of investment and operation costs of sewerage systems, by adapting treatment processes to the local context and fixing progressive objectives, as well as establishing regulations for industrial wastewater disposal; (ii) institutional aspect: it concerns putting in place operational structures governed by contracts between the communities, the service providers and the users; and (iii) financial aspect: aims at providing sewerage services with sustainable financial resources in order to avoid delays in the provision of sewerage systems, through the adoption of charges for both release and use.

- Development of wastewater reuse projects: the national High Water and Climate Council (CSEC) during its sessions of 1988, 1994 and 2001 defined the guidelines for the planned reuse of wastewater in agriculture. The promotion of treated wastewater reuse cannot materialize without taking the following important actions: (i) organization of the sanitation sector to evolve towards a framework where sanitation is an asset rather than a means of disposing of urban wastewater; (ii) adoption of the principle that wastewater constitutes an essential component of the national hydraulic potential and needs to be valued; (iii) setting up structures and providing them with the funds necessary for successful treatment, by transferring sanitation services to the agencies in charge of distributing potable water; and (iv) the adoption of the principle of "polluter pays" and the involvement of users in project formulation.

10.5 Impact of wastewater reuse

The reuse of treated wastewater in agriculture has several advantages: increase of the water resources potential of the country, savings in the conventional mineral and organic fertilizers, and preservation of the environment. However, it may also have negative impacts on the environment and on the health of humans and animals.

- Environmental impacts: A high concentration of nitrogen in wastewater can cause the pollution of groundwater, following the leaching of nitrates, and this poses a health risk, especially in the case where groundwater is used for drinking purposes in rural areas. To avoid quality degradation of groundwater by nitrates, the following actions are recommended: (i) to introduce in crop rotations high nitrogen consuming crops; (ii) to rationalize optimize the application of water and nitrogen through the control of doses and frequencies of watering, (iii) to avoid the utilization of reuse water in surfaces where the underground water is vulnerable, and (iv) to mix treated wastewater with the conventional waters.
- Impact on the human and animal health: pathogens are either responsible for the disease transmission directly by wastewater contact or indirectly by the consumption of raw products irrigated with wastewater. The most adequate measure allowing attenuating the negative impact of wastewater is its treatment before the reuse. All systems of wastewater treatment allowed getting a rate of exhaustion of more than 95 percent for Faecal Coli forms and 100 percent for eggs of Helminth. Therefore, this treated wastewater is of "A" quality and can be used without risk.

10.6 Institutional and legislative setting

The institutional and organizational scope of projects of wastewater reuse in agriculture is mentioned in the general orientation concerned with the development of the wastewater reuse in agriculture.

10.6.1 Institutional framework

The administration of the wastewater treatment sector meets some organizational difficulties due to the fact that there is a huge number and diversity of the intervening parties to inquire about wastewater producers (local communities), different facilities administrators (collection, treatment and irrigation) and users of treated water who intervene in the scheduling, the development and the management of the territory. Among these intervening parties we can mention:

- Ministry of Interior: In its capacity as the administration of local communities, this department assures the support and the control in the implementation of work of the politics of treatment. It also plays a privileged role in water management used by the slant of the General Direction of the Local Collectivities (DGCL),
- The local communities that, since the charter of 1976, are responsible for the public service management which liquid treatment with the implementation of works and the management of facilities,
- The Ministry of the Agriculture, responsible of the general planning of projects of the treated wastewater reuse in agriculture by its regional services (ORMVA and DPA) as well as the distribution, the management and framing techniques of water users (AUEA),

- The Ministry of the equipment that manages the allocation, the protection and the mobilization of hydraulic resources. From its end, the DRH plans the resources while the ONEP has for task the management of the distribution of the drinkable water, the control of the wastewater pollution susceptible to be used for the human feeding,
- The department of the environment that is concerned with the pollution of the receiving surroundings of the wastewaters. It is in charge of the coordination of all actions related to the protection of the environment and the establishment of disposal norms. The national Council of the environment issues the national directives,
- The Ministry of Health in charge of the protection of public health, of health awareness /education, the control and the treatment of diseases and the sanitary quality of water,
- The Ministry of the industry in-charge of the industrial water decontamination,
- The Water High and Climate Council (CSEC), loaded to formulate the general orientations of the national politics in water and climate issues.

The wastewater reuse requests a close coordination between the different departments involved in the operations of reuse at the regional level. To render this coordination effective, it would be needed to develop an institutional partnership by the establishment of an agreement that binds the different partners and identifies their responsibilities and their respective roles.

10.6.2 Legislative framework

In Morocco, the legal statue of water has been established progressively. The legislator's intervening to form the new legislations in the domain of water started during the period of the French Protectorate in Morocco. Several texts have been adopted. The main ones include:

- Dahir of July 1st, 1914 (abrogated by the new Law on water) completed by the dahir of November 8, 1919 on the public domain that puts the principle of the public state of all water and their channels,
- Dahir and the prime-ministerial decree of August 1st, 1925 (abrogated by the new Law on water) on the regime of waters, modified by dahirs of July 2, 1932, of March 15, 1933, of September 18, 1933 (abrogated by the new Law on water), of October 9, 1933, July 25, 1939, and September 24, 1952.

This ancient legislation was not adapted to the modern organization of the country and didn't deal, anymore, with the needs of its socio-economic development, a fact that has required the creation of a new modern water regulation by the adoption of the dahir n°1-95-154 of August 16, 1995) carrying enactment of the law n°10-95 on water. This law on water aims at establishing a national water policy based on a prospective vision that takes into account the development of water resources and the national needs for water.

The new Law 10-95 on water, in its IVth chapter treating the wastewater reuse constitutes the legal basis of the institutional setting of wastewater reuse projects. This Law stipulates in its article 57, that the administration defines the conditions for obtaining the authorization of wastewater utilization. It also stipulates that every user can benefit from the financial contest of the state and the technical support if his utilization of wastewater is compliant to the conditions set by the administration and has the effect of achieving water savings and to preserve water resources against the pollution.

Currently in Morocco, there are not any environmental and sanitary directives of the treated wastewater reuse. This law in article 51 states that the norms of quality to which water must satisfy according to the utilization that will be made have to define the following:

- Procedures and operative methods of experimentation, sampling and analysis,
- The quality standard defining them quality levels allowing to regularize and to standardize the approval of water quality,

- The physio-chemical, biological and bacteriological characteristics notably of the wastewater intended for irrigation.

The Law 10-95 stipulates in its article 84, that the wastewater utilization to the agricultural ends is forbidden when these waters don't correspond to the standard set by the legal channels. These standards are currently under preparation at the national level by the “Committee des Normes et Standards (CNS)” (Table 8).

Since 1994, date of its establishment, the “CNS” under the National Environmental Council, has developed quality objectives of the receiving environment (standards and quality) and the general and sectional limits of disposals. The CNS is composed of representatives of all concerned ministerial departments. Among the different proposed standards, there is a project of water quality intended for the irrigation that fixes the bacteriological, parasitological and physio-chemical parameters (Table 10-8). This law sets the standards of quality to which water must conform according to its utilization.

- Table 10-8 Project of quality standard of water intended for irrigation

Parameters	Limited values
BACTERIOLOGICAL	
Faecal Coliforms	5000/100ml*
Salmonella	Not present 5 litres
Cholera Vibrio	Not present in 450ml
PROITOZOA	
Parasites pathogens	Not present
Eggs, kystes parasites	Not present
Ancylostoma	Not present
Fluocococercaires Schistosoma hoematobium	Not present
PHYSICO-CHEMICAL	
Mercury Hg (mg/l)	0,001
Cadmium Cd (mg/l)	0,01
Arsenic As (mg/l)	0,1
Chromium Cr (mg/l)	0,1
Lead Pb (mg/l)	5
Copper Cu (mg/l)	0,2
Zinc Zn (mg/l)	2
Selenium Sé (mg/l)	0,02
Fluoride F (mg/l)	1
Cyanides Cn (mg/l)	1
Phenols (mg/l)	3
Aluminium Al (mg/l)	5
Beryllium Be (mg/l)	0,1
Cobalt Co (mg/l)	0,05
Iron Fe (mg/l)	5
Lithium Li (mg/l)	0,1
Manganese Mn (mg/l)	0,05
Molybdenum Mo (mg/l)	5
Nickel Ni (mg/l)	2,5
Vanadium V (mg/l)	0,2

Source: CNS (1995) *1000 CF/100ml for raw consumed crops

10.7 Obstacles facing development

In spite of the evident progress during the last decade in the technical, institutional, financial and legislative plan related to the development of process wastewater treatment and reuse, at the present time, no project integrating the three components was implemented. This paradoxical situation is explained by the existence of several constraints that persists in the institutional, financial and technical aspects preventing the development of the water reuse.

INSTITUTIONAL AND ORGANIZATIONAL CONSTRAINTS:

- Absence of legislative texts,
- Lack of coordination between the different intervening parties (administrative, operator, user).

Close dialogue between partners in the phase of treatment-reuse of water is necessary in order to coordinate their respective actions and to lead them to good end. The wastewater reuse asks for a close coordination between organisations integrated in operations of reuse where this task is confided to an institution that would be in charge of the follow-up, information, and the application of the legislative texts.

TECHNICAL CONSTRAINTS:

- The conception of wastewater treatment networks has been guided by the topography,
- The existence of various points of disposals in the big cities limits the reuse.

FINANCIAL CONSTRAINTS:

Lack of financial balance between expenses and returns. This is due to the:

- Delay accumulated in matter of wastewater treatment equipment,
- Lack of involvement of the state's sector of wastewater treatment,
- Weak purchasing power of the different levels of the population,
- High costs of equipment for the installation of wastewater treatment stations. It exceeds the financial capacities of communities extensively,
- Elevated expenses of mobilization or inter-seasonal storage of treated wastewater.

Due to all these constraints, the local corporation is obliged to classify, its objectives as follows:

- Protection of health and conditions of life of populations,
- Protection of the receiving environment,
- Evaluation of the treated wastewater reuse.

10.8 Findings and recommendations

According to the climatic and geographical context of Morocco, the treated wastewater constitutes an additional water resource in the areas suffering from water deficit, notably during periods of drought. They also constitute a factor of development at the national level by the expansion of irrigated areas, the enhancement of arid lands, and the improvement of the public health and the protection of renewable water resources. The wastewater reuse needs to develop and to vary. It requires the setting up of a promotional strategy and a policy of the utilization. Some considerable efforts need to develop in many domains in order to better optimize the utilization of this water. The reliable and economic treatment systems adapted to the local context need to be developed, as well.

Some recommendations:

- It is necessary to develop an institutional partnership by the establishment of an agreement that binds the different partners and identify their responsibilities,
- It is necessary to make sure that the usage of water must be associated with the phase of planning and management of reuse projects. The implication of users is a key element of project success,
- It is necessary to activate the issuance of the Moroccan standards of industrial disposals and to issue actions that will urge to activate the process of wastewater treatment and reuse.

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11 Saudi Arabia country paper

S. AL-MOGRIN[11]

Summary

The Kingdom of Saudi Arabia (KSA) is an extremely arid country with very limited water resources due to its scarce precipitation. Total water demand has tripled in the past two decades to reach nearly 45Mm^3/d by the year 2000. As a result, the annual water balance shows an incremental increase of the deficit in the national water budget. The diminishing fossil-groundwater reserves account for at least 80 percent of total water supply while agriculture is the largest water sink (80 percent). It is anticipated that these reserves tolerate the present use level only a few more decades due to over-exploitation. The situation is critical if mining of these reservoirs continued at the same rate.

Agriculture can accept water with marginal quality, such as wastewater effluents. It is estimated that at least 1.54Mm^3/d of treated effluents of domestic origin was produced in 1995. This amount is steadily increasing and expected to double by the year 2020. Although it is governmental policy to reuse all available wastewater effluents in irrigation by the year 2000, only 34 percent have been utilized. The Ministry of Municipal and Rural Affairs require unrestricted reuse of water for irrigation. But the Ministries of Health (MOH) and Agriculture and Water (MAW) desire restricted use to reduce health and environmental risks and to provide for sustainable maximum utilization of treated effluents. This practice requires upgrading of existing facilities.

11.1 Location and population

Geographically Kingdom of Saudi-Arabia (KSA) is located between the 18th and 32nd parallels of the Arabian Peninsula with an approximate area of 2.25 x 10^{6}km². KSA is bounded on the north by Jordan, Iraq and Kuwait; on the east by the Arabian Gulf and Oman; on the south by Yemen and on the west by the Red Sea. Last official census of the population estimates was 14 million with annual growth rate of 3-4 percent (Ukaily and Hussen, 1988). Population density was 6.3 capita/km^2 . The major cities are: Riyadh 2 m, Jeddah 1 m, Mecca 0.6 m, Dammam 0.5 m, Madina 0.3 m, Taif 0.2 m, Buridah 0.2 m, Abha 0.15, Alhafouf 0.12 m, and Tabouk 0.1 m. In 1992 population estimate was 16 million based on the annual growth rate.

11.2 Topography and climate

The topography of the country has four types of terrain: a narrow coastal plain (40km in depth) extend along the east coast between Red Sea and Al-Sarwat Mountains (elevation 1250m). To the east is the central plateau sloping gently toward the Gulf. KSA is famous for its desert terrain. The great southeastern sandy desert Alrubu Alkhali (meaning the empty quarter) occupies nearly one-fourth of the Arabian Peninsula area (640,000km²) and about 33 percent of the country is largely unexplored. The second largest desert is the northeastern Alnafound, which is a projection of the Syrian desert with an estimated area of 60,000km². This desert is linked to the Alrubu Alkhali by Al-Dahna desert which is sand belt extending for 1280km from north to south with an average width of 60km (area about 80.000km² and elevation ca. 500m). East of Dahna is low plateau with average width 160km and elevation 250m merging gently with Gulf coastal region. Apart from two major central and eastern oasis and southwestern highlands 90 percent of the country is desert area (Abouammoh, 1991).

The rainfall and temperature varies with terrain. Records from different meteorological stations show that the average annual rainfall readings are: Jeddah 50mm, Riyadh 60mm, Taif 96Mm, and Kahamismushit 119mm/yr respectively (Abouammoh, 1991). However, the mean annual precipitation over the whole country range from 50-85mm (Ukayli and Hussain, 1988 and Mohorjy, 1988). Yet, desert terrains may receive no rain for up to four years. Most of precipitations occur during winter months January - April and may be related to latitude. The mean annual rainfall over the different terrains of the country is depicted in

[11] Ministry of Municipalities and Rural Affairs. Technical Affairs; Department of Public Utilities

Figure 2. Temperature during summer range from 35-49°C but in winter the weather is pleasant. As a result of intense summer heat and lack of vegetation, the mean evaporation is high 500-1,778mm/yr (Mohorjy, 1988), clearly exceeding mean precipitation. Therefore KSA is the largest country in the world without running surface water characterized by hot-climate with severe aridity. The run off over the whole country is estimated to be 5.5Mm³/d (annual mean) with 60 percent occur in Red Sea coast belt (Ukayli and Hussain, 1988).

11.3 Agricultural development

The Ministry of Planning (MOP) launched five-year long-term developmental plans starting in 1970. The goal was to increase and enhance level of services of all public and private sectors. The country experienced massive expansion of urbanization, agricultural, industrial and infrastructure in the past 30 years. As a result, the country also witnessed a phenomenal rise in population from 7 million at the commencement of first developmental plan to 14 million based on 1988 official estimate.

Of particular interest is the vast development of the agricultural sector with the establishment of the Agricultural Bank. This governmental bank provides interest-free long-term loans for farmers and agricultural projects as well as 50 percent subsidies for farming machinery, equipment, seeds and fertilizers. The aim is to encourage private sector to support the national income through agricultural products and to reduce country's dependence on oil.

It is estimated that only 1 percent of the total area is considered arable land. The government freely distributed 1.5 x 10^6ha to farming enterprises of which 80 percent is cultivated. The cultivated area has increased by 130 percent in 1988 (Al'Mutaz, 1989). In 1992, 152,000 farms existed with an agricultural labour force of about 600,000. Livestock estimates are around 12 million head and livestock products including poultry and eggs. By 1990, agriculture contributed about 8 percent of GDP. Table 11-1 presents principal crops produced in 1970 and 1992.

This strategy is directed to self-sufficiency in food production. Several gigantic agricultural companies have been established as a backbone for agricultural production. The country became self-sufficient in wheat and poultry products. Wheat is purchased from farmers by the government and stored in silos.

- Table 11-1 Principal crops produced in 1970 and 1992 (in Mtons)

Crops	1970	1992
Dates	0.240	0.700
Wheat	0.026	4.2
Tomatoes	NA	0.435
Vegetables	0.470	0.792
Water-melon	NA	0.426
Fodder and forage	1	0

NA: not available

These facts, although directed to national security in a volatile region, are having a formidable impact on water consumption with the supply being limited. Therefore, on many occasions water experts have forecasted that KSA may face a critical situation due to a water deficit (Mohorjy, 1988; Abu Rizaiza and Allam, 1989; Abdulrazzak and Khan, 1990). Water shortages occur during the whole year with a peak during the long summer period.

11.4 Water resources vs water demand

The second and the third development plan (1975-1980 and 1980-1985) included commitment to provide sufficient quantity of good quality water for domestic use, water conservation, and the development of water sources and to seek new water sources for agricultural and industrial uses. There are no running surface waters. Water resources are available solely from ground water in two types of aquifers: the shallow unconsolidated alluvial and the deep sedimentary aquifers (Abdulrazzak and Khan, 1990).

The country is highly dependant on groundwater stored in major six consolidated sedimentary old-age aquifers located in eastern and central parts. This fossil groundwater, formed some 20,000 years ago, is confined in sand and lime stone formations of a thickness about 300m at depth 150-1500m. Fossil aquifers contain large quantities of water trapped in fissures. For example, Saq aquifers in eastern part of the country extend over 1200km northwards. Nevertheless all of these aquifers are poorly recharged because water entered these aquifers thousands of year ago and is continuously "mined" (Al'Mutaz, 1989). The natural recharge for these aquifers is around 3.5Mm³/d only (Abdulrazzak and Khan, 1990). These resources are precious as they are not the product of the ongoing hydrological cycle. The official estimate of these resources, according to the Water Atlas of Saudi Arabia, by the Ministry of Agriculture and Water (MAW), is 253.2Bm³ as proven reserves while the probable and possible reserves of these aquifers were 405 and 705Bm³ , respectively (Abu Rizaiza and Allam, 1989). The Ministry of Planning (MOP) showed in similar study that these reserves amount to 338Bm³ with secondary reserves to reach 500Bm³ (as probable) (Farooq and Al-Layla, 1987; Al'Mutaz, 1989) which correspond well with MAW estimates. However, estimates of the Scientific Research Institute's Water Resources Division at Dahran city, 36,000Bm³, exceed MAW and MOP estimates by more than 70 folds. However, of this figure they estimated 870Bbm³ as economically abstractable which compares favourably with previously stated figures for the possible estimates. Furthermore, they stressed that with technological advances more amounts could be utilized. Surprisingly, between these estimates comes another optimistic 2,175Bm³ figure by an engineering firm: The Saudi Arabia Engineering Consult. These studies may indicate that MOP and MAW estimates are very conservative.

The shallow aquifers are renewable and mainly located in the west and southwest of the country with a mean thickness of 200m. These aquifers can provide up to 3.14Mm³/d (Al'Mutaz, 1989) and are naturally recharged by an amount of 2.6-3.5Mm³/d (based on annual daily mean) (Ukayli and Hussain, 1988; Abu Rizaiza and Allam, 1989) of which 80 percent occur in the southwest. However, lower recharge figures have been reported by Mohorjy (1988), to be only 1.6Mm³/d. The storage capacity of these aquifers is estimated to be 84Bm³ (Abdulrazzak and Khan, 1990). Due to low rainfall these unconsolidated aquifers can only supply 3.13Mm³/d (1.145Bm³/yr which is only 1.4 percent of their estimated capacity). These aquifers are alarmingly over-exploited by 100 percent. Over-exploitation impacts of alluvial and surface water are already manifested in drop of water table and salt intrusion near coastal areas. For example, the water table has been reported to drop 10m in western and central regions in 10 years (Mohorjy, 1988), while the impact of fossil groundwater in the northern area the water table dropped 100m in only 10 years (Abu Rizaiza and Allam, 1989). Increased cost of pumping in central area as well as dry-up of some natural springs in western regions has been experienced (Mohorjy, 1988; Ukayli and Hussain, 1988). Surface water also obtainable from shallow wells near Wadis especially following rainy season as an "monsoon" auxiliary supplemental water source for irrigation with a mean recharge of only 2.5Mm³/d (Abdulrazzak and Khan, 1990). Other sources are classified as non-conventional sources, which include desalinated seawater and treated wastewater effluents used specifically for drinking water and irrigation purposes respectively (Table 11-3).

The Ministry of Planning estimates that the mean agricultural demand is 78 percent of the total water demand (Abdulrazzak and Khan, 1990). In 1985 72 percent of the total water budget was used for agriculture (Al'Mutaz, 1988). This share increased by 1992 to 80 percent (Abdula'aly and Chammem, 1994) and projected to reach 85 percent by 2000 (Abu Rizaiza and Allam, 1989). This increasing trend has most probably caused by the introduction of mechanised large-scale irrigation projects facilitated by technical development in ground water exploitation and advances in well drilling.

Yearly total water consumptions during period 1980-2010 are shown in Table 11-2 while contributions of different water sources to the total water demand is presented in Table 11-3.

- Table 11-2 Total water consumption in Mm³/day

Ref	1980	1985	1990[a]	1992[a]	2000 [b]	2010 [b]
1		24.24				
2			31.5	36.6	45.2	55
3	12.36	24.20				

4	26.3	37.5	38.4	46.6	57.5

a:based on mean daily for the entire year, b: projected

Sources: (1) Ukayli and Hussain, 1988. (2) Abdula'aly and Chammem, 1994.(3) Farooq and Al-Layla, 1985. (4) Abu Rizaiza and Allam, 1989.

• Table 11-3 Contribution of different sources of water to total water supply (percent)

	1985	1990	2000	2010
Fossil groundwater	73	78	82	84
Alluvial groundwater	11	6	5.9	4.5
Surface groundwater	10	8	4.5	3
Desalination	4.5	5.7	4.8	4
Wastewater	1.2	2.2	3.1	-

Sources: Ukayli and Hussain, 1988, Abu Rizaiza and Allam, 1989, and Al-Dubiban and Gafari, 1985

Several conclusions can be observed from this. There are increasing trends in both total water consumption and fossil ground water abstraction. There is a clear indication that the diminishing fossil groundwater is by far the largest supplier with an increasing share through the years. This is true to satisfy the ever-increasing demand. The second and most important conclusion is that the percentage contribution of treated effluents, although increasing, was below targeted share. Thirdly, the percent contributions of surface and alluvial water are decreasing caused by the increasing demand while the capacity of these resources are more or less fixed (i.e. 100 percent exploitation). Finally, the full capacity of desalination plants may have been reached by 1990. After that its share of the total water demand has started to decrease due to increasing demand. Therefore, reuse of effluents in irrigation should be maximised to alleviate the burden on the fossil ground water supply and the water consumed by irrigation should be rationalized without much affect on agricultural production. To delineate optimization of treated effluents, the interaction between the responsible governmental institutions must be addressed.

11.5 Institutions

Four main governmental institutions are involved in the field of wastewater reuse: The Ministry of Municipality and Rural Affairs (MOMRA), Ministry of Agriculture and Water (MAW), Ministry of Health (MOH) and the Meteorological and Environmental Protection Agency (MEPA). Each has a distinctive responsibility.

Water distribution, wastewater collection, treatment, operation and maintenance as well as expanding these facilities are the responsibility of MOMRA through six executive water authorities, five regional directories and 120 municipalities with a total work force of more than 2,500 (MOMRA, 1995). Blue print preparations, tendering bids and contracting of wastewater projects are the Ministry's functions. The Ministry operates a fast growing central laboratory in Riyadh, which is well equipped and staffed for microbiological, physical and chemical analysis using modern technology e.g. GC/MS, AAS, ICP, HPLC and other instruments for advanced and molecular level analysis. Principal objectives include research work and tasks to investigate and study problems encountered by municipalities and water authorities. Research activities and study cases are usually published in local as well as international journals.

MAW is responsible for the development and improvement of drinking water for municipalities. Planning and distribution of treated effluents is also one of its functions. Reuse permits, control, monitoring and enforcement are also under its authority. In short, MOMRA is the producer of treated wastewater effluents while MAW is the user.

Public health issues are the responsibility of MOH. Therefore MOH also plays an important role in establishing the wastewater regulation and effluent quality standards. MEPA is concerned with disposal of effluents to the sea as a part of its responsibility. Mainly it is involved in industrial discharge regulations including air. These institutions are involved equally in drawing wastewater reuse regulations and standards. In this respect it seems that MAW has the greatest influence.

Ancillary specialized agencies are KACSAT Scientific Research City at Riyadh, the Scientific Research Institute at KFPM University at Dahran city with primary objectives to build a competence and to promote technological development in the area of water and wastewater. In this regard special emphasis is placed on water and wastewater treatment technologies that promote effluent reuse and conservation of resources.

11.6 The stress of the national water budget

KSA face a severe deficit in the water balance each year. The shortage is entirely supplied from the fossil ground water reserves. About 80 percent of the total water demand is drawn from this diminishing water sources.

Although magnitudes of groundwater are high the ever-increasing demand will ultimately exhaust these reserves. Current abstraction rates are 10 times higher than the recharge and so the situation is critical. Depletion of fossil groundwater is anticipated in 2088 (Mohorjy, 1988), while Abu Rizaiza and Allam (1989) predict that the water system will not be “robust” by the year 2007 if the present conditions remain the same and groundwater from these confined aquifers is mined at an increasing rate.

The government action to water shortage has been seen at a high level. The Council of Ministries issued ordinance in 1980 call for conservation of water resources and wastewater is recognized as beneficial auxiliary water source rather than “waste” after it has been religiously approved by 1979 (Farooq and Al-Layla, 1985). The government is committed to a policy to use all available treated effluents as a supplementary source for irrigation by the year 2000. In late 1980, the Royal decree M/34 was issued: “Regulations for the conservation of groundwater resources”. Public and private agencies are to comply with said decree. This was followed by the formation of Water Conservation Committee at Dahran City in the same year.

As early as the 1970s, the government acted by implementing a countermeasure programmes for non-conventional water resources development. Measures such as desalination, reuse of wastewater, conservation plans, water harvest, and vegetation have been considered. Among the plans was the transport of fresh water from neighboring countries.

11.7 The Role of wastewater reuse

In 1979 the Islamic Council of Research and Consultation issued a statement after consulting with technical and health experts that properly treated wastewater can be considered clean if it poses no health hazard and meets health standards and criteria set for that purpose. It is assumed that often properly treated water returns to its natural form free from impurities that caused it to be banned in the first place.

During the rapid expansion of cities and towns during the second and third developmental plans (1975-1985), wastewater services have lagged behind drinking water which was given the top priority for many reasons. Among these are the belief in durability and sustainability of septic tank systems and the high cost of wastewater projects. The problem of septic tank systems appeared only later in these newly developed areas and towns. This was caused by clogging of the soil and water table rise. This problem was common and most severe in highly populated old areas without sewer systems. In the affected areas polluted surface water has risen to reach drinking water networks and tanks increasing the risks of health hazards. In some cases this may cause ponding on ground surface due to poor permeability of the soil.

MOMRA’s temporary actions are to abstract the surface water periodically through wells in depression areas in affected vicinities in order to lower the surface water and limit the damage.

Due to recognized damage of this problem, priority has been given to wastewater projects in populated areas with poor soil permeability were septic tank systems are no longer useful.

Statistically, 30 operating wastewater plants belong to 22 municipalities that are continuously expanding their services. There are 11 activated sludge plants, 11 trickling filters, 4 aerated lagoon plants, 3 tertiary or advanced plants, one RBC, and one secondary plant. A description of these WWTPs is presented in Table 11-4 while the fate of effluent from these plants is shown in Table 11-5. Approximately the wastewater networks reached 33 percent of the population by the year 1995 (MOMRA, 1995). Wastewater production ranges from 65-80 percent of the domestic water consumed in the country (Ukayli and Hussain, 1988; Abu Rizaiza *et al.,* 1995). Wastewater services throughout the country are strongly related to the demographic density. It is estimated that 90 percent of large size cities with a population more than 100,000 have sewer systems and the percentage decreases to 80 percent of towns with population of 30-100,000 but less than 50 percent of small towns and villages with population of 5,000 – 30,000 have sewer systems (Ukaily and Hussen, 1988). Service varies from city to city and is related to population size and problems associated with septic tank systems. It ranges from 15 percent in Buridah to 96 percent in Rastanura.

Cost analysis of wastewater collection and treatment has been found to be far more economical than depending upon traditional existing wastewater disposal systems of septic tanks (Abu Rizaiza *et al.,* 1995). Therefore the ultimate solution is the augmentation of wastewater networks, which means increased effluent production each year. The authors estimated that the annual average cost of negative impacts of septic tanks would be about 3.4 times higher than estimated costs of wastewater networks. Seventeen impacts, mainly health, social, environmental and economical on non-sewered areas were cited by the authors. These include public health impacts and aesthetical problems due to a pooling of wastewater, deterioration of building foundation and pavements land value decline. These factors had negatively affected land value in areas without sewage systems.

MOMRA has prepared at least 30 new design studies for wastewater projects for different cities and towns in KSA (not included in Table 11-4). These projects will be implemented once allocations are granted by the Ministry of Finance. Nowadays wastewater projects are prioritized by Budget Committees at the Ministry of Finance due to the acknowledgement of their value. Some of these projects are already under construction or at bidding stage. Expansion of wastewater networks has great priority by MOMRA because it is recognized as the only permanent solution to the aforementioned problems.

It is important to mention that the situation in the Gulf region during 1990-1991 has negatively affected plans for the allocation and execution of these projects and the upgrading or expansion of existing facilities as well. As a result of these events many wastewater projects have been cancelled or deferred.

Although only 33 percent of the population is served by wastewater networks, more than 1.123Mm³/d reached WWTPs throughout the country in 1989 (Al`Mutaz, 1989). This increased to nearly 1.203Mm³/d by 1990 (Al-Mogrin and Almaziad, 1990). In 1995, this amount increased by 28 percent (1.54Mm³/d) (Table 11-5). Therefore, more quantities of effluents will be produced each year because of the continuous construction of new wastewater projects as well as extension of existing facilities. At this pace the expected quantities of wastewater that will reach WWTPs by 2000 will be 2Mm³/d (Al`Mutaz, 1989). Nevertheless, this quantity is assumed to constitute 50 percent of the total generated wastewater. The rest is lost through septic tanks in unsewered areas (Abu Riziza, 1995).

- Table 11-4 Wastewater treatment plants in Saudi-Arabia

City	Population (million)	WWTP	Q in ($000m^3$)	BOD	SS	COD	NH3	TKN
Riyadh	2	Alhair	305	23	27	66	16	30
		Exten.1	100	21	24	50	4	12
		Kharijia	1	26	31	75	12	23
		Diplom.	9					
		Univ.	10					
		Kharj R	173					
Jeddah	1.5	Hail St.	50	20	19		14	
		Alkham	69	100	100		35	

		C. Plant	76	36	37			
		Bani M.	5	32	33		14	
		Univer.	7	33	35		14	
		Housi.	1	16	16		9	
		South J.	30[a]					
Mecca	0.65	Okaish1	30	87	71	129	20	
		Okaish2	35	23	23	6	9	
Medinah	0.5	Old	10	15	20	44	10	23
		New	53	6	8	35	15	21
Taif	0.25		40[a]	5	1	9	7	7
Ihssa*	0.25		140[b]					
Buridah	0.20		5					
Abha	0.15		8	11	12	60	23	
Dammam	0.15		133	8.2		231	0.5	1.43
Ouniza	0.05		10.5	17	23	100		
Khobar	0.05		69					
Kharj	0.05		16					
Khamis	0.05		3	15	15			
Jubail	0.025		52					
Yanbou	0.025		25					
Khafj	0.025		70					
Katif**	0.025		1.5[c]					
Total	**6M**	**30**	**1.5M**					

All are secondary treatment plants except as indicated. a: tertiary treatment,b: primary treatment, c: package treatment
Concentration of parameters are in mg/l.

Source: (Al-Mogrin and Al-Maziad,1990; MOMRA1995)

*three towns, **seven villages

• Table 11-5 Fate of wastewater effluent from WWTP in different cities

City	Service (%)	Q (000m³)	Irrigation	Land	Sea
Riyadh	52	600	165	360	
Jeddah	68	238	42	13	183
Mecca	50	75	8	67	
Medinah	20	63	52	11	
Taif	47	40	40		
Jubail	75	72	72		
Dammam		133	10		123
Khobar	66	69	5		64
Abha	37	8	2.5	5.5	
Buridah	15	5		5	
Ouniza	43	10.5	1.5	9	
Khafji	25	1.5			1.5
Kharj	80	16			
Khamis	3				
Yanbou	25				
Katif	80	70			70
Ihssa	74	140	133	7	
Total		**1.54M**	**547**	**553**	**258**

Source: Al-Mogrin and Al-Maziad, 1990) MOMRA, 1995

Therefore, of the total effluent, about 36 percent is used in irrigation, 34 percent is discharged to land, 18 percent is disposed of at seas, and about 2 percent is reused for industrial purposes. Little has been used for industry, ground water recharge and municipal applications. The low quantities, yet high quality, water requirements make uses other than irrigation very scarce in KSA.

11.8 Standards and guidelines

To date there are no national standards regulating discharge, disposal, or reuse but rather guidelines issued sporadically by different governmental agencies (Table 11-6). Efforts are under way to formulate and establish national standards for reuse of wastewater by joint committee from MOMRA, MAW, MOH and MEPA. Once formulated and passed it will be regulated by governmental channels. MAW play important role in setting these standards simply because MAW is the receiver of treated effluents.

Currently, permits for wastewater reuse and disposal to the sea and land are issued as an *ad hoc* process from MAW and MEPA. MAW requires secondary effluent and chlorination for restricted reuse while tertiary treatment and chlorination is necessary for unrestricted reuse. MEPA produced guidelines for discharge of effluents to the sea and land equal to unrestricted reuse required. Absence of enforcement of those guidelines is a major obstacle against their usefulness (Abu Rizaiza *et al.,* 1995). However, once national standards are established they will be rigidly applied.

• Table 11-6 Guidelines for reuse and sea disposal by different agencies*

	ICRC(1) 1979	MAW(1) (a)	1981(b)	MEPA(2) 1989	RCJY(3)	ARAMCO(4) 1980
BOD	10	30	10	25		20
SS	10	30	10	15	15	20
NO_3	10			5		
Turbid.[a]				75	5	
TDS					2000	
TC[b]	2.2	100	2.2	1000	23	2.3
Parasites[c]		1	1			
Oil&greas	Absent					

*Islamic Council for Research and Consultation (ICRC), Arabian-American Oil Company (ARAMCO), Ministry Agriculture and Water (MAW), Royal Commission of Jubail and Yanbou (RCJY), and Meteorological and Environmental Protection Agency(MEPA).

Sources: (1) Igbal, 1987; (2): MEPA, 1989; (3): Al-A'Ama and Nakhla, 1995, and (4): Farooq and Al-Layla, 1985.

Units in mg/l except noted a: NTU b: MPN/100ml, c: Viable intestinal helminthes eggs/l

It is necessary to establish sound standards on national levels to ensure public health protection and environmental protection especially soil and groundwater. Although some workers are in favour of relaxed standards or case-by-case basis (eg Al-Dubaiban and Al-Gfari, 1989), the suggested standards seem to be necessary for many reasons. The reuse programmes in KSA are planned for the long-term and treated effluent is expected to be part of the water budget. The second reason is highly related to the first as restricted reuse is not successful because of the entailed restrictions. In many cases this strategy is adopted on account of sustainability of such projects. Thirdly, there are simple cost-effective technologies available to upgrade secondary effluents to meet such proposed standards. Finally, such standards speed up permits for reuse programmes compared to case-by-case evaluations. Unrestricted reuse promotes long-term reuse programmes due to reduced risks associated with reuse. Therefore, tertiary treatment is eminent for each wastewater treatment plants in KSA to meet the current guidelines and anticipated standards.

Anticipated standards show be biased to impose more stringent standards which include many new parameters (Igbal, 1987) for the effective reduction of pathogens and toxins. For example the current guidelines of MEPA for sea disposal do not include inorganic and organic toxins. Their requirement is equal to that of unrestricted reuse in irrigation (i.e., secondary and disinfection).

Several authors are in favour of tertiary treatment Hammer *et al., (*1987); Abu Rizaiza *et al., (*1995). In contrast others suggest implementation of restricted reuse only for crops that are eaten cooked, fodder crops or other crops not for direct human consumption Igbal (1987); Al-Dubiban and Al-Gafari (1989). It is argued that tertiary treatment is an "unnecessary". However, a unique feature that makes tertiary treatment attractive is that no industrial effluents are allowed in domestic wastewater treatment plants. Industries are permitted only in "industrial sectors" in each city and industrial effluents are collected and treated separately in these industrial zones, and that is totally managed by the Ministry of Industry and Electricity. This fact makes cost of tertiary treatment of domestic effluents less than believed. Furthermore, one must consider that no nutrient removal is involved.

The use of secondary effluents imposes certain restrictions and limitations, such as no crops which come in direct contact with irrigation water should be irrigated with effluents and no crops that will be eaten raw or do not need to be peeled before eaten are allowed to be cultivated using effluent (Al'Mutaz, 1989). Other limitations pertain to the ban of the use of certain irrigation methods such as sprinklers, borders and furrow surface irrigation methods (Igbal, 1987; Al'Mutaz, 1989).

On the other hand, restrictive guidelines or standards may have positive impacts on the degree of groundwater pollution. The establishment and propagation of the first guidelines in 1981 by MAW and MOMRA have positively affected groundwater quality on national level. This is supported by findings of Alaa El-Din *et al., (*1994) from sampling 1000 wells around the country during 1984-1988 that were used for drinking water and irrigation purposes. Their study demonstrated improved trends in groundwater quality. They also concluded that animal and human wastes are the main sources for high N and FC pollution while over-pumping is a reason behind increased TDS content especially near coastal areas.

The suggestion of reuse of secondary effluents is probably based implicitly on the assumption that risk of contamination will be reduced under hot climatic conditions. Intuitively, pathogens are most likely to be deactivated by virtue of sunlight and dry harsh weather. However, no conclusive epidemiological evidence has been published to support this argument, which remains subjective. There may also be heat resistant or seasonal pathogens that proliferate during winter months. Although studies dealing with this issue in KSA are very rare, strong evidence exists for the presence of different species of infective parasitic intestinal helminthes such as *strongyloides* (adult and larvae) and embroynated *Ascaris lumbricoides* ova in chlorinated effluent from Riyadh Sewage Treatment Plant (RSTP) in all seasons. Their mean numbers were strikingly high (>100/l) exceeding limits 10 fold, (Bolbol, 1992; Al-Rajhi *et al*, 1992). In addition antigens of HAV, endemic disease in KSA, have been detected in 3 percent of samples as well as FS and E. *coli* in this chlorinated effluent (Barbour *et. al*, 1984; Al-Rajhi *et al*, 1992). Protozoan cysts were not detected during summer months due probably to the treatment process and the lethal effects of temperature of Riyadh. But since these effluents are to be used for irrigation throughout the year, the situation warrants attention. This is important for the winter crops such as wheat. It seems that RSTP decided to increase the chlorine dose to about 30mg/l but this action has increased BOD and COD in effluent that are greater than the recommended concentrations in the guidelines (El-Rehaili, 1995).

Necessity for tertiary treatment is recognized by MOH and MAW for the effective removal of pathogens. In 1981 the first tertiary pilot testing started at RSTP using RSF (Al-Dubaiban and Al-Gafari, 1989). Since then several studies have investigated the feasibility of RSF and chlorination for unrestricted reuse (Al-Sawaf, 1986; Hammer *et al.,* 1987). Although the results are good and comply with MAW and MOH requirements, the method used seems to be not attractive to MOMRA, the owner of WWTPs, because of costs, need for skills, and sludge production.

Chlorination has not been found effective in eastern part of the country as well. Indicator organisms (FC and TC) were detected on grown vegetables irrigated with secondary chlorinated effluent. These organisms were reduced to safe limits only after 24 hours elapsed after the last irrigation (Igbal, 1987). The author reported that survival of these bacterial organisms was much longer in the soil. This could suggest the importance of tertiary treatment and the use of effective alternative disinfectant. Even at high temperatures (20-30°C) the survival of viruses was found to be 15-60 days while that for FC was less than 30 days (Igbal, 1987). This called for the use of viral indicator such as coliphages.

Chlorination is used in all WWTPs around the country. However, these studies provide substantial evidence that chlorinated secondary effluent is not suitable for unrestricted irrigation. Viruses and parasites are not likely to be eliminated (Igbal, 1987; Al-Rajhi, 1992; Bolbol, 1992). Therefore little has been achieved in effluent reuse simply because effluents from most plants do not comply with health criteria even after chlorination. The gradual upgrading of wastewater treatment plants is a required step towards successful reuse programmes.

The use of potent disinfectant such as UVR is rarely investigated. Only one investigation was carried out to study effect of effluent temperature on the UVR inactivation rate constant (K) of FC. The author concluded that the UV dose of 180,000 uWs/cm² is required in order to reduce FC to 200/100ml in secondary effluents in Jeddah to comply with sea discharge guidelines of MEPA.

11.9 Appraisal of irrigational reuse practice

Because agriculture requires large quantities of water of marginal quality, almost all reuse projects in the country are directed towards irrigation. As mentioned earlier the administrative governmental bodies are committed to 100 percent reuse of available treated effluents by the year 2000. However, only 38 percent is achieved mainly because effluents of most of treatment plants do not comply with criteria set by MAW for that purpose. Several plants have been upgraded in Taif, Jeddah, and Jubail. Future plans include dual pipelines for residences in Taif city by the year 2020 (Ukayli and Husain, 1988). One is for drinking water and the other carries high quality effluents for home-lawn irrigation. In the western part of the country lawn irrigation consumes 54 percent of domestic fresh water demand (Abul Razzak and Khan, 1990).

Irrigation of different crops such as sorghum, corn, capsicum, alfalfa, tomatoes, squash, spinach, onions, eggplants, and most importantly wheat using treated effluents of domestic origin revealed its suitability for that purpose. Higher yields of these crops in the range of 50-110 percent have been reported compared to controls using fresh water (Al-Rajhi et al, 1992, Al-Jouloud, Al-Nahid).

In central part of KSA field experiments revealed that no adverse effects were observed for two-year effluent irrigation of wheat. No significant differences were found in terms of soil nematode, N fixation, and pest density, and soil-borne plant pathogens among lawns irrigated with effluent and those irrigated with ground water (Al-Rajhi et. al, 1992). Probably this was due to the absence of industry. However, high TDS is a feature of wastewater effluents in coastal areas of KSA. In Jeddah, it could reach 5800mg/l (Bowler et al, 1985) while in Dhahran it reaches 3400mg/l (Igbal, 1987). Infiltration of saline surface water to the system is the main source of salinity in coastal areas. On the eastern coast the yield was below average using this type of effluent yet economically justified (Igbal, 1987). The author concluded that with the use of drip irrigation the yield of tomatoes increased 6-7 fold and the mortality rate due to foliage damage was drastically reduced compared with sprinklers.

Provisions such as selection of salt-tolerant plants, dilution of effluents using groundwater irrigation may help to overcome the salinity problems. These measures are seen as economically feasible against expensive treatments such as RO or ion exchange treatment methods.

There are several motives and desires that generate the impetus for increased irrigation using reuse water rather than scarce water in stressed arid areas. Land disposal is practiced to inland dry wadis that frequently create running streams and farmers along these wadis irrigate crops indiscriminately and may use it for livestock consumption. For example, disposal of secondary effluent from RSTP (the largest WWTP in the country) creates a permanent stream 50km long. Ecological appraisal revealed pragmatic weed plants along margins. Seven introduced fish species established breeding in the stream, march-frogs were common and 22 species of migratory birds were recorded (Sidigi, 1995). However this may also have increased risks for human and animal health as well as environmental impact as explained earlier. High evaporation rates, due to intense heat and extreme dryness, not only cause huge amounts of treated effluent to be lost from these streams but also increase pollutant concentrations. Discharge of effluents to land could pollute water sources. For example, an incident of Typhoid fever breakout in northern city of Tabuk was attributed to land disposal of sewage to a depression area overlying an aquifer (Al-Quarwi, 1995). Seepage of sewage from septic tanks, as a diffused source, has been found to be a major cause of chemical and microbiological contamination of groundwater sources in areas without serwerage systems (Alaa El-din et al, 1994).

On the other hand, sea disposal of secondary effluents is practised in eastern and western coasts of KSA. Although it is a relatively safe method, neither the economic value of effluent nor its impact on marine life is fully realized. In Jeddah, effluents are disposed of to Red Sea. A bioassay study on sediments near the disposal sites revealed significant decreased numbers of *Faraminfera* organisms which is a predominant typical benthic species of unpolluted Red Sea marine water (Abouawf and El-Shater, 1991). Instead the authors observed abundance of *Rotalina* and *Millionlinera* species and their number correlated well with OM, TC and trace elements concentration in marine water of investigated sites. Eutrophicating substances have been found to increase in Red Sea coast receiving wastewater effluents that were found to be highly related to the quantity of sewage discharged (Buhairi and Saad, 1984). The authors attributed this to the poor exchange between the disposal site and the open sea. Measures such as modification of sea outfall designs and use of effective diffusers, to ensure adequate dilution in the zone of initial mixing, contribute to protection of marine life.

Therefore, reuse of wastewater effluents provides the ultimate protection of marine life and prevents such incidents that may have negative indirect latent impacts on human food chain through bio-concentration, bio-accumulation and bio-magnification of deleterious substances. Reuse of effluent can also provide solutions to problems of large-scale land discharge and sea disposal. But more stabilized effluents reduce the risks involved with such practices. This of course requires the upgrading of effluents through simple and cost effective tertiary treatment to comply with the purpose standards.

Mohorjy (1988) wrote: “Wastewater reuse must be considered a long-term alternative water supply”. He adds: ”For successful transfer and adoption of wastewater technology, it should be technically sound, economically feasible, socially acceptable, and environ-mentally non-damaging”. Imported advanced technology is not easily digested, especially in small communities that lack the technical skills. Methods, such as sand filtration, employing local material are the most suitable simply because sand is the most abundant and readily available material in KSA.

Reuse of effluents is entirely directed towards irrigation. Unrestricted irrigation is desirable by MAW because it is believed that reuse benefits are maximized through the adoption of this option that imposes less degree of restriction on crop selection, irrigation method, and provides more protection of human health. Most importantly from MAW’s perspective, this option totally eliminates the burden of monitoring and controlling restricted irrigation.

Several other measures for mitigating water scarcity and fighting aridity have been considered. These include the following:

ROLE OF DESALINATION

KSA has 2,500km of relatively unpolluted coastline (Mohorjy, 1988). Seawater desalination is practised to supply drinking water only. The final product is blended with groundwater at ratio 4:1. The first desalination plant was operated in 1971. Since that time several plants have been constructed and in 1981 the production was 0.623Mm³/d, which was 40 percent of the drinking water demand (Ciwick and Madah, 1981). Four years later it reached 1.66Mm³/d (Abdulrazzak and Khan, 1990).

Today there are 25 working desalination plants with value of US$5 billion (Farooq and Al-Layla, 1985) of which 67 percent are Multistage Flash Evaporation Plants (MSF) and 23 percent are Revers Osmosis Plants (RO) (Ukayli and Hussain, 1988). These plants jointly produce in excess of 2Mm³/d, which provides 70 percent of drinking water demand. (Bulgonaim, 1999). Al Jubail desalination plant (MSF) is probably the largest in the world with a capacity of 0.335Mm³/d (Mohorjy, 1988). It is to be extended in 2,000 to produce nearly 1Mm³/d (Farooq and Al-Layla, 1985).

Other main desalination plants in the country include plants in Jeddah, capacity of 0.220Mm³/d, in Mecca, capacity of 0.150Mm³/d and in Taift, capacity of 0.035Mm³/d respectively. The water produced at these plants is transferred inland via pipelines. Desalination in KSA is promoted by cheap energy and by the fact that it produces electricity (the MSF systems). These plants also provide 25 percent of total electricity produced in KSA (Bulgonaim, 1999). In addition there are more than 1,000 RO small-scale privately owned plants (Mohorjy, 1988).

Most of desalination plants exist on the Red Sea because of its less salt content than the Gulf. In the future 17 new plants will be built and 13 of these will be on the Red Sea (Bulgonaim, 1999). These plants are operated by an independent governmental organization "Sea Water Desalination Cooperation" under the auspice of MAW. The estimated cost of production US$1.18-1.38/$m^3$. Therefore desalinated water is not suitable for irrigation because of its high cost.

RAIN HARVESTING

Efforts have been made for rain harvesting projects principally through building dams. MAW contracted more than 60 dams mainly in west and south coast of the country to increase recharge of aquifers. Najran and Jizan with a storage capacity of 86 and 71Mm^3 respectively are the two largest concrete dams in the country (average height 60m) located in the south. Percentage of rain harvest due to development of dams has increased from 15 percent in 1985 to 45 percent in 1990 and of the total annual run off 30-40 percent is used and about 25 percent evaporates (Abdulrazzak and Khan, 1990).

RATIONALIZATION

The fourth development plan included rational utilization of scarce water resources, the introduction of conservation measures, strict regional water management, the establishment of priorities in water use, tariffs system, and coordination between agriculture and water developments.

Unfortunately most of the conservation plans are directed to domestic water while rationalization of irrigation water use is the key issue. Domestic water constitutes 5-20 percent of total national water while industrial demand is between 1-5 percent. In contrast, agriculture consumes 70-90 percent of TWD as seen earlier. Domestic water conservation strategies such as leakage monitoring, domestic water metering and incremental pricing, public education, installation of water saving devices are among several measures discussed in details elsewhere (eg Abdulrazzak and Khan, 1990). Domestic water conservation is part of the solution but agriculture as the largest water sink is much more important. The education of farmers to increase awareness is the most effective method for the "conservation consciousness" (Abdulrazzak and Khan, 1990).

Choice of irrigation method, time of irrigation and type of crop can have positive effects on water conservation in irrigation. For example, the use of sprinklers and drippers can reduce water consumption by at least 50 percent over furrow or border systems which are widely practiced (Abu Rizaiza and Allam, 1989). Selection of seasonal winter crops such as wheat, as it uses half of the amount required for vegetables, can be traded for water consuming crops.

Abdulrazzak and Khan (1990) wrote : " Implementation of conservation programmes are essential not only for preservation but also to "buy time" in order to discover new sources or new technology to be implemented before the resource situation reaches a critical stage.

VEGETATION

Increased vegetation of desert plants such as palm trees to fight desertification is one of the strategies executed jointly by MOMRA and MAW around the country. The goal is to mitigate dryness and high evaporation.

WATER IMPORTATION

The notion of transporting fresh water to KSA via gigantic tankers by its self reflects the magnitude of the problem. Several studies discussed the possible transportation of fresh water from Malaysia, Pakistan, Sudan and Egypt or via pipelines from Turkey (Farooq and Al-Layla, 1987; George, 1987). The cost of hauling large quantities of fresh water over short distances was found to be the least costly among other alternatives at cost US$1-2/$m^3$ at the 1987 consumer index (Farooq and Al-Layla, 1987). This cost does not include treatment before distribution. Several factors cast doubts about the sustainability of such inter-country projects. Economical, political and social constrains hindered their implementation yet they remain possible alternatives.

12 Syria country paper

AHMAD ZULITA[12]

Syria has a Mediterranean climate, characterized by arid and semi-arid conditions. Rainfall falls in winter, between October and May and is marked by fluctuations in terms of quantity that differs from one region to another. The average annual rainfall over the country is estimated at 46Bm^3 and 42Bm^3 over the last two years, due to prevalent drought. The average annual renewable water supplies (surface and groundwater) are about 10Bm^3/yr, in addition to Syria's share from the supplies of the international Tigris and Euphrates rivers.

Population growth (2.84 percent in 2000) has put pressure on the limited water resources, causing per capita share of the available fresh water resources to decrease. The gap between water supply and demand will increase further in the future.

Agriculture is the largest consumer of water. The irrigated area reached 1.21Mha in 2000 and consumes about 81 percent of the total available water resources. The government is planning to reclaim more land, an average of 20,000 ha annually according to Ministry of Irrigation's strategy, to provide food and to convert rain-fed lands into irrigated ones. The annual rate of increase in water demand differs from one basin to another, depending on the availability of reclaimable lands. For instance, it is higher in the steppe regions and south of Aleppo than in the other basins. Demand on water is increasing for human, industrial and animal consumption.

To face these circumstances, it is essential to work towards water resource use increase and rationalization but this doesn't solve the problem in the long run. Therefore, it is necessary to orient efforts also toward wastewater reuse as a non-conventional source of water. In other words, treated wastewater use for agriculture is the most important solution to provide irrigation water, in spite of the existence of some health risks and environmental problems.

Non-conventional water sources play a significant role in sustainable water resource management as an alternative to fresh water for different fields such as irrigation, aquaculture or others. Non-conventional water is defined as "water used more than once that has changed its quality in a way that cannot be used without treatment so as to improve its quality with the new uses or its use under specific conditions for attaining the purpose of production without any damage to environment elements in compliance with the legislation of water reuse".

12.1 Domestic and industrial wastewater

Domestic and industrial water effluents are estimated at 1.2Bm^3, so the government set a plan for the construction of treatment plants. Table 12-1 shows the location of plants the effluent of which can be utilized in irrigation, in support to the available water resources.

12.1.1 Domestic

Wastewater plays an important role in water resource management, as an alternative to fresh water use for irrigation. It has a considerable role in water conservation, in addition to several economic merits. The first objective lies in ensuring rational wastewater reuse, taking into account the protection of human health and the environment.

Sewage water was discharged into rivers or agricultural lands without any treatment, and this is unacceptable from the health point of view. This practice led to very high concentrations of pollutants, especially in the Barada River and Aleppo southern plains, resulting in the dispersion of dysentery. More than 75 percent of southern Aleppo and Damascus Ghouta populations are affected by dysentery. The situation would have become more critical if there was an infectious carrier such as cholera. Therefore,

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the best means for reusing this water is through appropriate treatment and safe reuse techniques. To fulfill this goal, efforts can be coordinated at national and regional levels and in collaboration with international organizations, for information and technical expertise exchange. In other words, this workshop provides an opportunity for the exchange of experience, knowledge circulation and addressing issues of regional dimension.

To face the above-mentioned problems, the Syrian government had to adopt the necessary measures of wastewater treatment and reuse for irrigation. Damascus wastewater reuse for irrigation is one of the pilot projects with important health, environmental, agricultural and economic impacts. A treatment plant treats water using activated sludge method, at 485,000m^3/day. According to the station, influent has about 390mg/l suspended solids and 340–380mg/l BOD, whereas the treated wastewater characteristics are 30mg/l SS and 20mg/l BOD. This water is used for irrigating an area of 18 000 ha, in Damascus Western Ghouta. The existing treatment plants and their characteristics are indicated in Table 12-1.

- Table 12-1 Wastewater treatment plants in Syria

City	Treated water (1000m^3/day)	BOD concentration		Notes
		Influent	Effluent	
Damascus	485	340 – 380	20	Under exploitation
Salamieh	5.85	532	40	Under exploitation
Aleppo	255	-	20	Under execution
Hama	70	300	30	Under execution
Homs	133.9	507	30	Under execution
Deraa	21.8	2.32	25	Designed and ready for execution
Sweida	18.75	290	25	Designed and ready for execution
Idleb	30	395	40	Designed and ready for execution
Lattakia	100.83	327	30	Offer invitation for execution
Tartous	33.447	344	40	Offer invitation for execution

12.1.2 Industrial

Due to the rapid increase of industrial activities and their large development in Syria, the population is exposed to increasing health and environmental risks, resulting from the large number of chemical factories in residential areas. Industrial development increased water consumption and, consequently, polluted water from these factories into neighboring environments increased. In Damascus, there are 250 tanneries discharging a large volume of polluted water, charged with chromium and heavy minerals, into Barada River from where it is used for irrigation. The total amount of water consumed by industry is estimated at 228.6Mm^3/yr in the Orontes basin, of which 29Mm^3 is lost and 200Mm^3/yr goes back to the Orontes River with different composition and pollution loads. This leads to poor water quality in the river and dams and, accordingly increases pollution risks.

Guidelines were established for industrial water whether for discharge into rivers, direct irrigation or dumping in sewage systems. To apply these guidelines, a large number of treatment plants were constructed in industries, such as oil refineries, fertilizer factories, iron factories, a number of sugar factories, and spinning and fabric factories. A central treatment plant for Damascus' tanneries was studied with the options to conduct preliminary treatment at the present location or to transfer it to the location of an old sugar factory in Adra, outside of the city.

The measures implemented so far, including the installation of treatment plants, are still not able to produce water quality suitable for irrigation, because of high industrial growth and low effectiveness of treatment plants. The Ministry of Industry elaborated laws to prevent the establishment of new factories if their design does not include industrial waste treatment to the required specifications. The existing factories are also required to establish preliminary treatment plants prior to their water discharge into the surrounding environment. Additionally, a unit for studying the environmental impact of projects was established at the Ministry of Environment and the required measures would be studied prior to issuing licences for the construction of new factories.

12.2 Wastewater use development

Water resource management and utilization under the dry and semi-arid climate of Syria constitute a challenge for all people working in agriculture and irrigation. The challenge is to stimulate optimal and scientific utilization, via modern irrigation techniques development and transfer, through future irrigation projects, and the utilization of every drop falling on the land. The limited water resources and the consequent imbalance between the available resources and demand make it essential to work and search for alternative water sources which are partially represented by treated wastewater reuse in irrigated agriculture. A substantial objective can be achieved by the introduction of wastewater as an element of the water balance in water use planning.

12.2.1 Wastewater quantity

DOMESTIC EFFLUENTS

Drinking water use was estimated at 1,481Mm^3 in 2000, with a net figure of 1,037Mm^3/yr because average losses are estimated at 30 percent. Assuming a return rate of 70 percent, the net effluent would be around 426Mm^3/yr.

INDUSTRIAL EFFLUENTS

Water used in industry was estimated at 285Mm^3/yr in 1995, leading to a total industrial effluent of 200Mm^3/yr, if the return rate is 70 percent. As industrial water use is expected to reach 688Mm^3/yr in 2015, the effluent will be around 480Mm^3/yr.

THE USE OF WASTEWATER IN AGRICULTURE

Most of the produced wastewater is discharged without treatment despite the fact that the implementation of the programme of wastewater treatment plants in five cities started ten years ago. In addition, the treatment plant of Aleppo is still under its initial testing operation stages.

The agricultural sector is the major consumer of water and still needs additional sources to achieve food security. Wastewater use poses health and environmental risks that require precautionary measures. To prevent these risks, the Ministry of Agriculture issued resolution No. 2823, dated 29/8/1990, to exclude vegetable farming from irrigation with polluted water sources of all origins. Consequently, the use of wastewater is restricted to fodder and industrial crops and fruit trees on small areas (Table 12-2).

- Table 12-2 Farming area irrigated with wastewater in Syria

Province	Area (ha)	Crops
Rural Damascus	3654	Fruit trees – fodder crops – uneatable raw vegetables
Quneitra	-	No wastewater except for Ba'ath city, Khan Arnabeh and Qahtanieh where wastewater is delivered to Al-Raqad valley
Deraa	-	Wastewater is discharged into the following valleys (Zidi, Al-Ghar, Al-A'aram, Abo Al-Labn, Ghazaleh)
Sweida	-	Wastewater is delivered into the open
Homs	1960	Winter and summer crops – Fruit trees (wastewater is discharged within irrigation canals branching from the Orontes)
Hama	159	Wheat – cotton – maize – sunflower – ground peanuts – fruit trees
Al-Ghab	224	Wastewater is discharged via covered canals to pour into the Orontes river.
Idleb	2000	Cotton – wheat – sunflower
Aleppo	19400	Wheat – cotton – maize – fruit trees – uneatable raw vegetables. Wastewater is discharged into Qweiq, Sajjour and Affrin rivers.

Raqqa	2155	Winter and summer crops – a small portion of vegetables
Deir Ezzor	-	-
Hassakeh	1800	Cereals – cotton – vegetables
Tartous	-	Wastewater is discharged into the sea
Lattakia	500	Citrus – summer vegetables. Wastewater is delivered into the sea.

The table shows that utilization of wastewater is low compared to its total volume. The total area irrigated with wastewater does not exceed 40,000ha, with water consumption of 480Mm^3/yr. The largest figure may reach 1,208Mm^3 the largest portion of which is lost in the sea or in valleys causing considerable damages to the agricultural environment, i.e. degradation of groundwater quality and of soil.

12.2.2 Future use

The use of wastewater is an urgent need to eliminate the pressure imposed on the limited available water resources. But it is also necessary to treat this water to remove pathogens and other elements. To achieve this goal, it is essential to undertake the following measures:

- Control pollution of water resources by wastewater, through:
    - Set up a plan for wastewater treatment (domestic and industrial),
    - Establish an efficient programme for the use of treated wastewater,
    - Complete the sewerage systems in the urban and rural areas,
    - Implement low-cost demonstration projects on the use of wastewater in high-population villages (5,000–20,000 inhabitants), as in some other countries of the region.
- Reduce the health and agricultural risks (soil – plant) resulting from industrial wastewater by adopting the appropriate means and legislation,
- Qualify national staff and to strengthen their technical and practical capabilities,
- Establish a central lab for conducting chemical, microbial and toxicity analysis altogether with the necessary equipment and tools,
- Establish a center specialized in the study of non-conventional water, jointly by the concerned ministries,
- Conduct specific research on non-conventional water use (drainage and wastewater) to get local criteria for the safe use of this resource. In this regard, the Ministry of Agriculture, through its Directorate of Irrigation and Water Uses (DIWU), has initiated studies on drainage water use more than 5 years ago, in its irrigation research stations of the Down Euphrates basin (Deir Ezzor). Several criteria have been identified on various crops that may be irrigated with this water. DIWU has also conducted special research on treated wastewater reuse for crops and vegetables, in the rural Damascus station of Nashabia since 1997–1998 season. This research aims at studying the impact of this type of water on the yield and the soil chemical and physical properties.
- Improve the economic efficiency of non-conventional water use through appropriate technology transfer.

12.2.3 Future expected results

If all the produced wastewater is treated, it will allow the use of 1.2Bm^3 for irrigating an agricultural area of more than 100,000ha with traditional surface irrigation. This area would be much higher if modern irrigation techniques are used.

12.3 Impacts of non-conventional water resources misuse

12.3.1 Environmental impacts

The limited water resources and their inability to meet the increasing demand, along with the continuous degradation of their quality, led the government to adopt the use of non-conventional water to support existing resources, through treatment and reuse of drainage and wastewater. The discharge of non-treated domestic and industrial wastewater leads to quality degradation of surface water, which becomes unsuitable for direct use. The consequences the pollution of rivers and other water bodies are summarized below.

- No water life due to the lack of BOD,
- Appearance of non-favorable plants and weeds that clog water canals,
- Dispersion of hateful odors resulting from the anaerobic decomposition of organic materials,
- Multiplication of insects and rodents.

12.3.2 Impacts on human and animal heath

During the period 1995-2000, it was noticed that the rate of typhoid and hepatitis infections increased ten times and that of diarrhea two times, in comparison with the period 1991-95. Animals were also attacked by several diseases, such as tapeworm and pulmonary tuberculosis and others, resulting from the use of untreated wastewater for fodder crop irrigation. The major factors favoring the development and dispersion of these diseases can be summarized as follows:

- Scarcity of groundwater resources and the orientation toward the use of wastewater to meet the shortage,
- Lack of infrastructure especially that related to wastewater treatment and disposal, i.e. random disposal without treatment most of the time,
- Lack of health awareness and proper handling of polluted water,
- Non-existence or lack of adoption of regulations related to the protection of environment and public health.

12.3.3 Impacts on natural resources

Most surface water resources have been polluted as a result of irrational wastewater discharge with BOD figures reaching 100ppm. The use of wastewater for agriculture may have adverse impacts on soil and plants because it may contain high concentration levels of harmful elements, such as nitrogen and others.

12.3.4 Economic impacts

The list below summarizes the major constraints facing the development of non-conventional water resources:

- Lack of information and knowledge on water resources, i.e. water quality degradation and sensitivity of water environment to pollution,
- Insufficient infrastructure, i.e. water supply, sewage systems, industrial and drainage water systems and desalinization plants. This leads to important losses that cause pollution of the environment and water bodies. Insufficient funding is the key problem to control this constraint.
- Lack of trained and qualified staff able to use modern and appropriate technology in the water sector in general and conventional water in particular.

12.4 Prevailing technologies for non-conventional water use

12.4.1 Wastewater treatment

The common technology of wastewater treatment differs from one region to another, depending on considerations of technical, economic, social, population, land topography, and wastewater standpoints. Treatment methods include activated sludge, used in Damascus, Hama, Homs, Deraa, Lattakia and Tartous, while the oxidation ponds method is used in Salamieh area, east of Hama, because of the availability of favorable factors such as low-cost land, low-cost project, easy utilization, low population, available manpower level and no need for disinfection.

12.4.2 Standards and legislation

Standards and legislation on the treatment and use of non-conventional water resources represent a very important element for the safe and rational use of these resources. Water legislation has been developed to assess the proper methods of water resources use and protection, especially non-conventional waters. Since the process of setting-up the required specifications of treated wastewater depends on its use and disposal after treatment, wastewater in Syria is treated for two major objectives:

- Supporting conventional water resources, especially groundwater resources, and their conservation from exhaustion, and increasing the irrigated area,
- Protecting wastewater sewers, every water source and the environment from pollution by sewage.

Consequently, the government set specifications for every type of treated wastewater reuse. There are specifications for using this water in agriculture or discharging it into public water streams and there are other specifications when this water is to be used in industry for cooling and other uses. There are also some precautions for which specifications and legislation have been issued, including:

- Prevention of sprinkler irrigation methods with wastewater, except for fodder crop such as clover (berseem) and with the condition of using special down-directed sprinklers,
- Identification of the crops to be irrigated with this type of water,
- Non-contact of fruits with water and soil,
- Fruit sterilization prior to their use,
- Prevention of irrigating vegetables (likely to be eaten uncooked),
- Collaboration of the Ministry of Health with Agriculture Agencies in order to control these guidelines, in addition to 1) routine check of agricultural production and 2) routine examination of personnel working in the field.

12.5 Pollution control

Water quality conservation and pollution control has a great importance under the conditions of limited water resources, in the efforts to use the entire available resources properly. In this regard, the measures that should be adopted are:

- Survey and list of all potential pollution sources,
- List existing and planned wastewater treatment plants and related information,
- Establish required water quality for each source,
- Conduct monitoring of all sources according to pre-established regular programme,
- Report on pollution and on necessary corrective measures.

12.6 Constraints and challenges

The use of non-conventional water resources is relatively new, compared to that of conventional water resources, especially surface water, and this goes back thousands of years when ancient civilizations prevailed in the region thanks to the relatively abundant water resources at the time. The present inability of conventional water resources to meet the increasing water demands in the world in general and in Syria in particular, is forcing the use of non-conventional water resources despite the many risks and problems associated with their safe and rational development and use. The main constraints and challenges comprise the following.

12.6.1 Technical

The sensitivity of handling treated wastewater and the need to identify appropriate technical and technological means for its proper use and safe disposal, require that the following technical constraints and challenges are lifted:

- Treated wastewater does not always comply with the specifications stipulated by the regulations for treatment plants,
- The specifications themselves are not always available or may be inaccurate for several reasons,
- Increase of treatment loads above the design capacity of treatment plants results in effluent quality below the expected level,
- Lack and/or insufficiency of quality indicators for assessing quality,
- Inability to cope with updated technologies for handling wastewater (collection, treatment, use and safe disposal),
- Increase of wastewater quantity caused by urbanization and poor infrastructure to deal with it,
- Low coverage of rural areas and poor maintenance of existing plants,
- Low capacity and technical knowledge to handle and use wastewater,

12.6.2 Institutional

The main issue is the lack of coordination among the many concerned agencies dealing with wastewater. Some agencies are in charge of operating the sewage system, while others are in charge of water utilization. This needs coordination, cooperation and integration of efforts. The situation is exacerbated by the lack of qualified technical staff to cope with complicated processes, as well as by poor laws and legislation, including penal laws, and the lack of enforcement means of the existing regulations.

12.6.3 Social and religious

Generally speaking, there is not enough public awareness on water shortage problems in the country. The current perception of water resources leads to their overuse and to the lack of interest in non-conventional resources. Poor demonstration means are leading to several wrong practices, such us:

- Non-compliance with laws, legislation and specifications, such as the disposal of wastes from kitchens and industrial shops directly into water streams. This disposal is charged with oils and greases that affect negatively the performance of treatment plants and the whole process, by forming an insulating layer of oil on water surface and screening the necessary oxygen,
- Unwillingness of all society categories to use wastewater because of its sources, essentially for psychological reasons attributed to the way the wastes are handled and used. In general, people object to the establishment of housing communities near to treatment installations and to the use of wastewater,

12.6.4 Financial and economic

The high cost of non-conventional water resources, as compared to that of conventional ones represents the largest constraint vis-à-vis the promotion of development and use of these resources. In addition, no funds are allocated for conducting studies and research on non-conventional water resources to promote their development and use.

12.6.5 Environmental

If not treated properly, wastewater is contaminated with several microbial pathogens, parasites, chemicals and organic materials that are harmful to humans, animals and the environment (soil, crops, groundwater). The surroundings where wastewater is used can be polluted by bad odors. However, most if not all of these negative impacts can be avoided through the use of appropriate treatment technology and the correct management of treated water.

12.7 Suggestions and recommendations

- Need to promote the reuse of non-conventional water resources (wastewater and drainage water) as an important and substantial substitute to conventional water resources. This requires the implementation of Syrian standards to avoid the negative effects of random use of these resources,
- Accelerate the installation of wastewater treatment plants in big cities, along with the control of industrial pollution sources, particularly factory wastes through initial treatment of their water, in order to have proper quality before discharge into public sewage system,
- Expand research on mathematical models to predict the effects of salinity and wastewater use for crops and to assess the use criteria of these waters,
- Promote collaborative research on non-conventional water resources development and management, in order to achieve water and environmental balance, to minimize dependence on conventional sources, especially non-renewable groundwater, and to expand the use of treated wastewater and drainage water for agricultural production, taking into account that the low-quality level of this water,
- Exchange experiences and training among Arab countries in the field of sea water desalinization, treated wastewater and rainfall harvesting, in order to reach the best techniques used for improving production efficiency, reducing construction, operation and maintenance costs of plants and prolonging the life expectancy of these plants,
- Install tertiary treatment of wastewater, to the extent possible, to eliminate pollution hazards,
- Adopt integrated management of non-conventional water resources,
- Develop databases and databanks, through subordination to specialized strategic research centers in the Arab League, or by the establishment of a joint Arab academic organization for water, in order to activate joint Arab work, water security, promotion of scientific research and joint studies, development of demonstration programmes, training and qualification,
- Construct industrial cities outside the main cities, in special locations, instead of their dispersion inside the cities, so as to allow the setting up of special sewage systems and to prevent wastewater discharge into the main sewage systems,
- Promote research on development of high-salinity and wastewater adapted crop varieties, to focus on local farming that depend on high-saline sea water or groundwater and to activate the role of extension in the field of non-conventional water uses, taking into account the avoidance of reverse environmental effects of such uses.

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13 Tunisia country paper

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Summary

In the arid and semi-arid regions, countries like Tunisia are facing increasingly more serious water shortage problems. Problems of water scarcity will intensify because of population growth, rise in living standards, and accelerated urbanization which threaten the water supply in general and agriculture in particular and lead to both an increase in water consumption and pollution of water resources. According to forecasts, increased domestic and industrial water consumption by the year 2020 may cause a decrease in the volume of fresh water available for Tunisian agriculture. Consequently, development of additional water resources as well as the protection of existing ones have been taken into account for several decades and water reuse was made an essential component of the Tunisian national water resources strategy.

A national reuse policy has been elaborated and implemented. Reuse is up to now mainly practised for crop irrigation and irrigation of recreational facilities, such as golf courses. Many projects expanding the areas irrigated with reclaimed water are under implementation. Other reuse opportunities such as groundwater recharge and industrial reuse are screened. Reuse development requires, however, setting up a specific strategy. Future reuse projects in the different activity sectors will depend on a better planning and management of reuse operations based on a real water demand. This means a better institutional, regulatory, and organizational setting. Economic and financial feasibility of water reuse applications needs to be better assessed. Technical aspects need also further study, along with applied research for specific applications. Education, information, and training of farmers and extension services also play an important role in promoting these practices aiming to achieve higher agricultural production without adverse impacts on the environment. In this paper, the water reuse achievements and prospects are presented.

13.1 Introduction

In the arid and semi-arid regions, countries like Tunisia are facing increasingly more serious water shortage problems. Problems of water scarcity will intensify because of population growth, rise in living standards, and accelerated urbanization which threatens the water supply in general and agriculture in particular and lead to both an increase in water consumption and pollution of water resources. According to forecasts (Ministry of Agriculture, 1998), increased domestic and industrial water consumption by the year 2020 may cause a decrease in the volume of fresh water available for Tunisian agriculture. Consequently, development of additional water resources, as well as protection of the existing ones have been taken into account since several decades and water reuse was made an essential component of the Tunisian national water resources strategy. A national reuse policy has been elaborated and implemented. Reuse is up to now mainly practiced for crop irrigation and irrigation of recreational facilities, such as golf courses. Many projects expanding the areas irrigated with reclaimed water are under implementation. Other reuse opportunities such as groundwater recharge and industrial reuse are screened. Reuse development requires, however, setting up a strategy strengthening the socio-economical, institutional, regulatory and financial aspects. In this paper, the water reuse achievements and prospects are presented.

13.2 Water resources

Tunisia extends from the Mediterranean coast in the north to the Sahara desert in the south and its total surface area is 164,150km^2. The Tunisian coastline extends over 1,300km. Average annual rainfall is around 594mm in the North, 289mm in the Centre, and 156mm in the South. The annual precipitation in Tunisia is on average equal to 37Bm^3. The annual evaporation varies between 1300mm in the north to about 2,500mm in the south. The water resources are about 4.7Bm^3 of which 2.7Bm^3 are from surface

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water and 2Bm^3 from groundwater. The volume of water brought on-line during the terms of the Eighth Economic, Social, and Development Plan (1997) was about 3,100Mm^3 i.e., 66 percent of the potential water resources, from large dams, hillside-dams, open shallow wells, deep tube wells, and springs. The country's five-year development plans emphasize water reuse and water harvesting. Reclaimed water is now a part of Tunisia's overall water resources balance (Table 13-1). It is actually considered as an additional water resource and as a potential source of fertilizing elements (UNDP, 1987a). Agricultural water reuse has been made an integral part of overall environmental pollution control and water management strategy. It is also considered as a complementary treatment stage and consequently, as a way of protecting coastal areas, water resources, and sensitive receiving bodies.

• Table 13-1 Accessible (A) and available (B) water (Mm^3/yr) for different time-horizons (Ministry of Agriculture, 1998)

	1996		**2010**		**2020**		**2030**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Large dams	1340	871	1800	1170	1750	1138	1750	1138
Hillside-dams and lakes	65	59	100	50	70	35	50	45
Tubewells and springs	997	997	1250	1150	1250	1000	1250	1000
Open wells	720	720	720	720	720	620	720	550
Reclaimed water	120	120	200	200	290	290	340	340
Desalinated water	7	7	10	10	24	24	49	49
Total	**3249**	**2774**	**4080**	**3300**	**4104**	**3107**	**4159**	**3122**

13.3 Wastewater characteristics

13.3.1 Wastewater treatment

Most residents of large urban centres have access to various adequate sanitation systems and the wastewater treatment facilities generally follow conventional designs. The sanitation coverage in the sewered cities is about 78 percent. This rate, related to the whole urban population (5.8 million), is 61 percent. Concerning industry, compliance with the Tunisian standards (INNORPI, 1989a) to discharge wastewater into the sewerage system is required. So, preliminary treatment plants to fulfill the discharge requirements stated in the regulations must be supplied. Subsidies are given to equip industrial units with pre-treatment processes.

From 240Mm^3 of wastewater discharged annually, 140Mm^3 (58 percent) are treated in 61 treatment plants (WWTP) of which around 41 have a daily capacity less than 3,500m^3 and 10 above 10,000m^3, Choutrana being the largest with 120,000m^3/d. Five treatment plants are located in the Tunis area, producing about 62Mm^3/yr or 54 percent of the country's treated effluent. Several of the plants are located along the coast to protect coastal resorts and prevent sea pollution. Municipal wastewater is mainly domestic (about 88 percent) and processed biologically up to a secondary treatment stage. Concerning industry, compliance with the Tunisian standards (INNORPI, 1989a) to discharge wastewater into the sewerage system is required. So, preliminary treatment plants to fulfill the discharge requirements stated in the regulations must be supplied. Subsidies are given to equip industrial units with pre-treatment processes. The treatment processes vary from plant to plant depending on wastewater origin and on local conditions. Out of 61 treatment plants, 44 are based on activated sludge (medium or low rate), 3 on trickling filters, 14 on facultative or aerated ponds. Sanitation master plans have been designed for several towns. The annual volume of reclaimed water is expected to reach 290Mm^3 in the year 2020. The expected amount of reclaimed water will then be approximately equal to 18 percent of the available groundwater resources and could be used to replace groundwater currently being used for irrigation in areas where excessive groundwater mining is causing salt-water intrusion in coastal aquifers.

13.3.2 Characteristics

There are some constraints related to reclaimed water quantity and quality.

Reclaimed water is consistent with the Tunisian standards regarding water quality required for agricultural reuse (INNORPI, 1989b). However, salinity and the microorganisms' content are the two major constraints related to secondary effluent quality. Reclaimed water is often salt-affected (Table 13-2) due to sea- or ground-water seepage into the collection network, to the plant location (near a salt lake), and to industrial activities. This salt load limits the range of crops to irrigate and the benefits related to water reuse, and may affect the soil properties and composition.

- Table 13-2 Reclaimed water annual flow and salinity level

EC (µS/cm)	Annual flow (m^3/yr)	percent
Slightly saline: 700 - 3 000	14,006,664	12
Medium saline: 3000 - 6 000	92,740,287	80
Highly saline: 6000 - 14 000	9,231,807	8
Total	**115,978,758**	**100**

Tunis concentrates 54 percent of the country's effluent, which means that large storage infrastructures are needed. On the other hand, peri-urban irrigated areas are mainly devoted to the production of eaten raw vegetables, which is a major constraint to reuse development in the case of crop restrictions. Availability of agricultural land is another limiting factor, especially along seashores. Transfer of water for reuse may then be required even though expensive.

13.3.3 Treatment costs

Sanitation charges are included in the drinking water billing. They are graduated upward based on consumption (5 blocks for domestic consumers: 0-20; 21-40; 41-70; 71-150; >150m^3/quarter), usage (domestic < industry < tourism) and degree of water pollution (3 levels for the industrial sector depending on BOD5, COD, and SS concentrations). The tariff structure, similar to the water supply one, is based on social equity; it spares low and medium domestic consumers (<70m^3/quarter) and affects the large ones. Sanitation charges are meant to cover operation and maintenance costs.

In the following, an attempt is made to estimate treatment costs. Data are presented for reclamation plants ranging in production capacity from 256 to 43,000m^3/d. Capital costs were derived from the National Sewerage and Sanitation Agency (ONAS) data. They include facility construction (design life of 45 years, return rate of 7 percent) and equipment purchase (design life of 15 years, return rate of 7 percent). Average capital cost is US$0.08/$m^3$ (US$0.003 to 0.49/$m^3$, N = 37) (1 DT = US$0.67). Capital costs for facultative ponds are the lowest, followed by aerated ponds and extended aeration, the conventional activated sludge and oxidation ditch. Annual O&M costs comprise treatment facility personnel salaries, operating fees (power mainly), and maintenance costs (equipment repairs and replacements). The average O&M costs per treated cubic meter, for the year 1995, was around US$0.07 (US$0.01-0.20/m^3, N = 37). The least O&M reclamation costs were for facultative ponds, followed by extended aeration, conventional activated sludge, aerated ponds, and finally the oxidation ditch process. Energy fees represent 60 percent of O&M costs, salaries 30 percent, and maintenance 10 percent. The average wastewater treatment cost is then around US$0.15/$m^3$, excluding wastewater collection costs but including old wastewater treatment plants with low capital costs. Total treatment costs at the reclamation plant remain the lowest for facultative ponds and extended aeration. Actually, the marginal treatment cost is supposed to be about US$0.30/$m^3$, investment costs representing 80 percent of the total marginal cost. Table 3 gives capital, and O&M costs for the different treatment processes. The treatment capacity was not taken into account.

- Table 13-3 Estimated capital cost, O&M costs, and total cost for different treatment processes

Treatment process	Capital cost ($US/$m^3$)		O&M costs (US$/$m^3$)		Total treatment	
	Mean	Range	Mean	Range	Mean	Range
Activated sludge (N=12)	0.06	0.003-0.33	0.06	0.02-0.17	0.12	0.02-0.37

Extended aeration (N=5)	0.05	0.01-0.08	0.05	0.03-0.08	0.10	0.06-0.16
Oxidation ditch (N=14)	0.12	0.02-0.49	0.09	0.02-0.20	0.21	0.03-0.52
Facultative ponds (N=4)	0.03	0.02-0.04	0.04	0.01-0.11	0.08	0.03-0.13
Aerated ponds (N=5)	0.05	0.007-0.11	0.08	0.03-0.13	0.13	0.05-0.21

N: number of treatment plants.

13.3.4 Reclaimed water alternative disposal

The non-reused effluent is still discharged into the receiving environment (sea, wadis, lakes, and sebkhas). So, a disposal route is required which means alternative disposal arrangements such as sea outfalls for coastal locations and disinfection (to comply with Tunisian standards) for inland sites. Actually, sea outfalls have already been implemented for Sousse (1.7km length, 14-15m depth), Jerba (1.1km length, 8-10m depth), Hammamet (1.6km length, 23m depth), and Monastir (1.5km length, 4.5m depth) (Howard Humphreys, et al., 1996). Reclaimed water disposal costs vary between US$0.02-0.04/m^3 (US$1 = 1.5 DT) for large treatment plants such as Sousse, Hammamet, and Monastir and are about 0.09 $US/ m^3 for the small ones such as Jerba.

13.4 Water reuse implementing approaches

A gradual approach to expanding reuse since the mid 1960s has been adopted (UNDP et al., 1992). The strategy has consisted of 1) extending wastewater treatment to all urban areas; 2) conducting pilot- and demonstration-scale irrigation operations on agricultural and green areas; 3) establishing large scale irrigation schemes; and 4) implementing a policy calling for an increase in the percentage of treated effluent that is to be reused. Different development phases can then be distinguished.

FIRST PHASE - RECLAIMED WATER TO SAFEGUARD CITRUS PRODUCTION

Some of the reclaimed water from Tunis has been used since the early 1960s to irrigate 600ha of citrus fruit orchards located at La Soukra (8km North East of Tunis). The reason for using reclaimed water was to reduce the impact of salt-water intrusion due to excessive pumping of groundwater. The reuse has enabled citrus fruit orchards to be saved. Effluents were thus used, mainly during spring and summer, either exclusively or as a complement to groundwater. Irrigation of vegetables was not allowed.

SECOND PHASE - PLANNED RECLAIMED WATER REUSE

The water reuse policy was launched at the beginning of the 1980s. The main applications of water reuse are agricultural irrigation, and landscape irrigation. Some pilot projects or studies have been launched for groundwater recharge, irrigation of forests and highways, and wetlands development. Water reuse was implemented after the construction of existing treatment plants. However, for new plants, treatment and reuse were co coordinated from the planning stage up to the implementation studies.

THIRD PHASE - DEVELOPMENT OF RECLAIMED WATER REUSE

Because of the water scarcity, enforcement of the water reuse policy will go on. Forthcoming and already implemented projects should allow a higher utilization of reclaimed water. Water reuse primarily for agricultural purposes and secondarily in other sectors, will continue to develop in Tunisia. Actually, there are several other water reuse opportunities when the water quality is in adequacy with the intended end use of the effluent (Asano and Levine, 1996). However, in order to move forward and to achieve a higher reuse rate, there are some prerequisites and the following questions have to be answered:

- What additional treatment should be provided to remove crop restrictions? What are the economic and social impacts of restrictions removal?
- How can increased users' associations' participation be improved (involvement from the planning to the implementation phase)?
- What institutional framework (coordination) and/or management structure (inter-ministerial) would improve the reclaimed water reuse rate?

- How can reclaimed water services (quality and reliability) be improved?
- How can the reclaimed water market be more clearly assessed? What should be done to develop other reuse opportunities?
- Which pricing policy should be set up?

Based on the on-going reuse projects, a study aimed at developing a strategy to promote water reuse was launched in 1997 (Ministry of Agriculture / Bechtel and Scet, 1998). The study showed that the strategy should be oriented towards the substitution of conventional water by reclaimed water for the high-rated water activities or the creation of a new demand based on strategic projects. Promotion of reclaimed water reuse should be based on (1) a real water demand, (2) the definition of appropriate water quality standards for the different uses, (3) a relevant regulation, (4) clarified and identified responsibilities for the different stakeholders, and (5) an efficient control on all the uses. The legal and institutional framework should be strengthened. Reclaimed water reuse should be more integrated to water resources management. Reuse projects must meet a real water demand -in quantity and quality- and have a sound economic basis. The wastewater treatment trains will depend on reuse opportunities. By upgrading the water quality and with more widespread information, reclaimed water reuse should gain wider acceptance in the future. Projects aimed at developing water reuse have been proposed such as upgrading of the water quality, improvement of Cebala and Ben Arous irrigated perimeters, groundwater recharge, etc. Some are under study or already under implementation and are presented in the following.

In order to remove crop restrictions, development of cost-effective and reliable additional treatment systems are under study. It has been estimated that the incremental cost for 3 maturation ponds in series should vary from US$0.05-0.04/m^3 for pond capacities ranging from US$1,500-15,000m^3/d. and from US$0.02-0.01/m^3 for 4 ponds with the same daily volume (Ministry of Agriculture / Bechtel and Scet, 1998). This cost is around 10 percent of the marginal treatment costs expected by ONAS. Other physical-chemical disinfection costs (which include a filtration step) such as chlorination were estimated at about US$0.06/m^3 for a daily treatment capacity of 50,000m^3 and US$0.09/m^3 for 5,000m^3/d.; UV at US$0.01/m^3 and ozone at US$0.13/m^3. Actually eight pilot wastewater treatment with a disinfection step (sand filtration + UV, or maturation) are under implementation.

The 11 towns project in the Mejerda catchment area. The Mejerda catchment area is the main source of irrigation water but also the drinking water supply for the Tunis, Cap Bon and Sahel regions. A sanitation programme to equip the 11 largest towns of this catchment area with sewerage networks and treatment plants in order to protect this reservoir and, particularly, the Sidi Salem's dam (450Mm^3) is under implementation. The project also includes household waste management and the creation of schemes irrigated with reclaimed water. The treatment process includes phosphate removal to limit risks of eutrophication from the discharge of non-reused water.

A new wastewater treatment plant is planned for the city of Tunis "The Tunis-West project" with a design capacity in 2016 of 105,000m^3/d. (41Mm^3/yr.). Inter-seasonal storage (9Mm^3 in a first phase, 15Mm^3 in a second phase) in hillside dams is included for water resources protection purposes, and increase of the resource. In a first phase, an irrigation scheme covering 1,000ha is planned. The total irrigated area should cover about 6,000ha. Farmers' willingness to reuse reclaimed water is taken into account. Water users' associations will manage the irrigation system. The water distribution system at the plot level will be optimized and irrigation saving methods will be encouraged.

13.5 Agricultural irrigation

About 35Mm^3 of reclaimed water are annually allocated for irrigation. A total flow of about 28Mm^3/yr of treated effluent (approximately 20 percent of the treated effluent) is being reused. In some areas, irrigation with effluents is well established and most of the volume allocated is being used, while in new areas where irrigation is just beginning, the reclaimed water usage rate is slowly increasing. The use of secondary treated effluents in Tunisia is for restrictive irrigation from which all vegetable crops are forbidden. The main crops irrigated with reclaimed water are fodder (alfalfa, sorghum, berseem, etc.) (45.3 percent), fruit trees (citrus, grapes, olives, peaches, pears, apples, grenades, etc.) (28.5 percent), cereals (22.4 percent), and industrial crops (sugar beet) (3.8 percent). 57 percent of the equipped area is sprinkler irrigated and 48 percent surface irrigated. Some farmers use localized irrigation systems. Cattle (milking cows, calves, sheep, and goats), not grazed on pastures irrigated with reclaimed water, are also fed with forage crops cultivated on the irrigated areas. A water reuse programme has been set up. The area currently equipped is about 6,500ha, 80 percent of which are located around Tunis. Main perimeters are Cebala (3200ha), La Soukra (600ha), Mornag (1047ha), Nabeul (350ha), Hammamet, Sousse, Monastir, Sfax, and Kairouan. Other projects are being implemented extending the area to 9,000ha. The area irrigated with reclaimed water is planned to expand up to 20,000ha, i.e. 7 percent of the overall irrigated area, with 14,500ha located around the Great Tunis. Major crop irrigation projects planned or under implementation are presented in the following.

13.5.1 Research studies and epidemiological aspects

The physical-chemical and biological quality of wastewater and their impacts on soils and plants were studied. The results showed the feasibility of water reuse provided that some precautions are taken (Bahri, 1987, 1995, 1998a, 1998b; Rejeb, 1990, 1992a, 1992b, 1993; Trad-Raïs, 1989, 1991, 1992, 1995, 1998; UNDP, 1987a). Storage in ponds showed an improvement of reclaimed water quality. A storage strategy for a better management of water quality needs however to be established.

Epidemiological studies were conducted in the area of Sousse in the wastewater-irrigated project of Zaouiet Sousse (Saâdi, et al. 1996). They did not show significant differences in stool samples (200) collected in two groups of population: an exposed and a non-exposed group. The rate of intestinal protozoan infection (Giardia and Endameba histolytica) was the same in the two populations. Helminth eggs were found in four percent of the exposed population when none was found in the non-exposed population.

13.5.2 Farmers' attitudes and expectations

A survey carried out among farmers of 7 schemes irrigated with reclaimed water (DHV Consultants, 1993) found that farmers worry about the quality of the irrigation water and its health effects on field workers. The survey pointed out however a lack of information amongst farmers about reclaimed water quality, health risks related to water reuse and impacts on crops and soils. More information and more involvement of the farmers in the decision making process would ensure the success of the projects. On most schemes, farmers are asking for more reliability of the water supply and higher water rates. They explain their reluctance to use reclaimed water by the restrictions on the crops they are allowed to cultivate. They would like to grow market gardening crops. Farmers next to schemes irrigated with conventional water strongly ask for being provided with conventional water. Cultivating food crops, particularly market garden crops, in the vicinity of towns is very attractive. Removing the restrictions on irrigated crops is expected to help farmers moving from rainfed to irrigated crops. One major obstacle to the water reuse development would thus be overcome. The removal of restrictions demands that two requirements are fulfilled: new regulations should be laid down and effluent disinfection treatments complying with these regulations have to be set up. The price of reclaimed water did not appear to limit water reuse.

13.6 Institutional aspects

Responsibility from wastewater collection to use in agriculture is shared among various ministries. The National Sewerage and Sanitation Agency, a subsidiary agency of the Ministry of Environment and Land Use Planning, is responsible for wastewater collection, treatment, and disposal. This includes construction, operation, and maintenance of the entire sanitation infrastructure. The National Environmental Protection Agency monitors water pollution and enforces pollution control with the International Environmental Technology Centre of Tunis.

The Ministry of Agriculture is in charge of the implementation of water reuse projects (mainly the Rural Engineering General Directorate before 1989), operation of the water distribution system, fees collection and enforcement of the regulations related to agricultural reuse for large perimeters (Regional Commissariats for Agricultural Development). The Ministry of Public Health regulates the hygienic quality of reclaimed water reused for irrigation and of marketed crops. At a regional level, the different hygiene departments are in charge of periodical monitoring, health education, and prevention campaigns. The Ministry of Tourism and the Property Agency for Tourism finance water reuse operations (irrigation of green areas: golf courses and hotel gardens). Water users' associations are in charge of the management of the water distribution system, fees collection and enforcement of the regulations related to agricultural reuse for small perimeters. A better coordination among institutions in charge of water reclamation and reuse is required to prevent responsibilities overlapping.

13.7 Legal aspects

Water reuse in agriculture is regulated by the 1975 Water Law and by the 1989 decree (JORT, 1989, Decree No. 89-1047). The Water Law prohibits use of raw wastewater in agriculture and irrigation of any vegetable to be eaten raw with reclaimed water. The 1989 decree specifically regulates use of reclaimed water in agriculture. Monitoring the quality of treated water for a set of physical-chemical parameters once a month, for trace elements once every six months, and for helminth eggs every two weeks was planned. As an enforcement of these regulations, using secondary treated effluents is allowed for growing all types of crops except vegetables, whether eaten raw or cooked.

- Table 13-4: Maximum concentrations for reclaimed water reused in agriculture.

Parameters (a)	Maximum allowed concentration
pH	6.5 - 8.5
Electrical conductivity (EC) (µS cm^{-1})	7000
Chemical oxygen demand (COD)	90 (b), (c)
Biochemical oxygen demand (BOD_5)	30 (b), (c)
Suspended solids (SS)	30 (c)
Chloride (Cl)	2000
Fluoride (F)	3
Halogenated hydrocarbons	0.001
Arsenic (As)	0.1
Boron (B)	3
Cadmium (Cd)	0.01
Cobalt (Co)	0.1
Chromium (Cr)	0.1
Copper (Cu)	0.5
Iron (Fe)	5
Manganese (Mn)	0.5
Mercury (Hg)	0.001
Nickel (Ni)	0.2
Lead (Pb)	1
Selenium (Se)	0.05
Zinc (Zn)	5
Intestinal nematodes (arithmetic mean no. of eggs per litre)	< 1

(a): all units in mg L-1 unless otherwise specified; (b): 24-hr composite sample; (c): except special authorization.

In separate documents, reclaimed water quality standards for reuse (Table 13-4) (INNORPI, NT 106.03, 1989b), wastewater disposal standards in receiving waters (INNORPI, NT 106.002, 1989a), and a list of crops that can be irrigated have also been set up. The reclaimed water quality criteria for agricultural reuse were developed using the FAO guidelines (Ayers and Westcot, 1985), the WHO guideline (1989) for restricted irrigation (< 1 helminth ova per litre), and other Tunisian standards related to irrigation or water supply. Specifications determining the terms and general conditions of reclaimed water reuse (as the precautions that must be taken in order to prevent any contamination (workers, residential areas, consumers, etc.)) have also been set up.

13.8 Economic and financial aspects

An adequate estimation of the water price is important for cost recovery and for water use saving. Devising an appropriate water pricing policy is, therefore, an important step in water reuse operations. With the creation of new schemes, water was often distributed free of charge at the beginning of the supply to encourage farmers to use it, then at a fixed price per hectare before evolving towards a price per cubic meter of water used. The price of the reclaimed water sold to farmers use to vary from one scheme to another. The charges were meant to cover some of the O&M costs (operation, maintenance, salaries, and energy). As for schemes irrigated with conventional water, this price was supposed to evolve progressively towards the real cost, remaining, however, lower than conventional water prices. Water services are metered on most of the schemes but there is still a high amount of unaccounted water leading to higher O&M costs. For instance, in the Mornag irrigation scheme, the O&M costs amounted in 1996 to US$0.13/$m^3$ (energy fees for pumping representing 68 percent of O&M costs, salaries 18 percent, and other costs 10 percent) and the selling price was US$0.04/$m^3$. Production cost, including capital costs (for the irrigated schemes), was then about US$0.20/$m^3$. Water from the Medjerda-Cap Bon canal (conventional water used in the same area), whose O&M costs were US$0.07/$m^3$, was sold at US$0.06/m^3. In order to promote water reuse, it has been decided, in 1997, to fix the price at US$0.01/$m^3$. However, the water reuse rate did not increase as expected and a deficit was generated. New bases should be adopted: a given water quality should be supplied to the farmers for a given price and based on a real water demand.

13.9 Recreational reuse

Since the beginning of the 1970s and with the development of tourism, a policy was set up for golf course irrigation with reclaimed water. Golf course irrigation means a high rate of water reuse and a water demand that lasts all the year long through varying climatic conditions. Actually, the eight existing golf courses are irrigated with secondary-treated effluent. Some are irrigated with reclaimed water blended with conventional water (surface or ground-water), or with desalinated water (Jerba). Irrigation water is in compliance with the WHO guidelines (1989) for water reuse on recreational areas with free access to the public (2.3 log units/100ml) during winter and part of spring (Bahri et al., 2001). Polishing secondary effluents through lagooning or seasonal storage would lower health hazards and contribute to increase this demand for reclaimed water (Bahri et al., 2000). Supplying reclaimed water to golf courses, green belts, and hotel gardens would result in an optimization of both investment and operation costs. These users are never very far from the treatment plants. They are big consumers and customers likely to be able to pay a price that would allow recovering operation and maintenance costs.

13.10 Groundwater recharge

Seasonal recharge of the shallow, sandy aquifer of Nabeul has been underway since 1985. Activated sludge effluents that were not used for irrigation during the winter season were infiltrated and stored in the aquifer, thus increasing the volume farmers can pump during summer season to irrigate citrus orchards (UNDP, 1987b). Groundwater recharge efficacy was proven not only by the increase of the water level in the wells but also by the improvement of the production of the surrounding wells. This experiment allowed an underground storage and an additional treatment step. According to the state of the art of soil-aquifer treatment (Bouwer, 1991, Brissaud and Salgot, 1994), improved operation of this facility would lead to a groundwater quality meeting unrestricted irrigation requirement (Rekaya and Brissaud, 1991). Performing coastal aquifer recharge, where the hydro-geological context is favourable, would make water reuse well accepted by farmers. This subject is still under study and other sites are screened for further studies.

Groundwater recharge including the comparison of different treatment processes preceding recharge is under study in the Cap Bon area and in the area of Medenine.

13.11 Lessons learned and challenges

The lessons learned from the Tunisian water reuse experience are summarized in the following with respect to the planning process, the technical aspects, regulations, and institutional and pricing aspects.

PLANNING

Implementation of water reuse operations is still a big challenge because of the complexity of the systems. Planning and management of agricultural reuse operations need to take into account the institutional, organizational, legal, regulatory, socio-economic, policy pricing, environmental, and technical aspects. There are steps to be taken if agricultural water reuse is to be used to its full economic potential.

The economic benefits and financial performance of reuse projects remain difficult to predict and optimize. Such planning and management uncertainties are crucial for project implementation and optimization. Furthermore, some costs and benefits are difficult to quantify (public health protection, economic development, etc.).

Agriculture and recreational uses cannot absorb all the available amount of reclaimed water. There is a need to prospect other reuse opportunities. The wastewater market assessment is still not considered as a basic step of project designs when it should help to satisfy the identified needs under the best possible economic conditions and to evaluate the price that farmers or other users would be willing to pay. As stressed by Asano and Mills (1990), finding potential customers who want and know how to use reclaimed water should be a key task in a planning process. A demand driven reuse approach is required but not easy to put into practice in planned systems.

Water users' associations need to be associated in the planning and management of water reuse projects to ensure the success of the projects.

Only 55 percent of the area equipped to use reclaimed water is irrigated. Farmers are taking steps to shift from rainfed to irrigated crops and more particularly to reclaimed water irrigated crops. Agricultural use of reclaimed water is more easily accepted and implemented in water-short areas where irrigation is already practiced.

Small schemes (200 ha) are easier to manage and control than large ones (>1000 ha).

TRAINING, EDUCATION, AND ACCEPTABILITY

Skills development and the help of extension services are required to overcome some obstacles towards reclaimed water reuse.

Public outreach and education programmes in order to generate greater acceptance of the project are an essential component of the planning of reclaimed water service. There is a need to initiate such efforts during the planning phases of the project.

Codes of good agricultural practices for agricultural reuse could assist farmers in reusing reclaimed water.

TREATMENT

Production of a water quality, which would satisfy multiple reuse or discharge purposes should be one of the objectives.

Crop restriction is a limiting factor for water reuse. Additional treatments at economic costs and meeting farmers' requirements will change water use and farmers perception. However, price of conventional water remains too low compared to tertiary treated wastewater.

Farmers are also asking for more reliability of the water quantity and quality supply, and higher water rates.

Equipment

Inter-seasonal and long-term storage are required because of the large variability of irrigation water demand. However, large storage volumes are needed as well as an adequate management of the water quality.

Use of resistant materials is recommended to avoid corrosion problems of the hydro-mechanical equipments.

Technical and agronomical aspects

Reclaimed water has to be used for crops with high economic returns. The production-processing-marketing chain has to be mastered for industrial crops which wastewater irrigation is recommended.

No deterioration in quality or quantity of the irrigated crops was reported in the agricultural reuse operations. Reclaimed water salinity remains one of the major limiting factors for agricultural reuse development and a long-term threat for aquifers.

Irrigation with reclaimed water was not followed by a change in the fertilization practices. The nutrient recycling that should take place through agriculture products needs to be optimized in order to prevent over-fertilization and groundwater pollution.

Use of water saving techniques such as micro-irrigation systems that would remove the restrictions on irrigated crops requires a good filtration system to prevent emitters clogging.

Regulation

The actual regulatory framework needs to be reconsidered on the basis of the acquired experience. New regulations should be laid down for different reuse opportunities.

Institutional

Reclaimed water development requires a stronger coordination among institutions involved in reuse operations or an ad-hoc reuse agency in charge of all reuse aspects (regulation and enforcement of standards and procedures, management, etc.).

Economic and financial issues

Economic and financial feasibility of reclaimed water reuse applications is not yet well assessed:

- At a micro-economic level, except for golf courses, farmers prefer conventional water to reclaimed water in spite of its attractive price. On the other hand, reclaimed water tariffs imply the delivery to users of a quality of water in compliance with the standards and more reliable water supplies.
- At a macro-economic level, CRDAs cannot recover O&M costs. Reuse projects do not really contribute to agricultural production and do not yet solve the environmental problem of reclaimed water disposal.

13.12 Conclusion

During the last decades, Tunisia has gained experience in the field of wastewater reclamation for irrigation of agricultural crops and green areas. The acquired experience is of interest to the Mediterranean climate region.

Water reuse has been made an integral component of the national water management strategy. Many projects expanding the areas irrigated with reclaimed water are under implementation. Agricultural reuse will remain the largest potential market followed by recreational uses such as golf courses.

However, water reuse has still to overcome several challenges:

- Technical aspects need further study, along with applied research for specific applications. Research efforts have to be made to improve the quality of the effluents in order to expand the range of crops and irrigation methods,
- Periodical wastewater control must be carried out in all wastewater irrigated areas. Use of reclaimed water requires follow-up by evaluation of long term effects of the elements brought by the water on soil dynamics, plant and groundwater contamination,
- Risk assessment studies will also have to be conducted on water-sludge-soil-plant-animal-human exposure pathways,
- Water reuse optimization requires a specific strategy. Future reuse projects will depend on a better planning and management of reuse operations based on a real water demand. This means a better institutional, regulatory, and organizational setting,
- Economic and financial feasibility of reclaimed water reuse applications needs to be better assessed,
- Education, information, and training of farmers and extension services also play an important role in promoting these practices aimed at achieving higher agricultural production without adverse impacts on the environment.

The efficiency of the water reuse policy mostly relies on the development of the agricultural sector. Tunisian agriculture will progressively be updated, thus increasing the reclaimed water demand.

Water reuse is an integral component of the national water management strategy. Many projects expanding the areas irrigated with reclaimed water are under implementation. Agricultural reuse will remain the largest potential market followed by recreational uses such as golf courses. However, water reuse has still to overcome several challenges. Water reuse optimization requires a specific strategy. Future reuse projects in the different activity sectors will depend on better planning and management of reuse operations based on a real water demand. This means a better institutional, regulatory, and organizational setting. Economic and financial feasibility of water reuse applications needs to be better assessed. Technical aspects also need further study, along with applied research for specific applications. Education, information, and training of farmers and extension services also play an important role in promoting these practices aiming to achieve higher agricultural production without adverse impacts on the environment. However, the efficiency of the water reuse policy mostly relies on the development of the agricultural sector. Tunisian agriculture will progressively be updated, thus increasing the reclaimed water demand.

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14 Turkey country paper

AHMET İDRIS AĞAR[14]

14.1 Water resources

The soil and water resources of Turkey are crucial to the development of the economy and sustainability of the society. Currently, rapid growth of population, irrigated agriculture and industrial development are stressing the quantity and quality aspects of the natural water systems. This situation is forcing changes to make conscious and systematic approaches for water resources management, covering all legislative, administrative, social, technical and economic water-related activities in an integrated manner. Irrigation development is an essential component of a sustainable agricultural development.

The soil and water resources of Turkey will need to be managed in a sustainable manner if the future well-being of Turkish communities is to be assured. The point is that any attempt to develop soil and water resources in Turkey must take into account the potential contribution that such water management technology can make as well as important issues in production, resource utilization and the environment.

In Turkey, typical continental climate prevails, with an annual average rainfall of 643mm. Precipitation ranges from 250 to 3000mm, changing considerably with region and season. The mean annual rainfall corresponds to 500Bm^3 water. Of this amount, it is estimated that 274Bm^3 return back to the atmosphere by means of evaporation from soil and water surfaces and evapotranspiration by plants, 41Bm^3 feed the underground reservoir through leakage and 186Bm^3 flow to seas or closed watershed lakes. In addition, It is determined according to flow observations that annually 6.9Bm^3 are added to the national water potential from rivers running from neighboring countries. Therefore, the gross renewable fresh water potential of Turkey is calculated as 234Bm^3; however, it should be noted that this is only an average value, the yearly actual figure depends on meteorological conditions which may vary from one year to another. Because of this, the total technically and economically useable surface and ground water potential is 110Bm^3. It is generally accepted that 95Bm^3 and 3Bm^3 of this amount will be provided from internally born rivers and from externally born rivers, respectively, while 12Bm^3 will be provided from groundwater.

Turkey has 26 watersheds totaling and average flow of 186Bm^3/yr, including all kinds of resources such as lakes and underground water. Some of the rivers are indicated in Table 14-1.

- Table 14-1 Total flow figures of selected rivers in Turkey

River	Annual potential ($10^9 m^3$)
Dicle	21,33
Fırat	3,66
Seyhan+Ceyhan	15,19
Kızılırmak	5,80
Yeşilırmak	6,48

There are examples of irrigation drainage water being used by farmers, in water-short circumstances like in the Konya closed plain. The latter lies in the central part of Anatolia, with annual rainfall of 320mm. A main drainage canal transports both drainage water and sewage water to the Salt Lake. Salinity is high with EC ranging between 2.0-7.0 dS/m, which may cause salinity problems on soils, and water is used for irrigating wheat, barley, alfalfa and sugar beet. Irrigation water is delivered into drainage canals during the irrigation period in summer. Quality evaluation, particularly salinity, sodium and SAR observations, showed no significant salt accumulation in the farmers' fields, which have been irrigated with this water. The results indicated that drainage water could be used for irrigation under proper management and

[14] Soil and Fertilizer Research Institute, Ankara, TURKEY

adequate drainage conditions. Additionally, underground well water with high levels of salt and boron is also being used for irrigation.

In Çukurova plain, in the Mediterranean region, irrigation water is not enough for all irrigation season. Generally in late summer, farmers have to use saline drainage water, to compensate for water shortage, for irrigating cotton fields.

In the GAP area, southeast Anatolia region, seven-point drainage water is being pumped into irrigation canals by DSI, because of the insufficiency of outlets for drainage water. This mixed water is being used for irrigation by farmer to produce cotton and salt tolerant plants. The salt concentration of irrigation water depends on the amount of pumped drainage water into the irrigation canal.

14.2 Waste water treatment and reuse

With the increasing pressures on natural water resources and the need to increase the productivity of agricultural lands, new problems have emerged. Irrigation water supplies in many parts of Turkey have become increasingly polluted by urban and industrial activities; concern is growing regarding the effects that polluted waters will have in the long-term on soils and the quality of crops. In addition, water supplies for irrigation are limited or being reduced in many areas, because of other uses, and there is now a strong interest in water reuse.

IN CENTRAL ANATOLIA

Karasu River is affected by municipal and industrial wastes of Bilecik and Bozüyük towns. Analysis showed that chemical oxygen demand and heavy metals (Fe, Zn, Cu, Pb, Mn, Co) were very high in comparison with the recommended maximum concentrations.

Ankara stream. A main branch of Sakarya River is affected by industrial, domestic and agricultural wastewater. Between 1992-1994, to determine the stream quality a project was carried out. In this study every month sampling was made from 20 sites along the Ankara stream and its tributaries in terms of physical and chemical parameters. The irrigation water quality was evaluated using some metal inorganic, organic and chemical parameters. According to the results, irrigation water quality was found to be T_3 A_2 and T_4 A_3. Because of Municipal and Industrial waste, irrigation water contains a number of toxic elements, pathogens and heavy metal. Especially Cadmium and Manganese levels were higher than the recommended maximum concentrations for irrigation. In addition, Nitrate Nitrogen (NO_3-N) and Phosphorus were found to be high. As a result Ankara stream was found very polluted (table 2) and using its water for irrigation was restricted. Consequently, Ankara municipality decided to build an advanced wastewater treatment system, which also disinfects pathogens. This system began to run in 1999, removing pollution from the stream and lifting all restrictions on the use of its water for irrigation.

- Table 14-2 Quality of stream water before wastewater treatment

Element	mg/l
Fe	0,80
Cu	0,22+
Mn	0,25+
Co	0,03
Zn	0,05
Cr	0,02
Cd	0,02+
Ni	0,06

IN MARAMA REGION

Ergene River and its branches, a study has been conducted between 1992-1994, with water samples from five sections of the river taken at monthly intervals. It can found that some sections of Ergene were highly polluted. Salt (4,5-7,2 dS/m), sodium, chlorine (RSC): and Chemical Oxygen Requirement (COR) appeared to be the main pollution parameters. For heavy metals, such as Pb, Zn, Cu and Cd, no hazardous concentrations were found, but Mn concentration was above the limits.

IN EAST BLACK SEA REGION

A research project was carried out between 1986-1988, to determine the pollution level of Yeşilırmak River and its tributaries. According to the results, the main sources of pollution were sugar factories, alcohol-sprits factory and coal mining, but pollution level was not found to be serious. Nevertheless, municipalities of the region wanted these factories to treat their wastes before dumping them into the Yeşilırmak River.

14.3 National policy/strategy and ongoing programmes

Turkey is better endowed with good quality water resources than many other countries. Most of the irrigation supplies, representing 62 percent of the total use, have salinity less than 0.7 dS/m, which allows the full potential yield from nearly all crops to be obtained. Sodium content of these irrigation waters, expressed as SAR, is low. Industrial and human water requirement is continuously increasing and so are their waste materials. The pollution problem is getting bigger and bigger. Regional and central foundations are carrying out assessment of pollution in rivers, lakes and irrigation waters. Soil and water management research is primarily conducted in 11 research institutes, located in different geographical regions of country, under the General Directorate of Rural Services (GDRS), affiliated to the Prime Ministry. The objective of the programme is to extend the potential of irrigated agriculture by using wastewaters and irrigation drainage flows. The project concerns are:

- Characterization of waste and drainage waters regarding their suitability and importance for re-use,
- Studies of production and implications of using waste and drainage water for irrigation purposes.

14.4 Problems and issues

Because of irrigation water shortage, there is an increasing interest in using wastewater from agribusiness and urban activities. In particular there is currently concern about the use of polluted water resources in the irrigation of agricultural lands, especially in western Turkey. Farmers have been experiencing irrigation water shortages on a regular basis in recent years. Solutions to the issues will clearly require research and training of farmers on reuse and irrigation water management.

Generally, water reuse research projects are carried out by GDRS regional and central research institutes. These projects concern mainly chemical and biological analysis of irrigation water. From time to time, some difficulties especially in heavy metal analysis come on the scene. There is a need of updating and sharing laboratory knowledge and experiences from these projects, which makes them very important.

Several laws and regulations have been put into force to ensure that the environment is protected and kept undisturbed, particularly soil and water quality, including wastewater treatment, limitation criteria, waste products as well as their use and disposal. The law-related issues are being improved on continual basis. In 1988, the Turkish Government signed an agreement for the adaptation of Turkish Environmental Legislation to EEC standards. This legislation includes many kind regulations for controlling water pollution and identifies many kind environment and pollution criteria. Nowadays, regulation about the control of soil pollution is being renewed by the Ministry of Environment. This new draft will be discussed for approval in the Turkish Grand National Assembly in the near future.

14.5 Institutions

In Turkey there are 4 institutions involved in water treatment and reuse.

- **DSI** deals with controlling water resources in great basins and supplying the required water for irrigation and drinking purposes. Additionally, underground water (aquifers) and drainage effluents are controlled by DSI.
- **GDRS** deals with supplying water and drainage effluent to the farm level.

Both organizations deal with the reuse of wastewater, each within its mandate.

- **The Ministry of Environment** deals with protecting the whole complex area. To this end, the ministry prepares laws and regulations and conduct monitoring.
- **Municipiliaties** deal with urban wastewater. Their duty is to purify waste products and to protect streams from pollution, mainly biological and chemical. For example, in Diyarbakır, urban and industrial effluent, sewer, rainwater collection and wastewater treatment systems will be build jointly by German and Turkish enterprises. This agreement was approved on 27 August 2001 by the Turkish Government.

14.6 Conclusions and recommendations

In Turkey, there is scarcity of irrigation water in some regions. This problem is likely to grow in the future with the implementation of new projects. Irrigation water takes the biggest share among sectors, therefore water saving through effective irrigation systems will have positive contributions to the other sectors and thus to the economy. To use water resources in an efficient way, the following recommendations are suggested:

- Need to investigate the practices and technology of wastewater reuse in irrigation th will support proper use of this resource,
- Results of research on the reuse of wastewater have to be transferred into practices. Training of farmers, staff and extension services are the key components for addressing these issues,
- Introducing and improving wastewater reuse management at the farm can save significant amounts of water, making more water available for irrigation,
- Farmers' participation in all stages of irrigation and water resources investments is important and should be considered for future applications.

15 Yemen country paper

QAHTAN YEHYA ABDUL-MALIK[15]

15.1 Introduction

Water is the main core in the socio-economic development in the country. Yemen, as other countries in the region, is situated in an arid and semi-arid zone, which is known for its scarce rainfall and high evaporation. Pronounced differences in the topography affect climatic conditions and limit agriculture to areas of rainfall and groundwater availability such as the western mountains, basin areas, and wadi beds. Rains occur only in spring and summer seasons.

The population is around 18.2 million 76 percent of whom live in rural areas and 26 percent in cities, and the annual population growth scores 3.7 percent (statistics year book, 2000). About 20 percent of the population in rural areas has access to safe drinking water but no access to adequate sanitation facilities. In the urban areas, 45 percent of the population has access to safe drinking water. There are only 9 wastewater treatment stations functioning in nine Governorates.

15.2 Water resources

15.2.1 Renewable water resources

The annual precipitation averages 500-800mm in the Western Highlands, and less than 50mm along the coasts of the Red Sea and Gulf of Aden. Surface water is considered to be an important source for irrigation. It consists of seasonal spate water and springs, with differing quality depending on the region. This source of water is less affected by drought and other natural and geographical factors. High runoff speed and heavy rainfall cause deep wadis and form several water basins. Topographic patterns control the flow of rainwater and lead it in two directions, the outer water basins (draining to the west in the Red Sea and to the south in the Gulf of Aden and Arabian Sea) and the internal water basins (draining east or west towards the Rub Al-Khali desert, the Ramlat Al-Sabatain and Wadi Hadramout).

Surface water is estimated to be about 1,500Mm^3/yr. Several dams and dikes were built on many main *wadis* for the purpose of directing spate waters into man made spate irrigation systems, which irrigate around 120,000-150,000ha. Groundwater resources are vital for agriculture. For their recharge they depend mainly on spate running water and rainfall. Runoff and springs in catchments areas are the main sources of groundwater recharge. The estimate of renewable groundwater is around 1,000Mm^3/yr, making the total renewable water resources 2,500Mm^3/yr, while the total demand is estimated at 3,400Mm^3/yr. The deficit, i.e. 900Mm^3/yr, is covered by overdraft from deep aquifers (NWRA-report 2000).

15.2.2 Non-conventional water

They consist of brackish water (highly saline), found in some regions, and municipal wastewater. The former is used for rock cutting industry, mainly in the Highlands, as well as for irrigating some tolerant crops, mainly in the costal plains. It is found some ground water aquifers but has not been intensively investigated and exploited.

The number of wastewater treatment plants in operation is nine, with a total actual flow of treated wastewater around 92,000m^3/day (33.5Mm^3/yr), as indicated in Table 15-1.

[15] Soil & Irrigation Engineer. Director Central Water Monitoring Unit. Ministry of Agriculture & Irrigation, Yemen.

• Table 15-1 Operational treatment plants and their main characteristics

Station	**Design capacity (m^3/d)**	**Type of treatment**	**Actual flow (m^3/d)**	**Treatment cost US$/$m^3$**	**Disposal method**
Sana'a	50,000	Activated Sludge	20,000	0.25	Irrigation*
Ta'aiz	17,000	W.S.P./Biological Ponds	17,000	0.03	Irrigation*
Al Hudeidah	18,000	W.S.P. Biological Ponds	18,000	0.03	Sea + Irrig.
Aden	15,000	W.S.P. Biological Ponds	15,000	0.03	Sea + Irrig.
Ibb	7,000	Activated Sludge	7,000	0.25	Irrigation*
Dhamar	10,000	W.S.P. Biological Ponds	6,000	0.03	Irrigation*
Hajja	5,000	Trickling Filter	1,150	NA	Irrigation*
Mukalla	8,000	W.S.P. Biological Ponds	6,000	0.025	Sea
Rada'a	2,800	W.S.P. Biological Ponds	1,500	0.025	Irrigation*
Total	132,800		91,650		
*Uncontrolled Irrigation.					

(Adopted from data provided by the Ministry of Electricity & Water, 2000)

The $33Mm^3$ produced corresponds to approximately 69 percent of the total design capacity of the nine plants. It is expected to reach the total design capacity in the next five years (Ministry of Electricity & Water, 2000). There are three additional treatment plants (stabilization Ponds) under construction in Aden, Yarim and Amran, with design capacity of 60,000, 3,500 and $6,000m^3$/day respectively. These stations will be operational in 2002. There are also three stations under planning in Beit Al-faqih, Bagel and Zabid.

The effluent quality varies from one area to another depending on the treatment method, the plant capacity and operational conditions. For instance, while it is very good in Hajjah, it is very low in Taiz (Table 15-2).

• Table 15-2 Treated wastewater quality in four stations

Parameter	**Sana'a**	**Aden**	**Dhamar**	**Hudeidah**	**Yemen standards**
BOD (mg/l)	24	N.A	102	106	150
COD (mg/l)	103	N.A	189	348	500
TDS (mg/l)	1852	1695	700	3110	450-3000
SS (mg/l)	28	N.A	580	128	50
EC (micromohs/cm)	2850	2840	920	5186	700-4000
FC/100ml	12,000	80,000	110,000	1366	<1000

15.3 Water resources development

Due to water scarcity, the state, in its policy and strategies, works in different directions to develop and conserve water resources including:

- **Rainfall water harvesting** through the construction of dams and other structures such as diversion weirs, water concrete tanks and canals, for providing surface water for multi-usages. The final aim is to reduce pumping from deep aquifers and to recharge shallow groundwater from the water stored in these reservoirs. There are around 650 water-harvesting structures in the country.
- **Improvement of irrigation efficiency** by introducing improved irrigation techniques (localized systems or improved surface irrigation) and on-farm water management. The area irrigated by improved systems is currently around 10,000ha spread around the country.
- **Extensive investigations for groundwater** with the purpose of tracing promising aquifers to cover drinking water requirements for the increasing population.

15.4 Water use

The agricultural sector is the dominant user of water resources (93 percent), while domestic and industrial sectors use 7-8 percent (Table3.) The cultivated area was estimated in 2000 to be about 1,143,441ha of which 45 percent is dependant on rainfall (514,550ha), while 55 percent (601,461ha) is irrigated by groundwater (40 percent or 457,375ha.) and surface water (15 percent or 217,549ha). Of the latter 63,985ha are irrigated by springs, many of which being essentially seasonal, and the rest from seasonal floods (spate Irrigation.)

The main rainfall areas are mountainous where terraces are built for growing barley, sorghum, maize and some pulses. In some areas, supplementary irrigation is needed particularly during dry seasons. Surface and groundwater are used mostly for this purpose.

Farmers pump groundwater from wells using diesel or electric pumps. These wells have different production capacity, from one basin to another, ranging from less than 5l/s to 50l/s and more. A total of 52,000 to 55,000 active wells have been estimated in the country, most having a relatively low production. The total volume pumped every year is estimated at about 1.5BCM. There are around 150 water well drilling rigs in use, owned by individuals or companies who generally have no drilling permits despite governmental legislation that limits the drilling of wells. Recently, the National Water Resources Authority started a programme of registrations of water wells drilling companies.

Another development that improves on-farm use efficiency of the availability water is the rapidly spreading use of plastic and galvanized pipes. In the period between 1997 and 2000 about 15,000 hectares of farmland have been connected to wells by this means. It is expected that this figure will rise by 8,000ha a year until 2010 (*Ministry of Agriculture, Statistical Yearbook* 2000). Consequently, there are estimates that average on-farm water use efficiency will increase from its current level of 35 percent to 60 percent, resulting in a reduction of water consumption (*Ministry of Agriculture, Statistical Yearbook* 2000).

- Table 15-3 Use of water over 30 years (1990-2010) by different sectors (Mm^3/yr)

Water Use	1990	2000	2010*
Agriculture	2,600	3145	3,328
Domestic	168	210	552
Industrial & Mining	31	45	90
Total	**2,799**	**3,400**	**3,970**

*Estimates.

Source: Adapted from: TNO Institute of Applied Geo-science Report, (1995).

It is clear that there is big gap between demand and the amount of renewable resources. The deficit is being covered from underground aquifers, with the risk of their depletion. The per capita annual water share does not exceed 140m^3, which is way below the water poverty line.

15.5 Treated wastewater reuse

There are two types of wastewater reuse in agriculture:

- **Controlled Irrigation** is practiced in government projects, under the Ministry of Agriculture and Irrigation, to build green belts mainly in the coastal plain cities (Aden, Hudeidah), as well as for sand dune fixation and desertification control in the affected coastal plains.
- **Non-controlled Irrigation** is common in the Highlands and Wadis, is practiced by farmers to grow corn and fodder crops in some areas (such as Taiz), whereas in other areas such as Sana'a, they grow restricted as well as non-restricted crops such as vegetables (tomato, carrot) and fruit tress.

15.6 Policies, strategies and programmes

All water related strategies, policies, and laws in Yemen call for considering treated wastewater as a water resource that should be utilized in a proper and safe manner. Some of these policies, strategies and laws are as follows:

- Water Resources Policy and Strategy (1999-2000),
- Irrigation Water Policy (2001),
- Watershed Policy (2000),
- Agricultural Sector Reform Policy (2000),
- Environment Protection Law (1995),
- Yemeni Water Quality Standards (2000),
- Draft Water Law (in the parliament for ratification, 2001),
- Draft Wastewater Reuse Strategy.(under development, 2001),
- Urban Water Sector Policy (1997).

Most of these strategies and policies support the implementation of wastewater management activities in the form of targeted projects and programmes.

15.7 Institutions

Several institutions deal with water and wastewater within their respective mandates and responsibilities; these are:

NATIONAL WATER RESOURCES AUTHORITY (NWRA):

Establishment of the National Water Resources Authority (NWRA) took place through presidential decree N° 154 in 1996. NWRA is responsible for water resource planning and monitoring, legislation and public awareness. It is currently still in the capacity building stage with only three branches established in the Governorates, in addition to its headquarters in Sana'a.

MINISTRY OF AGRICULTURE & IRRIGATION (MAI)

Before the establishment of NWRA, MAI was responsible for water resources planning and development. In 1996, it was restructured to be responsible for irrigation activities planning, development, implementation and monitoring. MAI is functioning through its offices in all Governorates, in addition to some specialized authorities in the fields of agricultural research and agricultural and rural development regional authorities, as well as agricultural cooperatives, companies and projects. MAI is also responsible for the provision of technical guidance and extension services to farmers. In the past years, MAI has also implemented several projects related to the reuse of treated wastewater, notably:

- Project "Watershed Management and Wastewater Re-use in Peri-Urban Areas of Yemen" (1998-2001), which was supported by the Dutch Cooperation and implemented with technical assistance from FAO. The project worked towards the reuse of treated wastewater for forestation. This and other projects served for elaborating the national wastewater reuse strategy,
- "Land & Water Conservation Project" (1992-2001), funded by the World Bank and technically supported by FAO, prepared several studies and technical reports on wastewater issues in Yemen. Its second phase, planned for 2003-2008, will include experiments for recharging treated wastewater in coastal plain areas to prevent seawater intrusion.

MINISTRY OF ELECTRICITY & WATER (MEW)

MEW is responsible for water supply and sanitation services in the cities. Within the ministry, a central corporation for water supply and sanitation was established, then decentralized during the last years in some major cities. The ministry and its communities are responsible for planning and developing water supply and sanitation services, including implementing sewage systems and constructing and operating wastewater treatment plants. The ministry is currently drafting a national sanitation strategy.

MINISTRY OF LOCAL ADMINISTRATION (MLA)

MLA is responsible for water supply and sanitation in rural areas (districts and villages level).

MINISTRY OF TOURISM & ENVIRONMENT (MTE)

MTE, through an Environment Protection Authority (EPA), is responsible for implementation of the Environment Protection Law established in 1995. This Law stipulates that an Environmental Impact Assessment (EIA) be conducted for projects which by their nature are a source of environmental pollution (Environment Protection Law, Article 36). EPA is responsible for monitoring pollution of natural resources in the country.

MINISTRY OF PUBLIC WORKS & URBAN PLANNING (MPWUP)

The ministry is responsible for observing and monitoring drinking water purification stations.

15.8 Issues related to the current practices

Generally, wastewater treatment plants are built in two different areas:

- Coastal Plain areas where most of the treated wastewater is discharged to the sea. Treatment is only secondary in this category.
- Highland areas where landownership constitutes the main problem for large-scale treatment plants. The effluent is discharged to Wadis where farmers are using it without any training or extension services.

There are several problems, starting from the water supply system to the treatment plants, then to the main users who are mainly the farmers:

- Odors and insects are prevailing in some treatment stations,
- Low quality treated wastewater produced from the stations,
- Farmers have no experience to deal with low quality water in agriculture,
- Public health impact and skin diseases among farmers,
- Soil salinity problems,
- Diseases occur in crops irrigated with treated wastewater,

- Animals suffer from some diseases due to direct contact with wastewater.

Institutional problems include:

- High water losses in water supply networks,
- Ineffective management,
- Poor maintenance,
- Low tariffs,
- Untrained staff,
- Frequent power cut-off in some treatment stations,
- Disposal of produced sludge and unwillingness of farmers to use it,
- Hospitals, industrial factories and car washing/lubricant change services are connected to public sewage network with no primary treatment,
- There are no integrated plans for the reuse of treated wastewater due to the low quality of the effluent,
- Poor coordination among the concerned agencies,
- Lack of environment impact assessment during establishment of some treatment plants.

15.9 Recommendations

Institutional and legal aspects are basic for the successful utilization of treated effluents and sludge. It is of high significance to clarify the legal framework and to assign clear mandates and responsibilities within the concerned institutions. Quality standards of the treated effluent and sludge have to be defined/applied as well as regulations and control procedures for monitoring.

The management of water, soil, crop and operational procedures play a crucial role in successful reuse of treated effluent and sludge at the field level. This includes appropriate irrigation methods, leaching, drainage, irrigation scheduling, etc. Crop management and cultural practices (crop restriction, placement of seed, etc.) also have to be developed.

Farmers training on relevant practices, awareness creation at all levels, economic feasibility studies, and clear financing schemes, including operation and maintenance costs, cannot be emphasized enough.

Annex I - Statute of the near east regional network on reuse of treated wastewater

Preamble

The FAO Regional Office for the Near East (RNE) and the WHO Eastern Mediterranean Regional Office (EMRO):

- Fully convinced of the importance of promoting the safe and efficient use of treated wastewater in agriculture as an essential additional source of water, reducing the use of chemical fertilisers, and at the same time safeguarding the environment.
- Conscious of the problems and challenges facing the countries of the Region in implementing water policy related to the use of marginal water in agriculture, especially treated wastewater and its health and environmental hazards.
- Aware of the mutual benefits that could be reaped and shared by all countries, as a result of their technical co-operation in such fields as: the exchange of information and experiences; linkages with other regional and international organisations; as well as research results on the use of advanced technology, and capacity building and training of personnel.
- Recognising the need for information sharing on the above subjects.
- Acknowledging that countries of the Region during several FAO/WHO forums have requested the Regional Inter-Agency Task Force on Land and Water Resources (IATF), spear-headed by the FAO Regional Office for the Near East and WHO to establish a Network on Wastewater reuse in the Region.

Have decided to establish the “The Regional Network on Reuse of Treated Wastewater ” which is to be known by the acronym (RETWAT), and thus shall be governed by the following disposition.

Name

The name of the network shall be “The Regional Network on Reuse of Treated Wastewater ”, hereinafter referred to as the “Network”.

The Region

For the purpose of this Network, the Region, shall result from the union of the FAO/RNE and WHO/EMRO Regions and consist of the following 29 Member Countries: Afghanistan, Algeria, Bahrain, Cyprus, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Kyrgyzstan, Lebanon, Libya, Malta, Mauritania, Morocco, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tajikistan, Tunisia, Turkey, Turkmenistan, United Arab Emirates, and Yemen, in addition to the Palestinian authority.

The Region may be sub-divided into the following five sub-regions:

- Maghreb: Algeria, Libya, Mauritania, Morocco, Tunisia,
- North-eastern Africa: Djibouti, Egypt, Somalia, Sudan,
- Middle East: Cyprus, Iraq, Jordan, Lebanon, Malta, Palestine, Syria, Turkey,
- Arabian Peninsula: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen
- Central Asia: Afghanistan, Iran, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan.

Objectives

The objectives of the Network shall be to foster co-operation among the concerned institutions in the Region particularly the exchange of information and experience among countries of the Region, specifically for:

- Promoting the safe and efficient use of treated wastewater and sludge for environmental protection and public health safety,
- Promoting exchange of information and data on ongoing relevant activities, research, and results achieved, and organizing exchange of visits and study tours among member institutions,
- Establishing and developing regional bibliographic data bases, as well as directories for professionals and institutions in the field of wastewater treatment and reuse,
- Strengthening the training capabilities and capacity building, and encouraging the appropriate training programmes in accordance with identified regional, and national needs and priorities,
- Disseminating information among other institutions/organisations on issues pertinent to the above fields.

Functions/Activities

In pursuance of the above objectives, the Regional Network shall assume the following functions:

- Convene a biennial workshop to discuss the Network's plan, evaluate programmes and review their implementation,
- Organise working sessions and seminars to discuss specific problems or undertake technical studies,
- Initiate alone, or in collaboration with other institutions and organisations, seminars, training courses, or workshops, or other for a,
- Review and assess the current practices in the management and reuse of treated wastewater and make them available to member countries,
- Help to strengthen the national information units and establish a regional database in the field of wastewater treatment and reuse in member countries; Assist in collecting data related to monitoring of the health and environmental impacts of wastewater reuse, in close co-operation with WHO/EMRO,
- Promote joint activities among countries of the Region particularly in the field of training and research.

Membership

There shall be three types of members:

- Country focal points,
- Concerned organizations and individuals,
- Honorary members.

One "focal point" and one alternate focal point shall be designated by the Government of each country of the Region, willing to participate in the Network. The focal point and the alternate focal point in each country of the Region shall be from different national institutions and shall have different fields of expertise (e.g. agriculture and health)

Concerned organizations and individuals are:

- Regional and international institutions and organisations undertaking similar activities and operating in the Region,
- National institutions directly concerned with the objectives of the Network,
- Research centres on land, water, health and environment, operating inside or outside the Region,
- Agricultural research-oriented private sector institutions and non-governmental organisations (NGO's) and natural resources management institutions,

- Other organisations or bodies as may be decided by the Secretariat of the Network,
- Honorary members shall be institutions or individuals from within or outside the Region, which provide moral, material, technical, or financial support to the Network,
- Membership in the Network shall be acquired by submitting an application to the Secretariat of the Network. Admission to membership shall be effective upon notification by the Secretariat.

Resources

The resources of the Network shall consist of:

- Resources devoted by each Member to the implementation of the activities of the Network,
- Grants and donations from individuals, governments, national, regional or international organisations, development banks and others which may be accepted on behalf of the Network by the Secretariat of the Network.

Secretariat of the Network

The Secretariat of the Network shall be entrusted jointly to FAO/RNE and WHO/EMRO, the WHO/EMRO Centre for Environmental Health Activities (CEHA), Amman, Jordan shall serve as clearing house for the Network.

Under the overall supervision of the Interagency Task Force on Water and Soil (IATF), the Joint Secretariat of the Network shall take, within the available resources, all necessary actions to meet the objectives of the Network. The Joint Secretariat shall run the activities of the Network, including for the clearinghouse function, as a Regional Project. Extra budgetary resources shall be sought to that end. The Joint Secretariat shall specifically have the following responsibilities:

- Organise the biannual meeting of the Network, prepare the reports of all meetings of the Network and arrange for their publication, distribution and preservation,
- Organise all kinds of meetings upon the request of IATF,
- Prepare the Network's Programme of Work and propose joint work programmes with other regional and international organisations and ensure co-ordination of all activities among the Members of the Network,
- Manage the above-mentioned Regional Project,
- Organise the Network’s communication and provide documentation services to facilitate easy access to necessary information on wastewater treatment and reuse in the Region.

Annex II - Opening statements

Message from Dr Hussein A Gezairi Regional Director Of WHO, Eastern Mediterranean Region

Dr. Hossein Abouzaid, Regional Adviser, Supportive Environment for Health, WHP/EMRO, delivered the following message on behalf of Dr Gezairi:

Your Excellencies, Distinguished Guests and Participants, Ladies and Gentlemen.

It is a pleasure to welcome you to this Regional Consultation for Launching the Regional Network on Wastewater Reuse being held jointly and in collaboration with the Office for the Near East of the Food and Agriculture Organization of the United Nations. I would like to thank the Government of Jordan for their hospitality and support, and in particular, His Excellency Dr Faleh Al Nasser, Minister of Health, and His Excellency Dr Mahmoud Dewairi, Minister of Agriculture, and their staff for their continuous support, cooperation and assistance.

By the year 2025, almost all countries in the Region will be unable to produce enough food for their populations because of scarce water resources. Disposal and use of untreated wastewater is also causing serious health and environmental problems, including pollution of surface and groundwater. Last month, the first Joint UNEP/WHO Regional Conference on Water Demand Management, Conservation and Pollution Control was held here in Amman. Its deliberations and recommendations highlighted the fact that one of the solutions to the crisis is the reuse of wastewater and greywater to augment supply and reduce pollution. Particularly in agriculture, the reuse of treated wastewater, greywater and drainage water can release fresh water for higher-value use and reduce fertilizer consumption. The cost of treating wastewater for irrigation is significantly less than that of developing many alternative sources of supply.

Human health aspects and environmental quality are closely connected with the use and final disposal of reclaimed water and sludge; health statistics show higher prevalence of the diseases associated with wastewater reuse. There are about one billion cases of intestinal nematode cases in the world each year, mainly in developing countries. The prevalence of intestinal helminth diseases can reach 100 percent in some countries of the Region. As you are all probably aware, in 1989, WHO published guidelines for safe use of wastewater and excreta in agriculture and aquaculture, following an exhaustive consultative process. A process of updating the guidelines has been initiated and a series of background documents are currently in preparation and will be made available for comments.

WHO is endeavoring to build capacity in the field of quality of reused wastewater. The regional programme in the coming biennium in the field of wastewater reuse is aimed at:

- Continuing capacity-building of institutions and training of professionals in the field of wastewater treatment and reuse;
- Building up capacity in institutions in the field of applied research;
- Building up capacity in water quality surveillance and control by training laboratory staff and providing laboratory equipment;
- Disseminating the latest information and know-how on the subject;
- Carrying out applied research of specific regional relevance and seeking feasible solutions to the problems facing the Region in the field of wastewater reuse;
- Publication and arabization of technical reference material related to the subject;
- Providing guidance on application, surveillance and monitoring of wastewater projects and on identification and enumeration of helminth eggs in influent, effluent and sludge; and
- Enhancing collaboration between the concerned regional authorities.

I hope that the launching of the Regional Network on Wastewater Reuse will enhance the transfer of knowledge in this field and strengthen cooperation between countries, which will, in turn, increase the benefits gained from the experience in this field and, ultimately, increase safe use of wastewater and greywater. WHO hopes that each country in the Region will establish a plan that, within 10 years from now, all wastewater produced will be reused in a healthy and environmentally sound manner and will be included in the integrated water and environmental plan of each country. We hope information dissemination will be expanded and that the regional network will work as a clearing centre for regional experience and knowledge. The Regional Office will do its best to support the Regional Network on Wastewater Reuse. WHO is ready to serve as a clearing house in the:

- Health and environmental aspects of wastewater/greywater reuse;
- Guidelines, regulations, codes related to the health aspects;
- Disease surveillance and monitoring related to diseases associated with wastewater reuse;
- Information exchange on wastewater reuse;
- Urbanization of the technical documentation related to wastewater and greywater reuse;
- Dissemination of the latest know-how in the field of wastewater and greywater reuse and enhancement of technical cooperation among the countries.

A number of existing documents, which are in electronic form, can be placed at the immediate disposal of the regional network. These include:

- The WHO guidelines for the safe use of wastewater and excretion in agriculture and aquaculture, in Arabic and English;
- Regional and country profiles on wastewater treatment and reuse;
- Training materials on health aspects of wastewater reuse, and training materials on appropriate wastewater treatment for agricultural reuse;
- Training materials on greywater reuse;
- Guidance on identification and enumeration of helminth eggs in influent, effluent and sludge;
- The list of equipment required to establish a laboratory unit for identification and enumeration of helminth eggs in influent, effluent and sludge.

WHO is ready to support the countries of the Region in carrying out any training or trouble-shooting assessments in the field of wastewater and greywater reuse. WHO is reconfirming its commitment to support the regional network and hopes that this meeting will launch the network on a strong and sustainable basis. I look forward to further cooperation with FAO in ensuring adequate follow-up on this initiative.

I hope the time you spend here in Amman and in CEHA will prove fruitful and informative, and I wish you a pleasant stay in this beautiful city of Amman.

May God bless your endeavors.

Opening Speech by FAO Regional Office for the Near East

Dr Mohamed Bazza, Senior Irrigation and Water Resources Officer, FAO Regional Office for the Near East, delivered the following message, on behalf of Dr Atef Y Bukhari, Assistant Director-General Regional Representative for the Near East.

Your Excellency Dr. Faleh Al-Nasser, Minister of Health,

Your Excellency Dr. Mahmud Duweiry, Minister of Agriculture,

Country Representatives and Participants,

Ladies and gentlemen,

On behalf of Dr. Atif Yahia Bukhari, FAO Assistant-Director General and Regional Representative for the Near East, I would like first to express our sincere thanks and gratitude to the Government of Jordan, represented here by their excellencies the Minister of Health and the Minister of Agriculture, for hosting this important event and providing it with all the support necessary for its smooth execution and success.

The hospitality of Jordan and its support and close cooperation with FAO for similar events and beyond is well acknowledged and it is always a privilege and a pleasure for us to collaborate with this great country and people.

Your Excellencies, ladies and gentlemen,

I am sure you all agree with me that the use of wastewater, particularly that of municipal origin, whether treated or not, is a fact in the Near East Region and elsewhere in developing countries. Although the interest in reusing treated wastewater is comparatively recent in most Near East countries, the concept of using sewage effluent for agriculture is more than 2000 years old. The trend in using intensively this resource will undoubtedly increase in the future, in view of the shortage of fresh water on one hand and the increased pressure on the available amounts on the other.

In the Near East Region, the use of wastewater for agricultural production offers an opportunity to fill part of the water shortage, to alleviate the burden on freshwater for other priority uses and to reduce food deficit. Nonetheless, this advantage can be offset by several threats to human health and the environment, unless wastewater is treated to the required level of standards and handled properly. While the technology and management tools for achieving a minimum of safety to humans and the environment exist, in practice we are still far way from reaching this level of water needs coverage in most countries.

Water resources planners and managers in the region are increasingly concerned with water shortage, devising ways to augment supplies and to manage demand of the available amounts through optimization of their use efficiency. From the strategic viewpoint, treatment and reuse of wastewater is both a supply management and a demand management, as the appropriate use of such non-conventional resource increases the availability of water and, at the same time, prevents decrease of supplies by pollution.

Your Excellencies, ladies and gentlemen,

In nearly forty years of collaboration with several countries of the Near East Region and elsewhere, FAO has provided support and accumulated a high level of experience on wastewater treatment and reuse. This has resulted in creating a substantial level of awareness, building the necessary capacities and raising the issue to decision-makers and investors. The joint collaboration with member states has covered a wide range of activities and programmes such as : pilot and demonstration field projects; strategy formulation and testing; training and institutional strengthening; enhancement of regional cooperation and exchange of experience; elaboration of national standards and quality monitoring programmes; production of adapted documents, including guidelines and manuals, etc….

As a result of these efforts by member states and FAO, as well as other international and regional organizations, the current stand of wastewater treatment and reuse is much better than its status twenty to ten years ago. However while these achievements can be considered as encouraging, we are still far away from reaching the potential offered by these resources, both from the standpoint of safety and that of optimal management and productivity.

In view of such potential resource and the need for additional efforts to reach it, FAO and WHO Member States participating in meetings and other fora on wastewater treatment and reuse, organized by FAO and WHO during the recent years, have recommended the establishment of a joint FAO/WHO Regional Network on Waste Water Reuse in the Near East, to serve as a forum for exchanging experience and enhancing greater cooperation. They further requested FAO and WHO to lead the Inter-Agency Task Force on Land and Water (IATF), for launching the Network. Today, we are very glad to see this recommendation materialize as a first step for joining hands to strengthen regional cooperation between member states on one hand, and with FAO and WHO on the other. I am fully convinced that the synergy created by such cooperation will contribute to properly addressing the issue of wastewater treatment and reuse in a more efficient manner, and assure you of FAO's continued support for achieving success.

While FAO and WHO, in collaboration with the other members of the IATF, will continue to provide their support to the Regional Network, its full ownership remains with its members who, I am certain, will spare no effort to make it operational, active and successful. For this reason, I would like to invite you to study in depth the procedures and working mechanisms of the Network, and to agree on every aspect related to its operation and management.

While launching the Network, you will also be addressing one of the hottest issues facing wastewater treatment and reuse in most, if not all, countries of the Region: the institutional aspect. Here also, it is expected from your honorable meeting to come up with reasonable and feasible recommendations that are likely to lift one of the major constraints and to contribute to the betterment of wastewater management in member states.

Before I close my contribution, I would like to mention that FAO has enjoyed fruitful partnership with its sister organization, WHO, particularly its Regional Office for the Eastern Mediterranean (EMRO) and the Centre for Environmental Health Activities on Health (CEHA), on this and other subjects for several years. I take this opportunity to thank them all for their collaboration and look forward to greater interaction on this and other subjects of common interests to the Region in the future.

Once again, I would like to welcome you for this important Consultation and to thank the Government of Jordan for hosting it. I wish you full success in your deliberations and look forward to your output and follow-up.

Thank you!

Annex III - Programme of the consultation

SUNDAY 11 NOVEMBER 2001

Arrival of Participants & Installation in Hotel

MONDAY 12 NOVEMBER 2001

08.30 - 09.00 Registration

09.00 - 10.00 Opening session

Inaugural speeches by the Host Country and representatives of FAO and WHO

10.00 - 10.30 Coffee break

10.30 - 11.30 keynote paper on Health Aspects of Wastewater Reuse - WHO

11.30 - 12.30 keynote paper on Experience on Wastewater Reuse in the Near East - FAO

12.30 - 14.00 Lunch break

14.00 - 14.30 "Adding a Loop - Experiences in Using Treated Wastewater in the Jordan Valley"

Dr. Andreas Kuck, GTZ

14:30 - 16:30 Presentation of Focal Points' country reports

TUESDAY 13 NOVEMBER 2001

09.00 - 10.00 Presentation on Institutional Aspects of Wastewater - FAO

10.00 - 12.30 Presentation of Focal Points' country reports

12.30 - 14.00 Lunch break

14.00 - 15.00 Presentation of the Regional Network on Wastewater – FAO/WHO

15.00 - 16.30 Discussion of the Network framework

WEDNESDAY 14 NOVEMBER 2001

07.30 - 14.00 Field visit and lunch

14.00 - 15.00 Discussion: Priorities of the region and follow-up activities

15.00 - 17.00 Recommendations and closure

Annex IV - List of participants

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