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The potential of irrigation water for increasing both food production and the living standards of the rural poor has long been recognized. Irrigated agriculture represents only 13% of the world's total arable land, but the value of crop production from irrigated land is 34% of the world's total. This potential is more pronounced in semi-arid and arid areas like the Near East. In this region, the provision of irrigation water is one of the most important factors for increasing agricultural production. The present irrigated area in this region comprises only 30% of the cultivated areas, but production amounts to some 75% of the total agricultural production. In large parts of the region, no crops can be grown without irrigation water.

The irrigation systems in the Near East belong to the oldest in the world. Irrigation has led to considerable and sometimes dramatic increases in agricultural production. It can bring independence from erratic rainfall and thus reliability of production and stable incomes.

On the other hand, past and existing trends in food and agricultural production in the region have led to a situation which, despite noticeable achievements, is fundamentally unsatisfactory. At present, the region is importing more than 50% of its food requirements and the rate of increase in demand for food exceeds the rate of increase in agricultural production. Because aridity is the major constraint for increased agricultural production, most of the countries in the Near East consider irrigation development a prime way of raising agricultural production.

I - National action programmes in the field of irrigation

Until the end of the Second World War, the expansion rate of land and water development in this region was very low. Rapid development started in the 1950s and gained full momentum during the 1960s. Many countries introduced national development plans in which the agricultural sector, and particularly the development of irrigation, was allocated top priority. At present, great efforts are being made in the region to make additional water available. In all large river basins, major surface storage reservoirs have been built or are under construction (Indus, Euphrates, Tigris and Nile).

In other parts of the region (Iran, Afghanistan, Syria, Jordan, Saudi Arabia and north Africa) a number of smaller dams are in different stages of planning or execution. Saudi Arabia, Yemen Arab Republic and the People's Democratic Republic of Yemen are planning to convert the traditional spate irrigation to perennial irrigation by better control of flood water of the seasonal wadis and the use of the groundwater reservoirs in the alluvial plains of these wadis. The larger groundwater basins known so far (Egypt, Sudan, Libya, Saudi Arabia and the Arab Gulf States) are being developed.

This process of rapid agricultural development under irrigation was accompanied by the process of desertification as marked by increasing micro-aridity and declining productivity. In many countries of the region desertification manifestations of waterlogging and salinity on irrigated lands are major problems due to poor management of irrigation water in the conveyance system as well as in the field. Increasing salinity of groundwater and falling water tables due to over pumping is another serious problem. In Saudi Arabia and the Gulf States, for example, the artesian flow of springs and wells is decreasing, water quality is deteriorating and the water level is falling due to increased extraction and perhaps decreased recharge, thus causing sea water intrusion.

The above-mentioned rapid development of irrigated agriculture has resulted in easily accessible water resources, such as river flows and shallow groundwater of good quality, now being almost entirely committed. Hence, the **scarcity of water supplies** to meet the needs of population growth and rapid development in agriculture as well as industry have 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 resources by non-conventional means. The latter includes two programmes, one is for increasing domestic water supply through desalination, and the other is for the treatment of sewage effluent and its use for irrigation purposes.

From the above, it becomes apparent that in arid areas, as is the case with the Near East, recycling of water may have a greater impact on future usable water supply than any of the other technologies aimed for increasing water supply, such as water harvesting, desalting of sea water, weather modification (artificial rain) etc. Treated sewage water can be used for irrigation, industry, recharge of groundwater and, in special cases, properly treated wastewater could be used for municipal supply. With careful planning various industrial and agricultural demands may be met by purified water thereby freeing fresh water for municipal use. In this respect, the reuse of sewage effluent for irrigation purposes seems to be the most promising method.

II - Wastewater use in agriculture

1. General

Human wastes, including sewage effluent, are a widely used resource in many parts of the world. With the introduction of the water-carriage system for domestic wastewater in the middle of the 9th century, many European and North American cities adopted crop irrigation as their means of wastewater disposal. Sewage farms, as they were called, were used in the United Kingdom as early as 1865, the United States (1871), France (1872), Germany (1976), India (1877), Australia (1893) and Mexico (1904). In most of these countries the impetus for sewage farming was river pollution prevention, rather than enhanced crop production: in England the dictum was "sewage to the land, rain to the rivers".

However, as cities grew and the proportion of their population connected to a sewer system increased, the land area required for sewage farming became too great. The practice became less popular and, with the development of modern wastewater treatment processes, such as biofiltration and activated sludge, during the first two decades of this century it disappeared completely in many countries soon after World War I since wastewaters could be readily discharged to surface waters without causing significant pollution. The sewage farms at Werribee (Melbourne, Australia) and Mexico City were notable exceptions to this trend, and they are still in operation some 80 – 90 years after their inception. However, indirect reuse – the use of water from rivers receiving wastewater effluents – occurs throughout the world, and is currently the most common process of using effluents not only for irrigation but also, after appropriate treatment, for potable supplies.

In the past two decades there has been considerable increase in the use of wastewater for crop irrigation (**Table 1**), especially in semi-arid areas of both developed and developing countries. This has occured as a result of several factors:

– the scarcity of alternative water for irrigation;

– the high cost of artificial fertilizers;

– the demonstration that health risks and soil damage are minimal if the necessary precautions are taken;

– the high cost of advanced wastewater treatment plants;

– the socio-cultural acceptance of the practice; and

– the recognition by water resource planners of the value of the practice.

Domestic wastewater is produced by those households which have an in-house, multiple-tap level of water supply service and flush-toilets connected to a sewer system, into which all other household wastewater (sullage) is discharged. In the developing world as a whole, few households produce sewage, because sewerage is too expensive a sanitation technology; the majority produce excreta (nightsoil) and sullage separately. However, in many urban areas sufficient househoulds are connected to a sewer system to make the agricultural use of sewage an attractive economic proposition: crops are both irrigated and fertilized by the water and nutrients in sewage, and at the same time, the wasteful disposal of these scarce resources, which often leads to major environmental pollution, is avoided. With proper management, crop yields are increased and no adverse health effects are induced. In current practice, wastewater irrigation of crops sometimes does lead to an excess of excreta-related disease amongst both farm labourers and consumers, but this is entirely due to the use of inappropriate techniques. It is now possible to design and implement wastewater use schemes that avoid the transmission of excreta-related infections, and thus the existence of potential health risks should no longer be considered sufficient reason not to continue and develop this otherwise very beneficial practice.

Some governments have, understandably, been cautious in actively promoting wastewater use, especially as there has not been until recently either a realistic appraisal of the health risks involved, nor sensible design guidelines for wastewater treatment prior to its use. However, such caution is now shown in practice by those that actually use the wastewater (farmers and market gardeners), and throughout the developing world untreated wastewater is commonly used to irrigate agricultural and horticultural produce.

Indeed, so valuable is the wastewater considered in many areas that sewers are broken into and the wastewater flow diverted to the field. Such a practice, by no means uncommon but of course illegal and causing substantial health risks, clearly demonstrates the perceived advantage of wastewater use. It is doubtful whether such practices can ever be eliminated unless governments develop and promulgate a national strategy for wastewater use. With proper precautions for both health risk minimization and the equitable distribution of wastewater for irrigation, this is the only way in which the potential economic advantage of wastewater use can be maximized, and its actual health risks eliminated.

2. Quantity and Quality of Wastewater

A - Quantity

Wastewater is composed of 99.9% water and 0.1% of other materials (suspended, colloidal and dissolved solids). In arid and semi-arid areas, water resources are so scarce that there is often a major conflict between urban (domestic and industrial) and agricultural demands for water. This conflict can usually only be resolved by the agricultural use of wastewater: the cities must use the fresh water first, and urban wastewater – after proper treatment – used for crop irrigation. If such a sequence of water resource utilization is not followed, both urban and agricultural development may be seriously constrained, with consequent adverse effects on national economic development.

The rate of wastewater generation is usually in the range 80 – 200 litres per person per day, or some 30 – 70 m^3 per person per year. Thus, in semi-arid areas with a water demand of, for example, 2 m^3 per year, one person's wastewater could be used to irrigate 15 – 25 m^2 of land. In other words, 1,000 people will produce enough wastewater to irrigate approximately 1,500–2,500 ha.

B - Nutrients

The suspended, colloidal and dissolved solids present in wastewater contain major plant nutrients (N,P and K) and also trace nutrients (such as Cu, Fe and Zn). Total nitrogen and phosphorus concentrations in raw wastewater are usually in the ranges 10 – 100 mg N/l and 5 – 25 mg P/l, and potassium is in the range 10 – 40 mg K/l. Treated wastewaters will contain less nitrogen and phosphorus, but approximately the same amount of potassium, depending on the treatment process used. For the irrigation rate of 2 m^3 per year commonly required in semi-arid climates, concentrations of 15 and 3 mg/l of total N and total P, respectively, in well-treated domestic wastewater (such as can be expected in the final effluent of a well-designed series of waste stabilization ponds) correspond to annual nitrogen and phosphorus application rates of 300 and 60 kg per ha, respectively. Supplementary fertilizer requirements can thus be reduced, or even eliminated, by wastewater irrigation.

C - Contaminants and toxins

Wastewater, in addition to its beneficial nutrients, also contains contaminants and toxins. The contaminants are the excreted pathogens – disease-causing viruses, bacteria, protozoa and helminths – which are present in varying numbers in all wastewaters. In Europe, for example, domestic wastewater often contains some 10^4 salmonella bacteria per litre; in developing countries pathogen numbers and diversity are much greater.

Wastewater, especially if it contains a significant proportion of industrial effluent, may contain compounds that are toxic to both people and plants. Heavy metals are an obvious example, but boron (derived from synthetic detergents) is an important phytotoxin, especially of citrus crops. Provided that the quality of the wastewater conforms to that recommended by the FAO for irrigation water (Ayers and Westcot, 1984), it may be safely used for crop irrigation. Domestic and normal municipal wastewater are usually of adequate physio-chemical quality for crop irrigation, and it is only necessary to pay particular attention to the boron sensitivity of the irrigated crop.

D - Application rate

The application rate of wastewater to crops is calculated in the same way as for irrigation with freshwater, with due regard to evapo-transpiration demand, leaching requirements and salinity and sodicity control.

III - Plans of some countries in the Near East for the use of sewage effluent for irrigation

1. Egypt

A - Master plan for water resources

Work to formulate a Master Plan for water resources development and use in Egypt was started in 1977. The Ministry of Irrigation, the custodian of water resources in Egypt, in collaboration with UNDP and the World Bank, completed the first phase of this activity in 1981.

The main objective of the Master Plan is to find optimal solutions for developing available water resources. This involves identifying the best use of these resources to achieve the targets of national economic and social plans in order to satisfy the increasing water needs of an expanding population: municipal, industrial, irrigation, hydro-power generation, navigation, aquaculture, environmental and public health protection demands.

One of the main targets of the Master Plan was to conduct comprehensive analyses of all forms of usable water resources, including reuse of wastewater from agricultural drainage, sewage treatment plants and industrial effluents. All possible alternatives were considered to find the most efficient and economically viable solutions. In this respect, the Water Master Plan (WMP) also considered changes in water quality suitable for irrigation as well as the impact on the environmental and public health. Various methods of wastewater treatment were considered, including an assessment of their capital and annual operating and maintenance costs.

B - Water for municipal purposes

Water demand for municipal purposes till the year 2000 was studied, based on the following assumptions:

i) 1976 was considered to be the base year, since it was the year when the latest population census was conducted. Population in 1976 was 36.6 million. The current forecast of population in the year 2000 is about 65.4 million, of which 29.8

million will be in rural areas (46%) and 35.6 million in urban areas (54%). Population was estimated to reach 50 million at the beginning of July 1986.

ii) The average consumption of potable water in rural areas is 72 litres per person per day and for urban areas – 160 l (pd). If water requirements for trades, industry, handicraft and total losses are included, *per capita* urban water consumption will be 213 l/(pd).

iii) Losses of water in the networks will be decreased from 40% to 25%.

iv) All the inhabitants of the main cities of Cairo, Alexandria, Port Said, Ismailia and Suez will be served by sewage networks and the sewage effluents will be properly treated for reuse. 75% of the people of the remaining cities and rural areas will have sewage systems.

On the basis of the above assumptions, the following estimates can be made as shown in **Table 2**.

Capital costs for the municipal water projects are estimated at L.E. 2.9 billion and L.E. 4.2 billion for sanitary drainage projects at 1985 prices.

Annualized costs of producing 1,000 m^3 of treated sanitary drainage are estimated at L.E. 30 to 50, compared to L.E. 5.4 for the Nile system, L.E. 10-30 for agricultural drainage reuse and the maximum cost for desalinized water production at about L.E. 1,000.

The plan for new lands reclamation within the next National five-year plan (1986/87-1991/92) includes five projects of 71,000 feddans (approximately 2.5 feddans equal 1 ha) of sandy soil which will be reclaimed and irrigated with the reuse of greater Cairo sewage effluents after being mixed with fresh water at a 1:1 ratio. Studies are now being carried out for the reclamation and irrigation of about 80,000 feddans of sandy soil in the Western Delta region (El-Bostan) by the reuse of sewage effluents from Alexandria which are at present discharged into the Mediterranean.

Future plan consider the expansion of the existing reuse of wastewater from Cairo and Ismailia sewage works to reclaim and irrigate 100,000 feddans in the Eastern Delta region.

Wastewater from domestic sources contains about 97% water and 3% solids, organic and inorganic materials. These solids are rich in some of the essential nutrients necessary for plant growth such as nitrogen, phosphorus, potassium, boron and zinc. The organic content of the sewage effluents improves the physical and chemical properties of sandy soils by increasing water retention capacity.

Sewage effluents help in minimizing the fixation of some nutrients, thus accelerating their availability for plant uptake. This contributes to a significant increase in the productivity of sandy soils. For example, the Gabel El-Asfar Farm, which consists of 3,000 feddans of sandy soil 25 km north-east of Cairo, has been irrigated since 1911 by wastewater from Cairo treatment plants (primary sedimentation in exposed basins) and has been producing successfully citrus, date palm and pecan nuts.

Crops chosen for cultivation by using sewage effluents should be those which cannot be contaminated by effluents. They include wood trees, palm trees, citrus, pomegranates, castor beans, olives and field crops like lupines and beans.

Scientific research has a big role to play in developing the reuse of wastewater for irrigation. Several studies are now being conducted in Egypt to detect changes in the physical and chemical properties of soil by successive use of sewage effluents. Other studies are attempting to identify the most appropriate irrigation method for the re-use of wastewater. A third category of research is to study the effect of sewage effluents on legumes growth under mineral fertilisation and rhizobia inoculation.

C - Water quality control

The Law No. 48 of 1982 concerns the protection of the Nile and its waterways from pollution and its regulations are issued by the Minister of Irrigation Decree No. 8/1983. This law prohibits the discharge or disposal of solid, liquid or gaseous wastes from commercial, industrial or touristic facilities, or from river units, sewage effluents and other discharges, into the waterways, unless a licence has been obtained from the Ministry of Irrigation under the conditions and in accordance with the standard regulations specified by the regulations.

2. Jordan

A - Introduction

Jordan is a country with limited water resources. The average annual precipitation ranges from 50 – 600 mm/year. Precipitation exceeding 600 mm/year occurs mainly in rocky and steep mountainous areas, where only a small percentage percolates to the water table. Pervious desert areas are relatively flat and receive the least rainfall.

It has been estimated by the Water Authority of Jordan that the available annual surface water and groundwater of the kingdom totals 1,100 MCM. Projected demands for these resources for various purposes for the 1986 – 2000 period are summarized in **Table 3**.

From the above table, it is evident that irrigation will use about 70% of the total demand. If future domestic and industrial water demands are to be met, given the existing surface and groundwater sources, treated effluent will have to become a major new source of irrigation water.

B - Existing regulations for reuse of water in Jordan

There are as yet no specific guidelines in Jordan for treated effluent reuse, but there are some regulations in Martial Law No. 2/1982 which limit agricultural use of wastewater to silviculture, fruit trees, fodder and vegetables which are cooked before consumption. The law also empowers the Ministries of Agriculture and Health with some enforcement responsibilities.

C - Existing reuse

There are as yet no planned direct wastewater effluent reuse, even though indirect reuse of wastewater effluent is taking place. At present, four treatment plants are in operation in Amman, Salt, Jerash and Aqaba, discharging a total of 74,500 m^3/day. In Amman and Jerash, the treated wastewater effluents are discharged in the Wadis where they mix with surface flow and then reach the King Talal Dam (KTD) from where water is used for unrestricted irrigation. Present live storage at KTD is 48 MCM, nearly 50% of which is supplied from the As-Samara waste stabilization ponds.

At Salt, the effluent is discharged to Wadi Shuieb which flows into the Shuieb Dam, where it is then used for unrestricted irrigation. During dry weather, effluent from the treatment works of Amman and Jerash are the base flow for streams in the wadis. These treatment plant effluents are used by farmers along the banks of wadis for restricted irrigation. Recharge to the aquifer also takes place through the wadi beds. In Aqaba, the present primary treated effluent is discharged to the sea.

It has been estimated that actual aquifer recharge in the vicinity of Amman and Zarqa is of the order of 5 MCM per year. For the As-Samra treatment plant, the total quantity of water recharged through seepage was about 1.6 MCM from September 1985 to July 1986.

D - Potential volume of wastewater for reuse

During the last few years, the sewerage network in Jordan has been expanding rapidly. During the next five years, all cities and larger villages will be served by a central sewerage system, covering 65% of the total population of the country. The As-Samra Waste Stabilization Ponds (WSP) System was commissioned in May of 1985 and by 1986 was receiving about 57,000 cubic meters per day of domestic wastewater and sewerage discharged from the metropolitan area of greater Amman. The site for the ponds is about 40 km northeast of Amman and can handle up to 110,000 cubic meters per day.

The wastewater treatment plants which will be established by 1995 will have a total flow of about 80,000 m^3/day (about 65 MCM per year). Not all of this wastewater can be used for irrigation since wastewater flows are relatively uniform, whereas irrigation requirements vary widely, depending upon crop types and seasonal demands. Effluent from waste stabilization ponds, such as those of the Amman City treatment plant, will be reduced by 10% due to evaporation. A conservative estimate led to the conclusion that about 30,000 ha can be irrigated with the above effluent.

E - Qualities of the treated sewage effluent

The quality of the treated sewage effluent is normally related to the quality of the potable water supply. The chemical composition of the municipal water supply of the major population centres in the country, if used for irrigation and with good management, should cause neither salinity nor alkalinity hazards. However, effluent from domestic wastes and industrial refuse is likely to have increased nitrogen, chlorine, sulphate and heavy metal contents.

The chemical analyses of treated effluents from four existing operational plants – Khirbet As-Samra, Salt, Jerash and Aqaba – indicate that the salinity of the sewage effluent is slight to moderate (0.7 to 3.0 ds/m). With this quality of water, a full-yield potential of most crops could be obtained. However, care must be taken to achieve the required leaching fraction in order to maintain soil salinity within the tolerance of the crops. Analyses of the data indicate that with good water management, the use of treated sewage water in Jordan for irrigation will present no serious problem as far as salinity, alkalinity and toxicity are concerned.

F - Planned reuse

In the interest of water conservation and to prevent groundwater contamination, it was decided to reuse wastewater as near as possible to the sites where it is produced. Thus, it is the current policy of the Water Authority of Jordan to use the wastewater effluents near the treatment plant sites. In addition, all new treatment plant project designs should have reuse components. In Aqaba, for example, all water will be used to develop a forest of palm trees and make a garden for the city. In Madaba, a portion of the water will be used to irrigate trees.

In the As-Samra treatment plant, the contract for the project called for the planting of over 19,000 trees. In addition, the Water Authority has completed planting a total of 500,000 apple, olive, poplar, eucalyptus and acacia trees. These trees were irrigated by about 2% of the available effluent. The bulk of this effluent is released to a nearby wadi from where it eventually discharges to the reservoir of the King Talal Dam, which provides irrigation water to the Jordan Valley.

3. Kuwait

Suitable water resources for agricultural development in Kuwait are very limited indeed. Consequently, the availability of irrigation water at a reasonable cost is one of the most important factors to be considered for the development of agriculture. Desalinated seawater used in houses is rather expensive for direct use for irrigation. Hence, it was decided to reuse wastewater. Untreated sewage effluent has been used to irrigate forest trees far away from inhabited areas for a long time.

Until the late 1970s, agriculture in Kuwait was severely limited. The total cropped area in 1976 amounted to only 732 ha. The country relied heavily on food imports and the imports of both fresh and dried alfalfa were considered unnecessarily high. In 1975 a 900 ha farm was established for the purpose of utilizing tertiary treated sewage effluent for the production of forage crops, mainly alfalfa, as cattle feed. At present (1986) the whole farm is under cultivation, producing alfalfa (more than 70% of the area) peppers, onions, potatoes and other crops using sideroll sprinkler irrigation.

In 1985 a new area of 700 ha was added to this farm using the same source of irrigation water and irrigation method, making the total area 1,600 ha. About 27 million m^3/year of treated effluent are currently being used, which will rise to 125 million m^3/year by the year 2010, constituting one of the most ambitious schemes for agricultural water reuse in the Middle East.

4. Saudi Arabia

A - Introduction

The Kingdom of Saudi Arabia, being an arid country, lacks perennial rivers. Groundwater constitutes the main source of the natural water supply of which agricultural irrigation consumes a major share. The rainfall in the Kingdom is low and therefore recharge of the deep sedimentary aquifers is mostly insignificant. Because of extraction of groundwater to meet the demand in various sectors, the non-renewable aquifers are showing signs of significant water level decline, and wastewater effluent can supplement these demands to a certain degree in non-domestic sectors.

The Kingdom's policy is to utilize all available treated municipal wastewater in a most beneficial manner for several purposes, among which the agricultural sector is afforded top priority. The importance of reclaimed wastewater is due to the great need for new water resources to meet the increasing water demands for agriculture and landscape irrigation, for industrial abstraction and for possible recharging of aquifers.

B - Utilization of treated wastewater in Saudi Arabia

The utilization of treated wastewater is presently estimated at 100 million cubic meters per year and by 1990 it is anticipated that the utilization of this reclaimed wastewater will be about 368 MCM per year (see **Table 4**). Numerous projects have been completed or are planned for the utilization of treated wastewater in the Kingdom. Sites at which wastewater is presently utilized or planned include Jubail, Medinah, Jeddah and Qassim. In Riyadh several projects are completed or planned. At the new campus for King Saud University the treated wastewater is used for power plant cooling water (3,000 m^3/d) and for landscape irrigation (1,000 m^3/d) on the campus. The Ministry of Foreign Affairs (Housing Project) utilizes treated wastewater for a drip irrigation scheme for its extensive landscape gardening. This wastewater treatment plant has a current flow of about 450 m^3/day, with an ultimate capacity of 1,135 m^3/day. The new King Khalid International Airport uses treated wastewater for landscape irrigation. The New Diplomatic Quarter and King Abdulaziz City for Science and Technology will use their treated wastewater for landscape irrigation when completed.

One of the largest projects presently underway in Saudi Arabia is the utilization of effluent from the Riyadh Wastewater Treatment Plant (RWWTP) for industrial purposes, landscape irrigation and agricultural irrigation.

At present, the Riyadh Wastewater Treatment Plant (RWWTP) treats over 250,000 m^3/day of wastewater. For over five years this treated final effluent has been used by the Petromin Oil Refinery in Riyadh and for over four years for agricultural irrigation at Dirab and Dariyah. Since 1981, the Petromin Oil Refinery has been utilizing 20,000 m^3/day of this treated effluent to produce three grades of water, one for utility water and process water for crude oil desalting and thirdly, the highest quality water, for boiler feed water. The balance of the Riyadh treated wastewater is then available for agricultural irrigation at Dirab and Dariyah.

In 1985 the 1,000 mm diameter, 55 km transmission line to Dirab carried 92,000 m^3 of treated wastewater per day, while the 30 mm diameter, 50 km transmission line to Dariyah carried 70,400 m^3/day for agricultural purposes.

It is expected that about 368m^3 and 674m^3 per year of reclaimed wastewater will be available in Saudi Arabia by the years 1990 and 2000 respectively. This is, however, a relatively small quantity compared to the water demand for agriculture and industry shown in **Table 4**.

C - Summary

In the Kingdom of Saudi Arabia, wastewater effluent has much potential usage and the Ministry of Agriculture and Water would like to utilize, as a matter of principle, every possible drop of the treated wastewater effluent in the most efficient and beneficial manner. The main emphasis at present is on irrigated agriculture and partly on industry. However, this does not preclude its utilization in landscape and green belt areas, afforestation and recreational parks.

In order to safeguard public health and to keep the environment clean, wastewater regulations have been proposed which require tertiary level treatment of the municipal effluent for unrestricted irrigational use.

Wastewater effluent is currently being pumped from Riyadh to farms in Dirab and Dariyab (about 160,000 m^3/day) and a significant quantity (about 20,000 m^3/day) is supplied to the Riyadh refinery. However, plans are now being made to supply and utilize another 80,000 m^3/day in Ammariyah near Riyadh and the quantity to the Riyadh refinery would be doubled. In the Riyadh area alone, about 4,000 ha is expected to be brought under wastewater irrigation.

Specialized consultants are currently studying the possibility of reusing the treated wastewater in the Madinah and Qassim areas. When these plans are implemented, in the year 2000, both the Madinah and Qassim areas will be utilizing about 140,000 m^3/day and 100,000 m^3/day, respectively. The total area to be brought under wastewater irrigation will be 820 ha in Qassim and 3,100 ha in the Madinah area.

5. United Arab Emirates

An extensive scheme for using treated effluent to irrigate municipal areas and for landscaping has existed in Abu Dhabi since 1976. The system was designed to provide eventually 70 million m^3/year of treated effluent from a population of 660,000. The treated sewage irrigation systems operate under low pressure to avoid spray irrigation being carried by the wind into populated areas.

The population of Al-Ain was over 150,000 in 1984 and is expected to reach 250,000 by the year 2000. The city has a sewage treatment plant designed to produce treated effluent suitable for selected irrigation purposes. Irrigation of crops that are likely to be eaten raw or partially cooked is not allowed. The surplus activated sludge is aerobically treated and dried on open beds. Sludge cake is then taken into the nearby composting plant for production of compost to provide humus for plants at roadsides and limited locations.

The existing sewage treatment plant in Dubay is not adequately equipped for the production of treated effluent of good quality, and the product is at present used only to water some parks by means of water hoses. Therefore, a new sewage treatment plant has been designed and construction work is underway. According to the design, the plant will produce increasing quantities of treated effluents, reaching its ultimate capacity of 200,000 m^3/day by the year 2005. There are also plans for a sludge treatment plant producing digested, conditioned and dried sludge suitable without restriction for agricultural and market garden users.

IV - Public health, cost and policy considerations in wastewater reuse

The most critical elements in treatment and use of sewage effluent in irrigation are public health and cost.

The wastewater must be treated and used in such a way that its content will not be hazardous to human beings or the environment. Pipes transporting treated effluent and potable water must be clearly differentiated to avoid drinking by human beings and animals. Bodily contacts by agricultural workers with the treated wastewater and exposure to aerosol drift must be minimized to reduce short-term and long-term effects of any remaining contaminants.

In order to protect public health, the effluent should either be properly treated before irrigation application, or its use should normally be restricted only to certain crops so that improperly treated wastewater will not come into contact with any part of a plant used for human food or animal feed.

In the Arab Gulf States wastewater reuse in irrigation has been practiced, though on a limited scale, for a number of decades. However, so far no epidemics or serious infections have been reported due to the limited use of the treated effluent and the safety precautions undertaken.

Although the technology for wastewater reclamation is available, economic considerations limit its use to special locations or particular purposes. As demands for existing resources in water-scarce areas become greater, use of treated effluent gains more acceptance for certain uses and releases natural sources of water for potable supplies.

Wastewater reuse becomes particularly attractive when it is planned in conjunction with environmental protection. Pollution control measures are becoming stricter all over the world and such regulations are also being set up in the Arab Gulf States. Therefore, an increasing number of sewage treatment plants are being established where the effluent is treated to certain levels that will prevent pollution and will allow some direct use or, after additional treatment, almost any use. Where treatment plants are planned for environmental protection, the marginal cost of advanced treatment and distribution system is only 25% of the total cost of the scheme.

In the Near East region, it appears that even if the whole project cost is charged to treated wastewater, the unit cost is still quite reasonable. The available unit cost estimates for treated wastewater in the region, together with the cost of desalinization, the other prominent non-conventional source, indicate that, in the early 1980s the cost of complete treatment of municipal wastewater for reuse did not exceed $0.40 per m^3 while the cost of desalinated water was not less than $0.70 per m^3 and reached $2.5 per m^3 in some countries of the region. This is a very favourable unit cost compared with that of desalinization of seawater, though the latter produces a drinking water quality product. Desalinization of brackish water by reverse osmosis-type membrane processes can produce fresh supplies at prices comparable with wastewater treatment, but an unlimited supply of brackish water and easy brine disposal are necessary, which are not always available.

However, as complementary alternatives, cost comparison of desalinated water and treated sewage effluent gives a fair indication of the potential wastewater reuse in the region.

However, the economic analysis of reuse projects is not always the determining factor. In many arid lands, such as in the Gulf countries, there is a desire to develop and maintain public green areas for amenity purposes. This type of utilization, as a policy, is often adopted as the sole use so that beautifying the environment creates another competitor for the limited water resource of the country.

In order to initiate any development in the wastewater reuse field, policies must be established ahead of other activities. After the assessment of the need for this practice, the policies and options can be laid out according to the requirements and characteristics of the country. In planning for reuse, it is essential to consider the source of the effluent and the purposes for which it will be used after treatment. Priority in policies must be given to public health environmental considerations due to the potential hazards associated with this practice.

Policies for wastewater reuse must be backed up by adequate legislation clearly establishing the measures governing the collection, treatment and scope for various government agencies. Furthermore, the institutional set-up for wastewater should be adequate to provide a framework for the allocation, use, quality and health and safety aspects and there should be continuous coordination and cooperation between the agencies concerned. Personnel at different levels must undergo thorough training to make wastewater reuse projects a success by maintaining safe and economic operations. Research is usually needed for developing improved management techniques and institutional arrangements for increased efficiency in the use of treated effluents for various purposes. Other research work may be required on ways to reduce the cost of treatment processes and to find answers to possible health hazards.

V - Summary and Conclusions

The limited water supplies in many countries of the Near East, one of the world's most extensive arid zones, has led to growing interest in the rational use and conservation of this resource, essential to human needs and economic growth. Augmenting the conventional water supplies by non-conventional water development techniques has been applied in the Near East, and is gaining wider support. However, it has been limited in application and only recently have plans been formulated for large-scale development of this non-conventional source of supply. In part, lack of knowledge of the long-term effects of use of treated effluent for various purposes, and also of the availability of other sources of water have prevented wider application. However, with the development of new technology and rising cost of water developed by conventional methods or by desalinization, there is a new opportunity in the field of wastewater reuse.

Sewage irrigation ensures the reuse of resources and achieves the best treatment of municipal wastewater. Efforts should be focussed on maximizing the benefits and on minimizing any detrimental effects on people or the environment. Sewage irrigation involves complex interactions and it is difficult to assess its long-term impact. Appropriate management is of primary importance and requires experience for the realization of its full benefits; routine monitoring is also essential. Further research should be carried out by a cooperative team composed of specialists from different scientific disciplines. Nothing short of a long-term research programme can provide the answers to questions on the effects of sewage irrigation on the environment, and on agricultural productivity.

A policy for wastewater reuse must be clearly established prior to any development activity in this field. An obvious basis for such a policy is to limit the use of treated effluent for purposes excluding potable uses, which would avoid or minimize the risk of human contact. The necessary legislation must be enacted to promote and control related activities and to create an institutional set-up. This latter should be adequate to provide a framework for the allocation, use, quality and health and safety aspects, and there should be continuous coordination and cooperation between the agencies concerned. Thorough training of personnel is essential to make wastewater reuse a successful practice by maintaining safe and economic operations. Training is recommended at different levels. Research work on wastewater re-use in the Near East should be directed towards finding ways to reduce cost and to reduce health hazards, largely virological.

One of the most important considerations in water reuse, besides health, is cost. In the early 1980s, the unit cost of treated municipal effluent in the region was established as $0.40/m^3. In planning for augmentation of the present water resources for industrial, agricultural and non-domestic municipal purposes, if the cost of the additional supplies is estimated to exceed the above figure (after updating for inflation), then wastewater reuse should be seriously considered as a possible alternative, especially if there is a population centre nearby with over 100,000 people and with an existing wastewater collection system.

For groundwater recharge and prevention of saline water intrusion to the aquifer, the treated wastewater should be close to drinking water standards. The period of natural purification during percolation through the soil layers may not be long enough and should not be counted on without adequate research work. If the groundwater becomes contaminated it is a mammoth, if not impossible, task to purify it again, incurring tremendous cost. This application of wastewater is used for watering gardens or irrigating crops and not directly for recharge, there will still be some percolation. Therefore, the quality of the treated wastewater should be very good to start with and contamination with pesticides should not pose a problem. Furthermore, continuous percolation of irrigation water may cause a steady rise in the groundwater levels, leading to accumulation of salts and other undesirable factors if the groundwater level is not controlled.

In general, one may conclude that wastewater re-use has a promising future in the Near East region and that its countries should start to adopt this practice as a serious alternative to conventional sources of water, if they have not already done so. Agricultural use of treated sewage effluent stands out as the largest potential use since it involves large quantities covering vast areas. Under strict controls, as mentioned above, wastewater reuse in irrigation will certainly continue to gain importance as the limited water resources of the region become insufficient to meet the requirements of all competing demands.

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Table 1: Global data on wastewater irrigation

Country		Area	Country		Area
Argentina, Mendoza		3,700	Australia, Melbourne		10,000
Bahrain, Tubli		800	Chile, Santiago		16,000
China, all cities		1,330,000	Germany (Braunschweig)		3,000
			(other cities)		25,000
India, Calcutta		12,500	Israel, several cities		8,800
(all cities)		73,000	Kuwait, several cities	(a)	12,000
Mexico, Mexico city		90,000	Peru, Lima	(a)	6,800
(all cities)	(a)	250,000	Saudi Arabia, Riyadh		2,850
South Africa, Johann.		1,800	Sudan, Khartoum		2,800
Tunisia, Tunis	(a)	4,450	United States (Ariz.)		2,800
(other cities)	(a)	2,900	(Bakersfield, CA)		2,250
USA (Fresno, CA)		1,625	USA (S. Rosa, CA)		1,600
USA (Lubbock, TX)		3,000	USA (Muskegon, Mi)		2,200

(a) includes planned expansion of existing reuse
Source: Bartone and Arlosoroff (1987)

Table 2: Domestic water budget for Egypt, 1980 - 2000
Water requirements in billion m^3/yr

	1980	1985	2000
Requirements	2.25	2.42	4.62
Consumption	1.10	1.08	1.80
Sanitary drainage discharges	1.15	1.34	2.82
Gross loss from the system	1.78	1.87	3.47

Table 3: Water demand for Jordan, 1986 - 2000
(million m^3)

Year	Industrial & domestic	Irrigation	Total
1986	120	401	521
1990	187	537	724
2000	268	606	874

Table 4: Summary of water demands, 1978, 1990, and 2000

Demand million m^3 /year

Item	1978	1990	2000
Urban networks			
Water supplied	196	979	1 643
Treatment losses	2	49	164
Sub-total	198	1,028	1,807
Agriculture	3,171	3,684	5,119
Independent industries	18	74	182
Other domestic use	113	54	27
Out-of-town parks	--	35	106
Sub-total	3,500	4,875	7,241
Wastewater available for reuse	35	368	674
Total	3,465	4,507	6,567