Prospects of Efficient Wastewater Management and Water Reuse in Jordan

Country Study

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I. The Country

1. Introduction:

Most of the Middle East region is considered as arid or semi-arid due to the scarcity of rainfall. This hard nature forced the inhabitants of these areas to move during the year looking for water and grass to maintain the life of their animals. In consequence, the movement of the inhabitants through the desert and their instability had negative effect on their socio-economic and cultural standards of living. To overcome this situation it is of prime importance to develop the water resources in such areas where it forms the backbone for any development in the region.

Despite the harsh climatic conditions we believe that water resources can be developed in the area using old and new techniques. This will inevitably form a solid base to develop the Wastewater treatment technologies to provide extra water recourses.

2. Country Profile

The following represent a brief description of the Hashemite Kingdom of Jordan:

Area: 89.900 km^2, (Fig. 1).

Population (1994 statistics) = 5.5 million

Rate of growth: 3.2% per year.

Population projection: 6.8 million by 2010 and 9 million by 2020.

Economic sectors: Agriculture ≈ 10%, industry 22%, services 68%.

Labor force: Agriculture ≈ 11%, industry 27%, services 62%.

Literacy rate: ≈ 80%.

Export: Potash, phosphate, fertilizers, small industrial products, manpower, vegetables and fruits.

Imports: Fuel, food (grain, meat, etc...), vehicles, heavy machinery, industrial plants, wood, iron, paper ... etc.

Energy: Only very limited gas fields, large oil shale deposits that are not yet mined.

Finally it shall be mentioned here that the food production in Jordan covers around 50% of the country's needs.

3. Topography

The country consists of different distinctive topographic units trending in a general north-south direction. These units seem to be dictated by a major geologic event which incorporates rifting along the Jordan Valley, Dead Sea, Wadi Araba, Red Sea line, which, during the last few tens of millions of years led to the formation of the rift valley along the same line with the corresponding highlands on both sides sloping in Jordan to the steppe in the east.

The rift valley forms the western part of the country. It trends in a general south-north direction from the Gulf of Aqaba through the Dead Sea to Lake Tiberias. The elevation of the bottom of the valley ranges from sea level in Aqaba at the shores of the Red Sea to around 240m ASL at a distance of 80km to the north, and from there it drops gradually to about 400km BSL at the present shores of the Dead Sea and further to around 750m BSL at the bottom of the Dead Sea, (Emery and Neev 1967). To the north of the Dead Sea the floor elevation rises gradually to around 210m BSL at the shores of Lake Tiberias. This rift valley, with a length of 375km, is about 30km wide in the area of Wadi Araba and narrows to around 4km in the Lake Tiberias area.

The highlands east of the Jordan rift valley rise to elevations of more than 1000m ASL in the north at Ajlun and Balqa and to more than 1200m ASL in Shoubak and Ras El Naqab areas. The width of this zone ranges from 30 to 50kms and extends from the Yarmouk River in the north to Aqaba in the south. These elevations drop gradually to the plateau in the east, but more sharply to the rift valley in the west. The mountains forming the highlands consist mainly of sedimentary rocks with deeply incised wadies draining in a westerly direction.

The steppe or plateau of Jordan developed at the eastern toes of the highlands with elevations of drainage areas ranging from 1000m ASL in the south to 700m in the northeast. The deepest part of this plateau lies at an elevation of 500m ASL; Azraq Oasis. The plateau is a peneplain with hills and weakly incised wadis, but generally a smooth topography.

Surface water, if not captured by westerly draining wadies, discharges into desert playas or qaas forming extended shallow lakes in winter and dry mud flats in summer.

The northeastern part of the country "the pan handle" is a flat plateau with a very smooth topography, which rises from 500m in Azraq area to about 900m at the Jordan-Iraq borders. It is interrupted by volcanic mountains, which rise to about 150m above the plateau level. The southern desert forms also a flat area intersected by partly deep incised wadis. The topography rises in its southwestern parts to more than 1500m ASL (Aqaba Mountains).

The most southern part of the plateau, which lies to the south of the Ras El Naqab escarpment, is considered a different topographic unit, although it belongs to the same plateau. This is because it is separated from the plateau by the prominent topographic feature; the escarpment, because it drains to the Dead Sea and because of its steep topography dictated by a different geology consisting of sandstones and a granitic basement complex. The elevation of the area is around 900m ASL, with a north-south width of around 100kms. This part of the country is sometimes referred to as the southern desert. It is strongly dissected by wadis with very rough topography in the western part and smooth topography in the eastern part.

4. Climate

Jordan can be classified as a semi-desert area. Only the highlands, with a width of around 30 km and a length of some 300 km, enjoy a Mediterranean type climate. Temperatures in the Jordan Valley, Wadi Araba and Aqaba can rise in summer to 45°C with an annual average of 24°C. In winter the temperature in this area reaches a few degrees above zero. Frost is a seldom event.

Along the highlands the climate is relatively temperate; cold and wet in winter with temperatures reaching a few degrees below zero during the night, to hot and dry in summer with temperatures reaching 35°C at noon, but with a relative humidity of 15-30%, which makes the heat more acceptable. During the hot summer, temperatures at night drop to less than 20°C and cause dew to form.

The plateau; the eastern and southern deserts are hot in summer and cold in winter. The temperature may reach more than 40°C during summer days and drop in winter to a few degrees below zero, especially during the night. Also here, the relative humidity is low. In winter it is generally around 50-60%, and in summer it sometimes drops to 15%. The low relative humidity throughout most of the year makes the hot summer days more tolerable and the cold winter days more severe.

5. Precipitation

Precipitation (ppt) in Jordan falls normally in the form of rainfall. Snowfall occurs generally once or twice a year over the highlands. The rainy season extends from October to April, with the peak of precipitation taking place during January and February. These peaks become less pronounced the scarcer the rainfall an area receives (Fig. 2).

The highest rates of ppt fall over the highlands of Ajlun, Balqa, Karak and Shoubak which receive long-term annual averages of 600, 550, 350 and 300mm respectively. To the east of these highlands, and more strongly to the west, ppt decreases drastically (Fig. 3), e.g., (it decreases from an average of 600mm/year in Ajlun to 250mm/year in the Jordan Valley) within a distance of 10kms and a difference in altitude of 1200m. The decrease in easterly direction is twice to three times slower than due west; e.g. (from 300mm/year in Shoubak to 50mm/year some 30kms east of the town).

Generally, the following facts can be stated about precipitation in Jordan:

- The average annual amount of water falling over Jordan's territories is 7200 MCM increasing to 12000 MCM in a wet year and decreasing to 6000 MCM in a dry year.

- Only around 1.3% of Jordan's area receives an average annual ppt of more than 500 mm, only 1.8% between 300 and 500 mm, 3.8% between 200 and 300 mm, 12.5% between 100 and 200 mm and the rest, 80.6%, receive less than 100mm/year.

The above is still an inadequate picture of Jordan's water situation. But knowing that only about 3% of the total area of the country receives an average annual amount of ppt exceeding 300mm may illustrate the situation better. Worth mentioning is that 300 mm/year of ppt is the least amount needed to grow wheat in dry farming areas under the prevailing climatic conditions. In addition, 83% of the total amount of ppt occurs in areas receiving less than 300mm/year, which means that only 17% of ppt can be used in dry farming. The rest of 83% requires certain technologies to be made available for the different uses. An exception, is range land, where 300 - 150mm/year of ppt may be adequate. A part of ppt water flows in wadis, and it either collects in dams or in desert playas. Another part infiltrates and joins the groundwater resources of the country. The dry climate, the atmospheric dust and the low intensity of precipitation affects also the quality of precipitation water, generally reflected in increasing salt contents.

6. Evaporation:

The climatic conditions in Jordan do not only affect the amount and distribution of precipitation, but they also impact strongly the potentials of evaporation which range from about 1600mm/year in the extreme northwestern edge of the country to more than 4000mm/year in the Aqaba and Azraq areas. Along the rift valley the potential evaporation increases from a minimum of 2000mm/year in the north, to some 2500mm/year in the Dead Sea and to more than 4000mm/year in Aqaba. These rates are 5 to 80 times the average amounts of ppt these areas receive.

Potential evaporation rates of the plateau areas increase in easterly and southerly directions from an average of 3000mm/year at the eastern toes of the highlands to around 4000 in the center of the plateau. The southern rates are 3500 to 4400 mm/year. Potential evaporation rates of the plateau and southern desert are 12 to 100 times the amount of ppt falling over these areas. The high evaporation potential all over the country makes precipitation, especially in the eastern and southern parts of the country, ineffective because ppt-water readily evaporates, leaving soils deprived of their moisture content and hence, not allowing for the development of plants. The high evaporation rates and the low precipitation amounts lead generally to salt concentrations of the water which increases the salinity of infiltrating, and in dam-stored water.

II. Water Resources

A. Surface Water Resources

Jordan does not possess rivers in the world-wide known scale, except the Jordan River which used to discharge around 1400 MCM/year into the Dead Sea before the development of the water resources in its catchment. Even this river is a very small source compared with international rivers like the Nile or Euphrates, because its total annual discharge amounts to only 1.5% of the former and 4.3% of the latter. Other surface water resources in Jordan are found in the Yarmouk and Zerka rivers and in wadis like Karak, Mujib, Hasa, Yabis and El-Arab, in addition to flood flow wadis in the different parts of the country.

1. The Jordan River Area:

1·1· Jordan River

The surface catchment area of the Jordan River measures 18.194 Km², of which 2833 Km² lie upstream of the Lake Tiberias outlet. The eastern catchment area, downstream of Tiberias, measures 13.027 Km², and the western, 2344 Km². The headwaters of the Jordan River originate from three main springs: Hasbani in Lebanon; Dan in Israel; and Banias in Syrian territory occupied by Israel. The three streams join in Israel to form the Upper Jordan River. The surface catchments of the springs do not alone account for the large quantities of water discharged from them; therefore, their underground watershed must extend further to the north, northeast and eventually north-west, beyond the surface catchments and into Syria and Lebanon.

The total discharge of the Jordan into the Dead Sea -- prior to the implementation of the different water projects in Jordan, Syria and Israel -- was 1370 MCM/year. This amount has now declined to a mere 250-300 MCM/year -- mostly as irrigation return flow, inter-catchment runoffs or saline spring discharges. Saline springs in the immediate surroundings of Lake Tiberias and at its bottom are channeled downstream of Tiberias into the headwaters of the Lower Jordan River.

The discharge of the Yarmouk River into the Jordan River was around 400 MCM/year prior to the use of the water by the different riparian. In the last few years, this amount has gradually declined to small discharges, only as a result of large floods, which cannot be accommodated by the existing extraction facilities.

The other wadies and springs on both sides of the Jordan Valley are dammed or captured by other constructions. Water remains runoffs due to rains over areas downstream of water collection constructions, return flows or saltwater discharges which then joins the river.

1·2· Yarmouk River

The Yarmouk flows at the borders of Syria and Jordan and joins the Jordan River in an area partly occupied by Israel. The river drains both flood and base flows of Jordanian and Syrian territories. The total catchment area of the river measures 6790 Km², of which 1160 Km² lie within Jordan upstream of Adasiya and the rest within Syria and in the Jordan River area downstream of Adasiya.

Along its course from the foothills of Jabel Druz to its confluence with the Jordan River, many important wadies and creaks in terms of water quantities join the Yarmouk like Harir, Allan and Raqqad in Syria and Shallala and El Humra in Jordan.

The catchment area of the Yarmouk River is agrarian, with small types of industries located in the main towns in Jordan and Syria. The small effluents of two waste water treatment plants (stabilization ponds) reach the river during floods. Also, the leachates of El-Ukheider solid waste disposal sites directly reach the river course on days when their liquid loads exceed evaporation and infiltration potentials.

The average annual rainfall over the catchment area is 372 mm/yr. In the northwestern parts of the catchment, which border on the Hermon Mountains, precipitation increases to an average of more than 1000 mm/yr. It decreases to 250 mm in the southeastern corner of the catchment. The discharge of the Yarmouk River in Adasiya during the forties, fifties and beginning of the sixties of this century is given in the literature to equal 467 MCM/yr. (1927-1964). More recent measurements, although masked by unknown usage of the riparians, indicate a decline in the river discharge, conditioned by: increasing extractions from the groundwater in the catchment area, which leads to declining base flow; and decreasing precipitation in the last five decades (Salameh 1993).

The river flow during the period 1950 to 1976 averaged 400 MCM/year. Recent measurements of flows and estimates of riparian extractions indicate an average total discharge of around 360 MCM/year.

The water quality of the Yarmouk River reflects the land uses within the catchment area, which are still restricted to rainfed and some irrigated agriculture. Pollution parameters can be measured in the discharged water especially during low flows.

1·3· Zerka River

This Zerka River is the second largest in Jordan in the area of its drainage basin and its mean annual discharge. The catchment area measures 4025 Km^2 and extends from the foothills of Jabel Druz to the Jordan Riveer

The river consists of two main branches; Wadi Dhuleil, which drains the eastern part of the catchment area, and Seel-Zerka, which drains the western part. Both meet at Sukhna to form the Zerka River. Naturally, the eastern branch drains only flood flows as a result of precipitation, whereas the western branch drains flood and base flows. The most densely populated area in Jordan which is the catchment area of Zerka River comprises around 65% of the country's population and more than 80% of its industries.

The urban waste waters are generally sewage and treated in different waste water treatment plants to varying degrees. Also, most industries located in the catchment area treat their waste waters before discharge into the surface water system. In addition, solid waste disposal sites are located within the catchment area. Their leachates reach surface and groundwater resources causing local pollution and threatening to contaminate the aquifers.

The catchment area of Zerka River receives an average annual precipitation of 237mm. The eastern catchment, which comprises around half of the total catchment area, receives an average amount of precipitation of 182 mm/year. The middle part between the eastern catchment and the western highlands receives an average of 243 mm/year. The western catchment, comprising the highlands and the Jordan Valley area, receives an average of 397 mm/year.

Precipitation over the highlands may be in the form of snow; in the eastern part of the catchment it is generally rainfall. The highest amount of precipitation falls over the highlands of Salt and Amman. In an average year it reaches 550mm; it increases in a wet year to 750mm and decreases in a dry year to 350mm. In the most eastern part of the catchment the average precipitation in a normal year is 80mm, increasing to 150mm in a wet year and decreasing to 50mm in a dry year.

The potential evaporation ranges from 1600mm/year along the western highlands, to 2000mm/year in the eastern part of the catchment. Meanwhile, there is not enough water to satisfy the needs of the evaporation force of the climate, which is far less during the winter months than during the summer months -- a fact which allows precipitation water to infiltrate and recharge the ground water during the rainy season.

The average annual discharge of Zerka River at Deir Alla for the years 1950 to 1976 was 64.88 MCM/year. After 1976, the natural system of the river was changed by different factors such as construction of the King Talal Dam on the Zerka River (1977), importing water into the catchment area for domestic and industrial uses and discharging their effluents to the Zerka River system.Such activities controlled the river flow and increased its discharge on the one hand, and negatively affected its water quality on the other.

The King Talal Dam on the Zerka River was commissioned in 1977 with a total capacity of 56 MCM, which was raised in 1988 to 89 MCM. The natural flow of the Zerka River can not fill the dam in an average year. But since increasing amounts of water were imported into the catchment area from other areas to satisfy the increasing demand, effluents reaching the dam are expected to fill it almost yearly.

At present, the domestic and industrial waste water contributions to the inflows of the river are estimated at 50% of its discharge. The water quality of the river changes dramatically between summer and winter. In winter, flood water constitutes most of the river discharge, and although it contains domestic refuse and waste water, the quality during floods remains acceptable for most uses.

1·4· Wadi El-Arab

The catchment area of Wadi El-Arab borders the Yarmouk catchment and measures 267km².The average amount of precipitation ranges from 500mm over the highlands west of Irbid, to 350mm in the Jordan Valley (North Shuna). The potential evaporation ranges from 2000mm/year in the northwest, to 2400mm/year in the southwest of the catchment.The average discharge of the wadi is around 28 MCM/year equally distributed between flood and base flows.

A dam was constructed on Wadi El-Arab in 1987, with a total capacity of 20 MCM to collect flood and base flows for use in irrigation in the Jordan Valley area. Since its completion the dam was filled by waters originating within its catchment, only in the very wet year of 1991/92. In the other years, water was pumped from King Abdallah Canal during floods to increase the stored amount of water in the dam for use during the dry season. The catchment area is agrarian, but Irbid City is expanding westward into the catchment, which may put increasing pressure on the quality of the water collected in the dam.

The wastewater treatment plant for Irbid City was constructed in the upper reaches of Wadi El-Arab. And although the effluent of the treatment plant is piped to bypass the dam, floodwaters still enter the treatment plant and wash its contents and the wastes along Wadi El-Arab into the dam reservoir, negatively affecting its water quality. Drilling of wells and pumping of water upstream of the dam resulted in groundwater level declines and hence the ceasing of groundwater natural discharges. In the last ten years the drop in the ground water levels in Wadi El-Arab wells exceeded 25m -- a fact which questions the future reliability and durability of this drinking water source supplying Irbid governorate.

The water collected in the dam is generally of good quality and can be used for different purposes. When used for domestic purposes, conventional treatment of filtration and chlorination is sufficient. Of some concern is the relatively high trihalomethane potential, especially the formation of bromoform during the dry season upon water chlorination.

1·5· Wadi Ziqlab

The catchment area of Wadi Ziqlab measures 106km² and extends from the Jordan Valley eastwards into the highlands. Its eastern parts receive an average amount of precipitation of 500mm/year, whereas its western parts in the Jordan Valley receive only 300mm/year.

The potential evaporation ranges from 2050mm/year in the west to 2200mm/year in the east. Various springs issue along Wadi Ziqlab with a total discharge of some 5 MCM/year. In addition Wadi Ziqlab drains another 5 MCM/year of floodwater.

A dam was constructed in Wadi Ziqlab with a total capacity of 4.3 MCM in 1966, and with the aim of using its water for irrigation in the Jordan Valley area. The catchment area is agrarian with natural forests and very little population.

1·6· Wadi Shueib

Wadi Shueib drains an area of approximately 180km² lying to the west of Suweileh region at elevations of 1200m down to below sea level. Precipitation over the catchment area partly falls in the form of snow in its eastern parts and ranges on average from 500mm/year in Suweileh and Salt mountains to 150mm in the Jordan Valley area.

The potential evaporation ranges from 2700mm/year in the eastern parts to 2500 mm/year in the western parts. The average natural flow of the Wadi is 1.8 MCM/year as flood flow and 3.9 MCM/year as base flow. In addition the effluent of the Salt town wastewater treatment plant, one of the best functioning in Jordan, is discharged into the wadi.

In the catchment area different towns and villages, like Salt, Fuheis and Mahis, discharge their treated and untreated wastes along the wadi and its tributaries.A dam was constructed in Wadi Shueib in 1968 with a capacity of 2.3 MCM and with the aim of using its water for irrigation in the Jordan Valley. In addition to base and flood flows, this dam now receives irrigation return flows and the effluent of the well-functioning Salt town waste water treatment plant.

1·7· Wadi Kafrain

Wadi Kafrain drains an area west of Amman with an extent of 189 km² lying at elevations ranging from 1200m ASL down to areas lying below sea level in the Jordan Valley. Precipitation in the eastern parts of the catchment, averaging 550mm/year, may fall in the form of snow, whereas in the western parts the average reaches only 150mm/year and falls completely in the form of rain.

The potential evaporation ranges from 2700mm/year in the eastern parts to 2400 mm/year in the western parts. The average discharge of Wadi Kafrain is 6.4 MCM/year, consisting of 1.6 MCM/year flood flow and 4.8 MCM/year base flow. In addition, Wadi Sir and Hussein Medical Centre wastewater treatment plants end up in Wadi Kafrain or its tributary wadies. In the catchment area different towns and villages, like Wadi Sir and Naur, discharge their wastes along Wadi Kafrain or its tributaries.

In 1968, a dam was constructed at the entrance of Wadi Kafrain into the Jordan Valley with a capacity of 3.8 MCM. This dam now serves as a storage facility for irrigating downstream lands and for recharging the underlying aquifer. It is now being raised to a capacity of 7 MCM.

At present, the dam receives in addition to flood and base flows, irrigation return flows, treated and untreated waste waters and groundwater discharged from artesian wells drilled into the lower pressurized aquifer. Hence, it receives good quality water from springs and artesian wells, medium quality water of floods mixed with treated and untreated waste waters and bad quality water from irrigation return flows and waste water treatment plants.

1·8· Other Wadies Discharging into the Jordan Valley

These wadies are not dammed and include Yabis, Kufranja, Jurum, Rajib, Hisban and other small catchments. The rainfall on these areas ranges from 150 mm/year up to 550 mm/year, with potential evaporation rates ranging from 2100 mm/year to 2700 mm/year.

The base flow of these wadis is used in irrigation along their courses and partly at the foothills on the Jordan Valley. Flood flows still reach the Jordan River lower stem.

2. Dead Sea Wadies

2·1· Wadi Zerka Ma'in

The catchment area of Wadi Zerka Ma'in measures 272 km² and ranges in elevation from 1000m ASL to 400m BSL. Precipitation over the catchment falls in the form of rain and ranges from 350 mm/year in the highlands surrounding Madaba city to 100 mm/year at the shores of the Dead Sea. The potential evaporation rates range from 2900 mm/year in the east to 2400 mm/year in the west at the shores of the Dead Sea.

Zerka Ma'in discharges directly into the Dead Sea an average amount of 23 MCM/year, of which only around 3 MCM/year as flood flows and 20 MCM/year as base flow. The base flow consists of thermal water issuing from tens of springs ranging in discharge from seepage size to 150 l/s.

2·2· Wadi Mujib (including Hidan)

The catchment area of Wadi Mujib measures 6.596 km² and ranges in elevation from 1100m BSL. Precipitation over the catchment area falls in the form of rain and seldom in the form of snow. It ranges from 350 mm/year along the mountain highlands to 100mm/year at the shores of the Dead Sea.

The potential evaporation in this catchment ranges from 2450 mm/year at the shores of the Dead Sea to 3500 mm/year in the eastern part of the catchment. Wadi Mujib downstream of the confluence of Wadi Hidan discharges an average amount of 83 MCM/year directly into the Dead Sea. Half of the river flow consists of base flow and the other half of flood flows.

The lower reaches of the wadi system contribute with an average base flow of around 30 MCM/year of mostly lightly mineralized water issuing from the sandstone aquifer complex. The salinity of some springs resembles those of Zerka Ma'in, containing around 2000 mg/l of dissolved salts.

The catchment area is sparsely inhabited, with moderate agricultural activity and almost no industry. Therefore, water pollution is not a major issue in Wadi Mujib area.

2·3· Wadi El-Karak

The catchment area of Wadi El-Karak measures 190 km² and lies at elevations ranging from 1000m ASL to 400m BSL. The average precipitation falling over the catchment area ranges between 350 mm/year in the high mountains and 100 mm/year along the shores of the Dead Sea. The potential evaporation ranges from 2600 mm/year at the shores of the Dead Sea up to 3100 mm/year along the highlands.

The catchment of Wadi El-Karak is a moderately inhabited and agrarian area. It includes the city of Karak and numerous towns and villages. Karak city possesses a waste water treatment plant the effluent of which discharges into Wadi Karak. As in the case of other Dead Sea wadis, the lower reaches of Wadi El-Karak are rich in springs and water seepage issuing from the sandstone aquifers. The average discharge of Wadi El-Karak is around 18 MCM/year, of which 15 MCM/year issue as base flow. The base flow is generally used in irrigation along the intermediate reaches of the wadi.

2·4· Wadi Hasa

The catchment area of Wadi Hasa lies to the southeast of the Dead Sea, but the water flowing in Wadi Hasa discharges directly into the Dead Sea, hence, it is considered one of the Dead Sea catchment areas and measures 2520 km² and is the second largest among the Dead Sea catchments after Mujib.

Precipitation over the area ranges from 300 mm/year along the highlands down to 100mm/year in the Dead Sea area and 50mm/year over the eastern parts of the catchment. Precipitation over the highlands sometimes falls in the form of snow.The potential evaporation rates range from 2800 mm/year in the Dead Sea area up to 3900 mm/year in the eastern parts of the catchment.

The average discharge of Wadi El-Hasa is around 34 MCM/year. Only about 2 MCM/year flow as floods, and the rest consists of groundwater discharges along the lower reaches of the wadi. Like the other catchments of the Dead Sea, the groundwater discharged along the lower reaches consists partly of mineralized thermal water.The catchment area is sparsely populated, with no industries and very low agricultural activities. Therefore, it is not expected that water pollution has taken place.

2·5· Wadies between the Major Dead Sea Catchments

Different small areas between the major Dead Sea catchments discharge directly into the Dead Sea. These areas between Wadi Hisban and Zerka Ma'in, Zerka Ma'in and Mujib, Mujib and Karak and Karak and Hasa measure a total of 972 km², with a total discharge of around 30 MCM/year. This discharge comes almost completely from groundwater issuing along the lower reaches of the wadies as thermal water.

3. Wadi Araba Catchments

Wadi Araba itself is not a base level for either surface or groundwater. Both discharge either to the Dead Sea or to the Red Sea. The northern part of Wadi Araba discharges into the Dead Sea and the southern one into the Red Sea via the Gulf of Aqaba.

3·1· The Northern Wadi Araba Catchment

The northern Wadi Araba catchment extends for about 100 km from the Dead Sea shore southward, with a width of 25 to 30 km and a total area of 2938 km². Precipitation falls in the form of rainfall, except on the highlands where it may fall in the form of snow. The average long term precipitation is 300 mm/year over the mountains and 100 mm/year in Wadi Araba area. The potential evaporation ranges from 2800 mm/year at the southern shores of the Dead Sea to 3500 mm/year in the southeastern parts of the catchment.

Different wadies drain the catchment into Wadi Araba. The major ones are Wadi Khuneizir, Wadi Fidan and Wadi Buweirida, with average discharge of about 11, 4, 5.5 and 3 MCM/year respectively. The major part of discharge comes from the base flow of the wadis. In addition to the major wadis, numerous small ones drain the area. The overall total discharge of all the northern wadis into Wadi Araba is 26 MCM/year.The flood flows, which reach Wadi Araba infiltrate rapidly into the course-grained alluvium deposits building the bottom of the wadi. They seldom directly reach the Dead Sea. But the infiltrated water flows in a northerly direction to reach the Dead Sea as seepage or submarine springs.

The catchment area is sparsely populated. The main centers are Tafilah and Shoubak which are devoid of industries. Agriculture is practiced in the highlands, where rain fed crops are produced along the wadi courses and in Wadi Araba, where the base flows of wadis and pumped groundwater are used for irrigation. The area still possesses a certain potential for developing agriculture and for improving the efficiency of irrigation projects.

The domestic wastewater of Tafilah is treated in a wastewater treatment plant, and the effluent is discharged along Wadi Fifa. The amount of effluent is very small (a few hundred cubic meters daily) and it infiltrates along the wadi and discharges with the groundwater issuing along the lower reaches of Wadi Fifa or it joins the groundwater in Wadi Araba.The total groundwater throughput of northern Wadi Araba into the Dead Sea is calculated to average 22 MCM/year (Abu Zirr, 1989).

3·2· The Southern Wadi Araba Catchment

The area extends around 75 km north of the Gulf of Aqaba, with a maximum E-W width of 30 km. The total catchment area measures 1278 km² with an average precipitation of 150 mm/year in the northeastern parts and less than 50 mm/year in the southern parts and Aqaba area. The potential evaporation rates range from 3300 mm/year in the north to 4100 mm/year in the southern part.The area is barren, with very low population density (less than 1 person/km²). Also, the type of climate and aridity do not support life and do not allow urbanization.

The total water discharge from the eastern wadis into the area is estimated at 1 MCM/year, indicating the very low potentialities of the area. The throughput of southern Wadi Araba into the Red Sea is around 10 MCM/year. This groundwater originates as an aquifer to aquifer discharge coming from the eastern highlands. At the southern end of Wadi Araba, a few kilometers from the Gulf of Aqaba, a flowless water treatment plant was constructed to serve Aqaba city.

4. Wadi Yutum Catchment

Wadi Yutum catchment drains an extensive area in southwest Jordan, east of Aqaba into the Red Sea. The extent of the catchment is 4.400 km². Precipitation over the area falls in the form of rainfall and ranges from 150 mm/year in the highlands to less than 50 mm/year in the central and eastern parts of the catchment area. The potential evaporation is very high and ranges from 3400 mm/year in the western parts up to 3800 mm/year in the eastern and southern parts.

Since the area is flat, precipitation water infiltrates into the barren rocks, mostly consisting of sandstones and weathered rocks. There are no groundwater discharges in the area, and the surface water forms as floods resulting from intense precipitation. But even that is a very small amount of 1.5 MCM/year compared with the extent of the catchment area.

5. Jafr Basin Catchment

Jafr Basin is an exitless depression in southern Jordan, with a catchment area of 12.200 km². It is a flat area bordering the highlands in the west. The average precipitation ranges from 200 mm/year at the foot of the highlands to 30 mm/year in the middle and eastern parts of the catchment. The potential evaporation ranges from 3300 mm/year in the western parts of the catchment to 4000 mm/year in the center of the depression.

The total discharge of the catchment is around 15 MCM/year, of which 10 MCM/year flow as floods into the Jafr depression, where they either evaporate or infiltrate into the ground down there. The base flow, in the form of spring discharge, is totally used in irrigation.

The catchment area is very sparsely populated, with Ma'an and Shoubak as major urban centers. Agriculture has been developed along the foothills of the mountains in the west by extracting groundwater. The main industry in the area is a cement factory located in the northwestern edge of the catchment.

6. Azraq Basin Catchment

The Azraq Basin is an exitless depression in the eastern plateau of Jordan. The bottom of the basin lies at an altitude of 500m ASL. The drainage basin measures 11.600 km² and extends in the north beyond the borders of Jordan.

Precipitation falls in the form of rain and ranges from 300 mm/year over the Jabel Druz southern slopes to less than 50 mm/year in the Azraq depression itself. The average precipitation over the area is 90 mm/year. The potential evaporation ranges from 3300 mm/year in the northern parts of the catchment to 4000 mm/year in the central and eastern parts.

The total discharge into the basin is around 27 MCM/year, of which 15 MCM/year issue as groundwater from different springs in the Azraq Oasis itself. Surface water comes as floods from wadis pouring into the depression as a result of precipitation events over the catchment. Few dispersed urban centers and industries are found in the catchment area.

7. Hammad Basin Catchment

Hammad Basin is a very large, flat plateau extending in four countries: Jordan, Syria, Iraq and Saudi Arabia. In Jordan, the area measures 19.270 km.

Precipitation over the area ranges from 150 mm/year to 50 mm/year, with potential evaporation rates of 3800 mm/year. Since the area is flat, different surface water collection sites (playas) developed. As a result of precipitation, during the rainy season hundreds of flat areas fill with up to two meters of water, which either evaporate or infiltrate to the underlying aquifers and flow very slowly to ultimate base levels like Sirhan depression, the Dead Sea or the Euphrates area. What remains in the playas after evaporation are salty silts waiting for the next flood .The amount of surface runoff is relatively small and averages 5 MCM/year, whereas the groundwater, which forms in the area, averages around 10 MCM/year.

B. Groundwater

1. Groundwater Aquifers

The groundwater aquifers of Jordan are divided into three main complexes, (Fig.).

- Deep Sandstone Aquifer Complex.
- Upper Cretaceous Aquifer Complex.
- Shallow Aquifer Complex.

1.1. Deep Sandstone Aquifer Complex:

This complex forms one unit in southern Jordan. To the north, gradually thick limestones and marls separate it into two aquifer systems which, nonetheless, remain hydraulically interconnected.

A. Disi Group Aquifer (Paleozoic):

This is the oldest, and in the north, the deepest water bearing sediment sequence in Jordan consisting of sandstones and quartzites. It crops out only in the southern part of Jordan and along Wadi Araba - Dead Sea Rift Valley. It underlies the entire area of Jordan. The southern part of the complex forms the fresh water aquifer of the upper Wadi Yutum - Disi-Mudawwara area.

The main flow of the groundwater in this system is directed towards the northeast. Only in the southern parts a groundwater divide in the Rum area separates a small southern region where the groundwater moves towards the west and south.

B. Kurnub and Zerka Group of Jurrassic-Lower Cretaceous Age:

This is also a sandstone aquifer underlying the area of Jordan and overlying the Disi group aquifer. It crops out along the lower Zerka River basin and along the escarpment of the Dead Sea, Wadi Araba and Disi region.

Wells drilled in this fine-grained sandstone aquifer have fairly good yields. Direct recharge, however, is limited to small outcrop areas. The groundwater in this aquifer, aside from the recharge areas, is mineralized. The Kurnub - Zerka aquifer system is being exploited mainly in the lower Zerka River catchment and in the Baq'a areas. The direction of groundwater flow in this aquifer system is towards the northeast in the southern part of Jordan, towards the west in central Jordan and towards the southwest in northern Jordan (Salameh and Udluft, 1985). The sandstone aquifer complex (Disi and Zerka/Kurnub) is interconnected through the Khreim group and is regarded as one basal aquifer and hydraulic complex.

1.2. Upper Cretaceous Hydraulic Complex:

This complex consists of an alternating sequence of limestones, dolomites, marlstones and chert beds. The total thickness in central Jordan is about 700m. The limestone and dolomite units form excellent aquifers.The lower portions of this sequence (A1/2), consisting of about 200m of marls and limestone, possess in some areas relatively high permeabilities and form a potential aquifer. An aquitard (A3) consisting of about 80m of marl and shale overlies the A1/2 and separates it from the overlying A4 aquifer. The latter consists of pure semicrystalline karstic limestones and hence it has very high permeability and porosity. The A4 aquifer crops out along the highlands and is recharged there. To the east this aquifer is confined by the overlying aquitard consisting of marls and limestones (A5/6).

The A5/6 aquitard is overlain by the most important aquifer of the sequence; namely the Massive Silicified Sandy Units A7-B2, which consists of limestones, chert-limestones, sandy limestones and marly limestones. It crops out along the highland and is being recharged there. To the east, like the A4 aquifer, it goes over in a confined aquifer, overlain by layers of marls.

The whole aquifer complex is overlain in the eastern desert by a thick marly layer (B3), forming a competent confining bed. Therefore, in some locations, flowing artesian wells are drilled into this aquifer. The groundwater flow in this complex is directed from the recharge mounds in the eastern highlands, partly to the western escarpment within the faulted blocks and mainly to the east, where it discharges along deeply incised wadis or flows further eastwards. Along its way to the east, a part of the water seeps to the underlying sandstone aquifer complex, and the other part appears in Azraq and Sirhan basins as spring discharges.

1.3. Shallow Aquifers Hydraulic Complex:

It consists of two main systems:

A. Basalt Aquifer:

Basalts extend from the Syrian Jabel Druz area southward to the Azraq and Wadi Dhuleil region, forming a good aquifer of significant hydrogeological importance. The recharge to this aquifer system is provided by precipitation in the elevated area of Jabel Druz. From there the groundwater moves radially to all directions. Geological structures favored the formation of three main discharge zones namely, the upper Yarmouk River basin, the Wadi Zerka basin and the Azraq basin.

B. Sedimentary Rocks & Alluvial Deposits of Tertiary and Quaternary Ages:

These rocks form local aquifers overlying partly the previously mentioned aquifer complexes or are separated from them by aquitards. They are distributed all over the country, but are mainly concentrated in the eastern desert, Wadi Araba - Jordan Valley, Jafr Basin and the Yarmouk River area.

Recharge takes place directly into these aquifers themselves or via the underlying basalt aquifer, as in the case of the Azraq basin, or from the surrounding aquifers, like the cases of the Jordan and Wadi Araba valleys. The groundwater flow in this system, in the eastern desert, is directed radially towards the Azraq oasis and towards El-Jafr from the west and south of the Jafr basin.The groundwater flow in the main valley fills depends on the underground conditions. But it mainly takes place from the escarpments into the valley deposits.

2. Groundwater Basins in Jordan:

Groundwater basins or groundwater balance areas are those areas which could be separated and defined to include appropriate and regionally important aquifer systems. The groundwater divides are either aquifer limits or important and relevant geomorphologic or geologic features.

Groundwater basins in Jordan (Fig.) are also separated according to the same criteria, with some of these basins recharge and discharge taking place within the same basin. In most basins more than one aquifer complex is present and hence, any definition of groundwater basins should refer to a certain aquifer system and not necessarily to all aquifer systems underlying the basins.

The National Water Master Plan of Jordan (NWMP. 1977) defined the groundwater basins in Jordan. In this work Jafr is subdivided into Jafr and Disi-Mudawwara:

1. Yarmouk basin.
2. Northern escarpment to the Jordan Valley.
3. Jordan Valley floor.
4. Zerka River Basin.
5. Central escarpment to the Dead Sea.
6. West Bank.
7. Escarpment to Wadi Araba.
8. Red Sea basin.
9. Jafr basin.
10. Azraq basin.
11. Sirhan basin.
12. Wadi Hammad basin.
13. Disi-Mudawwara.

2.1. Groundwater in the Yarmouk basin and the northern part of the Jordan Valley escarpment:

The groundwater in the Yarmouk River basin is found in the B2/A7 aquifer at depths of less than 200m in the highlands. The groundwater flow is directed towards the Jordan Valley area. The geologic formations, which overlie the B2/A7, consist of marly layers and form aquicludes dipping with increasing angles towards the Yarmouk and Jordan rivers. This configuration results in confining conditions with piezometric heads measuring tens of meters above the ground surface along the mountain slopes of the Jordan Valley. Mukheiba wells at the slopes to the Yarmouk River and Wadi El-Arab wells in Wadi El-Arab, upstream of the dam, tap the B2/A7 aquifer and discharge artesian water.

The recharge to the aquifer takes place in the highlands of Irbid and Ajlun and further to the northeast beyond Jordan’s territories.The deeper lying aquifers of A4 and Kurnub release some water to the B2/A7 in an upward movement, through the overlying aquicludes because their piezometric heads are higher than those of the B2/A7 (El-Nasser 1991).El-Nasser (1991) calculated a recharge to this aquifer of 127 MCM/year, with base and spring flows of 100 MCM/year. In this figure the groundwater resources extending to Wadi Yabis, Wadi Jurum, Wadi El-Arab and the Yarmouk River are included.

Present day artificial extractions of 73 MCM/year indicate that the aquifer is being over-pumped by around 56 MCM/year. In the National Water Master Plan of Jordan (NWMP, 1977), the renewable groundwater amount, which does not appear as base flow is calculated to be 23 MCM/year. The Water Authority of Jordan gives an estimate of 47 MCM/year of available groundwater for the area. The quality of the water in the unconfined portion of the aquifer is suitable for the different uses.

In the confined portion of the aquifer higher temperatures and pressures result in the dissolution of minerals, which add more salts to the water. Upon release of pressure the water suffers from chemical disequilibrium and it hence requires purification to be made suitable for domestic uses.

The dissolution of uranium minerals and its disintegration, together with the daughter elements, results in high concentrations of radon gas in the discharged water, making its treatment a conditional necessity for domestic use. The water of the Mukheiba and Wadi El-Arab wells requires chemical treatment, because it is in chemical disequilibrium with the ability to precipitate carbonates in the supply system and water use facilities. Irbid governorate water network has been suffering from this shortcoming since 1986 because Wadi Arab well water reached this network.

These analyses indicate that the water quality in the unconfined portions of the aquifer (Nuayma and Yarmouk University wells) is suitable for all uses, although some signs of pollution are becoming more evident in the increasing concentrations of nitrates and phosphates. The high radon concentrations in Mukeiba and Wadi El-Arab wells make the water treatment essential to rid drinking water of this carcinogenic agent.

2.2. Southern Part of the Jordan Valley Escarpment:

The groundwater in this area is found in two aquifer systems; the Upper Cretaceous limestone system and the Lower Cretaceous sandstone system. Conditioned by the geology and morphology of the area, the groundwater table of the limestone aquifers is not continuous, and the groundwater is mainly found in blocks which may extend for a few kilometers in length and width and are separated from each other by faults or other unconformities. The general groundwater flow is directed towards the Jordan Valley and discharges there, either as springs or seepages, or flows laterally to the lower lying areas and enters the recent deposits occupying the Jordan Valley floor.Recharge to the aquifers takes place along the highlands of Amman and Balqa (Salt) area.

The amount of available, renewable groundwater, which does not appear as base flow is estimated at 10 MCM/year.The Lower lying aquifer, the Kurnub sandstone contains confined mineralized water. Wells drilled in Kafrain, Rama and Wadi Hisban areas produce artesian water with salinities up to a few thousand ppm.

Naturally the water in this aquifer flows upwards through the recent sediment cover to the earth surface and discharges along the lower reaches of the Jordan River side wadis.The flowing wells drilled into this aquifer, which produce mineralized thermal water, are not used and are not controlled. Therefore, they are draining and depleting the aquifer, which will certainly result in depriving the overlying Upper Cretaceous aquifers of their support system and hence lead to a continuous drop in their groundwater levels.

The unused water discharges of these flowing wells should be stopped as a conservation measure of the groundwater resources of the country. The water of the Upper Cretaceous aquifers is of good quality and is suitable for different uses. But, since the catchment area is continuously becoming more urbanized, some signs of groundwater pollution are becoming evident. (Hisban and Wadi Sir Springs). The groundwater found in the Lower Cretaceous aquifer is mineralized, thermal and artesian. It discharges CO_2, H_2S and radon gases in addition to its high iron contents which form a scale upon the water coming into contact with the atmospheric air.

In its natural state the groundwater of this aquifer can only be used to irrigate salt-tolerant crops. For any other use it should either be mixed with less saline water or be desalted.

2.3. Jordan Valley Floor Area:

The aquifer along the Jordan Valley floor consists of alluvial fans and other recent sediments inter-fingering with the salty, clayey deposits of the ancestors of the Dead Sea, like the Lisan Lake, which tens of thousands of years ago, extended northwards beyond the present shores of Lake Tiberias (Horowitz 1971). The groundwater flow is directed from the mountain foothills to the Jordan River course.

Recharge to this area takes place through lateral flows from aquifers extending to the east of the mountain foothills. Some direct infiltration takes place from precipitation water over the area where soil profiles are thin and rocks are porous and permeable.

Deep groundwater mainly in the Lower Cretaceous aquifer is salty and under artesian conditions, and it seeps upwards through the recent sediments to the surface, forming saline springs (Wadi Mallaha). The amount of available groundwater in this area ranges from 18-20 MCM/year (WAJ 1991, NWMP 1977). The water quality in the northern Jordan Valley area is generally good and suitable for irrigation; in certain parts it is even suitable for drinking purposes. To the south, the water salinity increases due to the presence of saline formations and due to irrigation return flows. In certain parts there the water salinity goes up to a few ten thousand parts per million (Wadi Mallaha).

Locally, alluvial fans contain water with an excellent quality for all uses. The extensions of these fans towards the Jordan River contain increasingly brackish and salty water as a result of irrigation return flows and salty formation influences.

2.4. Amman Zerka Area:

Two main aquifers underline this area, namely, the deep A4 and the shallow complex consisting of B2/A7 or A7 along or B2/A7 together with wadi fills and basalts. But the main aquifer consists of the A7 limestones. As in the Surface Water section, the Amman Zerka area can be divided into two parts; an eastern part extending to the northeast of Wadi Zerka and a western part extending to the west of Wadi Zerka. This division is important because of the different groundwater flow systems prevailing in the area. Wadi Zerka and Zerka River form the effluent stream of the area's groundwater. Groundwater originating in the eastern part flows in a westerly direction, and that origination in the western highlands of Amman and its surroundings flows in an easterly direction. At the longitude of the Zerka River, in its south-north course, both groundwater currents converge and discharge in the form of springs.

The renewable groundwater amounts in the area average 88 MCM/year. Around 35 MCM/year return to the surface as base flow along the Zerka River, and the remaining 53 are pumped through wells distributed over the basin. Over-pumping is already taking place along Wadi Zerka and in the eastern part of the area, such as in Dhuleil and Khalidiya subareas.

Recharge to the eastern parts of the area comes from precipitation falling over that area and partly from Jabel Druz. Floodwaters flowing within the area contribute to the groundwater recharge. Irrigation activities, especially in Dhuleil area, result in irrigation return flows, which infiltrate back to the groundwater body underlying the entire area. Recharge to the western part takes place along the highlands of Amman and its surroundings and along the wadi courses which discharge floodwater. Return flows of domestic water used in houses and for commercial purposes form a non-negligible part of recharge.

In the Amman-Zerka area, leaking water supply networks and sewerage systems contribute also to the groundwater stock of the area. Irrigation, industrial and domestic return flows contributions to the groundwater amount to about 40 MCM/year. Industrial effluent infiltration can be estimated at 5 MCM/year, whereas domestic cesspools leak around 25 MCM/year, and irrigation return flows contribute an average of around 10 MCM/year.

The natural water system of the Amman-Zerka area is now highly disturbed by pumping water into the area. An annual average of about 65 MCM/year is brought into the area from outside and used there. This fact is continuously bringing the water system of the area out of balance. In some parts of the area; along Wadi Dhuleil for example, a rise in the groundwater levels is registered since 1985, whereas in Dhuleil area the contrary is taking place. This is because of the infiltration of semi-treated waste water in the first case and over-pumping in the latter. Both badly reflect on the groundwater quality.

For Amman-Rusaifa area it is estimated that 30% of the naturally and artificially discharged water is recycled water, returning from leaking pipes, cesspools and other uncontrolled systems. In Dhuleil area, return flows amount to several million cubic meters per year, which, during the last two decades, have gradually led to aquifer salinization. Along the course of Wadi Dhuleil downstream of Khirbet-es-Samra, a rise in the groundwater levels of up to 25m has been registered during the last 10 years, caused by the infiltrating treated and untreated waste waters from Khirbet-es-Samra treatment plant, which rendered the groundwater unsuitable for almost all uses including irrigation.

The groundwater qualities in the area represent a complex issue affected by various factors of recharge, discharge, inflows of waste waters, mixing of different water qualities, leaching of solidwastes and others. Therefore, no generalization concerning the water quality can be made for the whole catchment. But larger, major subareas can be delineated with features characterizing each of them. (See chapter on pollution).

2.5. Dead Sea area

This area lies to the east of the Dead Sea and extends some 50 kms eastwards. The ground water is found in two different aquifer complexes; the upper limestone aquifer complex and the lower sandstone aquifer complex. The groundwater in the two complexes has totally different histories.

The upper aquifer receives precipitation water, which infiltrates through the soil and rock covers and discharges in short time periods, measured in a few years. It is a renewable source of water. The total available groundwater amounts to around 87 MCM/year. Half of it discharges to the surface through springs along the upper reaches of the wadis of Zerka Ma'in, Wala, Mujib, Karak, Shaqiq, Ibn Hamad, etc. Groundwater is also artificially extracted from the aquifer through wells along the highlands in the areas of Madaba, Mujib, Katranah and Karak. It is used for domestic and irrigation purposes.

The lower aquifer (sandstone complex):

This aquifer does not receive any appreciable amounts of direct recharge by precipitation. The water in it originates from other areas. Due to its outcrop altitude, below sea level, and due to the presence of the graben and the Dead Sea which serves as an ultimate base level for all surface and ground water, the groundwater in the different areas in Jordan is somehow attracted by gravity to flow to the Dead Sea. Because of the outcropping of the sandstone aquifer complex (which extends under the entire area of Jordan) along the Dead Sea shores, the water in the different aquifers tends to flow to the Dead Sea area. The water in the sandstone complex comes from different sources, like leakings from the upper aquifers, underground flows from Disi area, in addition to very limited direct recharge to outcrops. The total discharge from the lower aquifer complex east of the Dead Sea is around 90 MCM/year of mostly thermal mineralized water (Salameh and Udluft 1985).

The water quality allows only for restricted uses like irrigating salt-semi-tolerant crops. But this thermal water can also be used for therapeutic purposes. Together with the climate prevailing in the area and the Dead Sea water, the thermal spring water issuing from the sandstone aquifer complex represents a potential wealth element for the country. The water quality of the upper aquifer ranges widely in the concentrations of the different parameters. Whereas, the concentrations are relatively small and within the acceptable standards for the different uses in the recharge areas, they increase rapidly along the groundwater flow directions and along some geologic lineaments because of mixing processes with piezometrically - rising, lower aquifer groundwater.

The water of the lower aquifer can only be used for irrigating salt-semi-tolerant crops. The higher salinity is partly a result of overpumping and upcoming of the lower aquifer groundwater. Irrigation return flows and wastewater seepages have not yet affected the aquifer, although some signs are indicating their effects, like slight increases in the nitrate and phosphate levels.

2.6. Northern Wadi Araba:

The wadi floor is built up of alluvial sediments brought from the surrounding mountains in the east and west with thicknesses of thousands of meters. The water at greater depths is saline due to the effects of the Dead Sea interface and to the geologic history of the area and especially of former extensions of the Dead Sea.

The groundwater in the area is found in the fluviatile deposits, talus and alluvial fans with a total thickness of about 250mm. The groundwater flows from the mountains in the east in a westerly direction, with a component towards the north; the Dead Sea. Generally, all the groundwater of this area discharges into the Dead Sea. The throughput of water from this area into the Dead Sea was calculated to be around 22 MCM/year (Abu Zirr 1989). The fresh water renewable resources amount to some 8 to 10 MCM/year.

Generally, the water salinity increases in the direction of groundwater flow; from the areas adjacent to the recharge areas to the discharge areas. In addition, irrigation return flows are gradually leading to groundwater quality deterioration. The increasing salinity, phosphate and nitrate contents are some indicators of that. The development of the groundwater resources of the area for irrigation purposes may be restricted by the salinity of the water which is already showing the effects of additional salinization due to irrigation return flows.

2.7. Southern Wadi Araba:

The wadi floor here is also composed of alluvial sediments brought from the surrounding mountains in the east and west. The thickness of the sediment fill is measured in kilometers, but the fresh and brackish groundwater is found in the uppermost portions of the aquifer.

The groundwater flow is directed from the north to the Red Sea in the south. Recharge comes from precipitation falling on the surrounding mountains in the east, it infiltrates there in the barren rocks and flows laterally into the fluviatile and alluvial deposits covering the wadi floor. A part of the recharge takes place along the wadi courses of the side wadis and wadi Araba itself. The throughput of the aquifer is calculated to be around 10 MCM/year composed mostly of brackish water.

The source water quality resembles that of the northern part of Wadi Araba. Here again the salinity increases in the direction of groundwater flow; from north to south. In the southern Wadi Araba area there are almost no irrigation activities, and the effects of the Dead Sea and its ancestors have not affected the area there. Hence, the increase in water salinity is less expressed than in the northern part.

The analyses of the Palm Forest Well 2 indicate the less pronounced salinization of the southern part of Wadi Araba, although the well water quality here may be affected by inflows of the nearby Aqaba waste water treatment plant as indicated by their high nitrate concentrations.

2.8. Disi-Mudawwara area:

The Disi-Mudawwara aquifer system crops out in south Jordan and extends southwards into Saudi Arabia and northwards in the underground of Jordan, where it overlies the Basement Complex, which consists of intrusive igneous rocks functioning as an aquiclude. This sequence of sandstones and shells underlies the entire area of Jordan at different depths, generally increasing in northerly and north-easterly directions. The Disi aquifer consists of medium-to-fine- grained sandstones with a total thickness of about 1000 meters. The average precipitation over the area is around 80mm/year, with an average potential evaporation of 4000mm/year.

The groundwater in the Disi area is unconfined and lies at a depth of around 80 meters below the surface, whereas in the Mudawwara area, the water is confined and partly artesian. The groundwater flow is directed towards the north and north-east. The average permeability of the aquifer is 1.68×10^{-5} m/s with a gradient of 0.143%. Assuming a flow of 40 kilometers in width and a maximized saturation depth of 1000 meters, the throughput of the aquifer is calculated to be equal to: $1.68 \times 10^{-5} \times 1.43 \times 10^{-3} \times 40 \times 10^{3} \times 10^{3} \times 30.5 \times 10^{6}$ = 30.5 MCM/year. This figure could be indicative of average recharge or the total flow as a result of fossil gradient adjustment.

The C^{14} ages of samples collected from that area range from 11,000 - 13,000 years. At present, it is generally accepted that the groundwater in Disi-Mudawwara area does not receive major replenishment. This means that the groundwater in the aquifer is fossil and that its extraction is at the expense of storage; in other words, this extraction is a mining process.

The groundwater in Disi has a very low salinity and is free of pollution signs of any type. Since the aquifer is found in a non-industrialized area with a very low population density, industrial and urban types of pollutants are not to be expected to affect the groundwater in the long-term. But it is expected that irrigation in the area will lead to irrigation return flows infiltrating to the groundwater hence to salinity increases and to pollution by agricultural pollutants such as fertilizers.

The Disi-Mudawwara aquifer, extending in the underground of the entire country, underlies all geologic units, and is, on a regional scale, hydraulically interconnected with the aquifers of the different units. This implies that any extraction from this aquifer at any location in Jordan is going to be reflected in lowering the water level in the upper aquifers.

Extraction of water increased from 15 MCM/year in 1983 to 85 MCM/year in 1995. The total amount of extraction during this period was around 850 MCM, causing a non-recoverable drawdown in water levels ranging from 3 to 20 meters. This non-recoverable, irreversible decline is a major warning concerning the persistence of water resources. The final results of the hydrological studies on the Disi-Mudawwara aquifer can be summarized as follows:

- The groundwater is fossil and the recharge is estimated at 30 MCM/year. The age of the groundwater is measured to be more than 10,000 years.

- The total pumping of about 850 MCM in the last few years caused a drop in water level amounting to more than 20 meters in some areas.
- The groundwater body of Disi-Mudawwara underlies the entire area of Jordan and is, on a regional scale, hydraulically interconnected with all overlying aquifers. Hence, extraction from this water body will affect the groundwater resources in Jordan, as it lies in the upgradient direction, and will ultimately cause a general drop in the water levels.
- There are indications that the water salinity has started to increase due to salt releases from the overlying Khreim confining unit.
- The Disi-Mudawwara aquifer water is the only strategic water reserve of Jordan.
- This water is the only long-term source for the water supply of Aqaba.

2.9. The Azraq Area:

This area forms the northern part of an elongated geological depression known as Sirhan Depression. It functions as a base level for both surface and groundwater which collects there to form an oasis. The groundwater in this area is found in different aquifer systems ranging from recent deposits to deep sandstone aquifer complexes.

In the shallow aquifer, consisting of recent deposits, basalts and partly the B4-formation, the water is renewable. In the intermediate aquifer complex consisting of Upper Cretaceous formations, the water is moving, but its main recharge areas lie far away in Jabel Druz and in the highlands of Amman - Madaba - Karak and Tafilah. Therefore, it has relatively an old age -- hundreds to thousands of years.

In the lower sandstone aquifer complex the water also has a relatively old age, not because it was stored in the aquifer for a long time, but because it has, since hundreds to a few thousands of years, been underway from the source areas towards the underground of the Azraq area. The source areas are:

- The highlands of Amman - Madaba - Karak and Tafilah, from which precipitation water infiltrates into Upper Cretaceous rocks, flows in an easterly direction and percolates down to the lower aquifer complex.

- Disi-Mudawwara area from where the groundwater flows with a component towards the Azraq area, feeding the lower aquifer complex.

- The highlands of Sharaa mountains, where the precipitation water infiltrates into the exposed rocks consisting mainly of Cretaceous deposits and flows crossing the Jafr Basin in the underground towards Azraq.

All these components of groundwater join in the underground of Azraq Depression and flow in a westerly direction towards the Dead Sea to be discharged there as mineralized thermal groundwater (Compare area 5).

The groundwater in the different aquifers, from the shallow one to the deep complex, is hydraulically interconnected with the following movement directions:

- In the shallow aquifer all the groundwater flows towards the oasis with only a lateral component.
- In the intermediate aquifer the groundwater flows from west, north and south towards the Azraq Oasis. Some of that groundwater seeps upwards to the shallow aquifer, and some downwards to the sandstone aquifer complex. Another portion flows further eastwards to Saudi Arabia.
- In the sandstone aquifer complex, the downward leakage of the overlying aquifers, as well as the groundwater flowing laterally from the south and eventually the east, flows in westerly and eventually northwesterly directions to the Dead Sea and probably to the Jordan Valley areas.

The amount of groundwater available in the shallow aquifer is calculated to be 20 to 24 MCM / year. Due to over-pumping, the water levels in the surroundings of the oasis have in recent years, dropped by a few meters, to a few tens of meters which has resulted in ceasing the discharge of Qaysiya, Soda and other springs feeding the oasis, and in increasing groundwater salinities. The water of the basalt aquifer is of a very good quality for different uses.

The water quality of the intermediate aquifer depends on the depth and site of collection. A well drilled in the Azraq area (AZ1), producing artesian water from the intermediate aquifer, has a salinity of 1500 µs/cm. The well also produces carbon dioxide, hydrogen sulfide and radon gases, indicating the confined nature of the aquifer in that area, which leads to the upward and downward leakages of the aquifer water to the overlying shallow and underlying deep aquifers.

No analyses of the deep aquifer water in Azraq area are available, but the same water is discharged along the eastern Dead Sea shore from the thermal springs there. From hydrodynamic and hydrochemical points of view it is justifiable to assume that the discharged, thermal, mineralized water at the Dead Sea eastern shores resembles in its quality the deep aquifer water underlying Azraq. The upper aquifer is now under heavy over exploitation with some 600 producing wells with dropping water levels by 10s of meters and rapidly rising salinities.

2.10. Jafr Area:

The main groundwater aquifer in the area is B4 - Formation of the Balqa group, consisting of thin beds of chert, limestones, clays and marls with a total thickness of 20 - 25 meters. The B2 A7 and the Kurnub and Disi sandstones form the deeper aquifers, which are separated from each other by thick aquitards. The different aquifers are weakly interconnected. The groundwater flow in the B4 aquifer is generally directed from west to east. In the lower aquifers, the groundwater flows in a general northerly direction with components towards the northeast and northwest. The groundwater in the deeper aquifers, represent a support and backbone of other groundwater bodies found northwest and south of Jafr Basin. Hence, extracting the water of the deeper aquifers would undermine other resources.

Recharge to the B4 aquifer takes place in the mountainous highlands of Shoubak lying to the west of the Jafr Basin. Direct recharge by precipitation is negligible, because the surface area of the playa, where floodwater collects, is covered by very fine sediments, which do not allow for the rapid infiltration of recharge water. The total recharge to the B4 aquifer is around 7 MCM/year (Parker 1979). Because of over-exploitation, the groundwater resources started to deteriorate in the late sixties, after only a few years of extraction. The salinity increased rapidly from 600 to 700mg/l in the early sixties in the different wells, to values between 700 and 2800mg/l in the early seventies.

Since that time, no major changes have taken place in the water quality. Although some water salinities increased beyond their values of the early seventies.Jafr Basin was the first main groundwater area in Jordan to suffer from over-exploitation, resulting in groundwater resources depletion and salinization. Nonetheless, experiments with over-extraction have continued and have led, during the last two decades, other groundwater areas to depletion and salinization.

2.11. Sirhan and Hamad areas:

The groundwater in these areas is found in a shallow aquifer consisting of upper Cretaceous and Tertiary rocks and recent sediments of wadi fills, basalts and alluvial deposits.

The general groundwater flow direction is oriented towards the local base level of Sirhan Depression extending in a southeasterly - northwesterly direction. The permeabilities of rocks underlying both areas are very small. Rocks, which extend from the highlands of Jordan towards the east show a general decrease in grain size and a general increase in siltation and cementation. Therefore, aquifers are not well developed and the water movement through the rocks is very slow. This results in small yields of aquifers and hence wells, and in longer intensive interactions of water with rocks, which are viable for dissolution, resulting in higher salinities of the water.

The estimated available groundwater resources for the Sirhan and Hamad areas are 5-10 MCM/year. Due to the large extents of those areas the groundwater is considered as sparsely available and can only be used for restricted local development (ACSAD 1980).The groundwater, in addition to its scarcity, suffers from a salinity problem. The water is generally brackish and needs certain technologies to be made suitable for relevant uses. The salinity of the water ranges from around 1000 µs/cm up to 4500 µs/cm. The majority of sources have a salinity of about 2000 µs/cm.

C. Patterns of Water Use

1.Water Use

1.1. Domestic Uses

A total of 260 MCM/year are presently used in Jordan to satisfy domestic uses. The water supply network suffers from corrosion and damage, which lead to losses estimated at 50% of all the supplied water.

Calculating the per capita domestic water use in Jordan shows that it averages around 85 l/day. Compared to the domestic uses in Europe of 150-250 l/c.d., to those of Israel of 280-300 l/c.d., to the Gulf States of 280-450 l/c.d., and to Iraq, Syria and Egypt of 130 l/c.d., it can be said that Jordanians are using the least of all, not only because they are extremely concerned about water use, but also because water is much less available. Concerning domestic water use, especially during summer, 85% of Jordanians live at the hygienic brink. Less water would mean public health detriments.

1.2. Industrial Uses

Industries in Jordan use at present around 45 MCM/year of water. The large part of this amount is consumed by the phosphate mining, potash and fertilizer industries. Almost all industries in Jordan suffered from water shortages, which led them to recycle their wastewater wherever and whenever it was possible. One of the major concerns of new industries is how and from where to obtain water. Water availability forms also a limiting factor for the establishment and expansion of certain water-consuming industries like paper, steel, oil shale extraction, etc.

1.3. Agricultural Uses

Irrigated agriculture is an important factor in the economy of Jordan. Irrigation in Jordan dates back to its development by ancient civilizations in this part of the world.The major water amounts used in Jordan are those consumed by irrigation. Animal husbandry and fish farming consume only negligible amounts of water.

The consumed amounts in this sector depend on the availability of resources; amounts of water stored in dams, yield of springs, discharges of wastewater treatment plants and others. At present around 650 MCM/year, are used for agricultural purposes, part of which is fossil, non-renewable water. As a result of governmental and private sector development, the irrigated cropping area reached 610.000 dunums in 1994.

Perhaps farmers of few countries in the world share with Jordanian farmers their awareness of the importance of water. Despite the high cost of implementing drip irrigation instead of the traditional irrigation methods (surface), farmers have been installing these new techniques. Also, an external factor affecting the amount of water used in irrigation is how much is allowed to enter Jordan's territories from the regional water resources such as the Yarmouk. This amount has been monotonously declining for about 8 years, which has reflected badly on the production of crops and land productivity in the Jordan Valley area.

1.4. Total Uses

The total water uses differ from year to year and depend on the available resources. In 1994, the total uses added up to about 910 MCM.

2. Water Balance: Resources versus Consumption:

The demand for water in Jordan exceeds the available resources, and with the passage of time, the gap between both demand and supply is widening. The surface water resources have been developed to a large degree to be mainly used in irrigation. Dams, canals and advanced irrigation systems were introduced to make the best use of the available resources. The water sources, which have not yet been developed are very limited and are expensive to make available. As an example, there are plans to construct 5 dams on Hidan, Wala, Mujib, Karak and Hasa Wadis with total additional captured water amounts of 60 MCM/year; some of which is water with relatively high salinity. The construction cost of such dams exceeds JD 2.60 /m^3 of water. Nevertheless, the government of Jordan is planning to construct these dams to assist in alleviating the severe water shortage in the country.

The Unity Dam, planned for construction on the Yarmouk River, is supposed to supply Jordan with an additional 80 MCM/year of good quality water, which may moderately alleviate the water shortage problem in Jordan. Construction of the dam has already started and it is expected, that by the time it is completed the gap between demand and supply will have risen sharply. Hence, the Unity Dam will, by the time of its completion, only alleviate a small portion of the water shortage problem.

Desert wadis are presently developed, by constructing weirs to collect floodwater (water harvesting) for both agricultural uses and groundwater recharge. But even the development of all the desert wadis will mean a small addition of around 30 MCM/year to Jordan's water resources.

The groundwater resources of the country are overexploited at a rate of around 250 MCM/year (2002). Some groundwater basins like Jafr and Dhuleil were depleted in the seventies and eighties. Others like Azraq, Disi and Agib are showing signs of depletion, such as declining groundwater levels and increasing salinity. If the present overexploitation continues at the same rate, these groundwater resources are expected to be exhausted within the coming decades.

III. Waste Water Treatment in Jordan

1. Introduction to Waste Water Treatment (WWT)

Waste water is essentially water that has been fouled by communities through its use in the various daily activities such as cooking and washing. Domestic sewage is mainly composed of human body wastes and sludge. Industrial sewage comprises numerous and various chemicals including those toxic to humans and nature. Sewage is extremely hazardous in content mainly because of the number of disease-causing organisms and toxic matter that it contains. The proper treatment and safe disposal of sewage into a receiving watercourse is of most importance for two major reasons:

a. The removal of pathogens and hence the spread of communicable diseases.
b. The oxidation of the organic matter it contains and prevention of pollution of surface and groundwater.

In many water-blessed countries sewage is treated before disposal into the nearest watercourse, where it is not used directly for any specific purpose. The case is different in some parts of the developing world where water resources are scarce, population density is high and continuously growing, and health and hygiene awareness are minimal.

In countries where water is not readily available and agriculture is predominant, treated waste water could be used to irrigate relatively large areas of cropped land. Jordan's desperate need for water imposed a necessity for the reuse of treated waste water in agriculture. To meet this end, several waste water treatment plants were constructed to treat sewage from major cities in Jordan. The average inflows of wastewater treatment plants and pollution parameters in effluents (2003) in these stations are shown in Annex 1. It has been estimated that some 80 million m^3/year of water could be retrieved from sewage treatment plants, and these are enough to cultivate at least around 160,000 dunums with alfalfa and various trees such as olive and apple. If proper and efficient treatment of waste water could be achieved, the effluent -- rich in nutrients -- would even be suitable for aqua culture.

2. Methods of waste water treatment

Various methods for waste water treatment have been developed over the past decades. Many are conventional, such as activated sludge and biofilters, and others slightly less conventional, such as oxidation ditches, aerated lagoons and natural treatment such as waste stabilization ponds.

2.1 Conventional waste water treatment

This method is usually used in temperate climates. It comprises the following stages of treatment:

a. Preliminary treatment: which is the physical removal of large suspended solid particles usually through screening, or the physical shredding and tarring of such particles through communication.

b. Primary treatment (sedimentation): which is the gravitational separation of a suspension into its component solid and liquid phases. At this stage the aim is to clarify the liquid from the solids it contains, and thus reduce the load on the secondary treatment phase.

c. Secondary or biological treatment (Biofiltration or activated sludge where the liquid from the primary sedimentation tanks is treated in either a biofilter (also known as the percolating trickling filters) or through an activated sludge process.

In the first case, settled sewage is distributed over a 1.8m deep bed of coarse aggregates. The sewage trickles down over the surface of the aggregates, where a microbial film develops and the bacteria, which constitute most of the film, oxidize the sewage as it flows past. In activated sludge, the settled sewage is led to an aeration tank, where oxygen is supplied either by mechanical agitation or by diffused aeration. The bacteria which grow on the settled sewage are removed in a second tank.

d. Sludge treatment, sludge from primary and secondary sedimentation tanks, are anaerobically digested and re-used as fertilizers.

Although conventional treatments are most commonly used intemperate climates, they are also used in hot climates. They can achieve high BOD removal at very short retention times which makes them very efficient when large areas of land are not available and where the high temperature of the surroundings may cause a large amount of water loss through evaporation.

Conversely, they are heavily mechanized and require high construction and maintenance costs, as well as several skilled operators ,in spite of their high efficiency in BOD removal, the rate of pathogen removal is very low, consequently, chlorination activity is a must, which may cause a hazard in trihalomethane formation.

2.2 Less conventional methods of waste water treatment

a. Oxidation ditches:

The oxidation ditch is a modification of the conventional activated process. It receives screened raw sewage and provides long retention times; the hydraulic retention time is commonly 0.5 - 1.5 days and for solids it is 20 -30 days. Mechanical rotors are needed to aerate sewage, and BOD5 removals are consistently more than 95%.

b. Aerated Lagoons:

Aerated lagoons are activated sludge units operated without sludge return. They were developed from waste stabilization ponds, by introducing mechanical aeration to supplement the algal oxygen supply. It was found that instead, the algae disappeared and the microbial flora resembled that of activated sludge. Aerated lagoons achieve BOD5 removal greater than 90% at comparatively long retention times (2 - 6 days).

c. Waste Stabilization Ponds:

These are large relatively shallow basins enclosed by earthen embankments. The raw sewage enters the first pond and follows continuous treatment in successive ponds. The process is natural and is carried out by the action of algae and bacteria. There are three basic types of ponds: anaerobic, facultative and maturation ponds.

***d.* Anaerobic ponds:**

They are relatively deep ponds, 2 - 5m, and considered as pre-treatment ponds where the sewage received is of high organic loading (100 - 400g BOD5/m/day) and contains high amounts of suspended solids (> 300mg/l). The organic loading is so high that they are devoid of dissolved oxygen - hence the name anaerobic.

The solids settle to the bottom where they are digested anaerobically and the supernatant is discharged into further ponds. The efficient operation of the ponds depends on the balance between acid-forming bacteria and methanogenic bacteria; i.e., a temperature< 15C °and pH > 6 are required.

***e.* Facultative ponds:**

These ponds are designed to receive either raw sewage or effluent from anaerobic ponds and septic tanks. They are usually I - 2m deep, with a mixture of anaerobic activity in the lower layer of the pond and aerobic activity towards the upper layer of the pond. Some of the oxygen required to keep the upper layer aerobic is due to surface aeration, but most of it is produced by photosynthetic algae which grow naturally in the ponds. The bacteria present utilize the oxygen to oxidize the organic waste and release carbon dioxide as one of its major end products. Carbon dioxide is readily utilized by the algae during photosynthesis. Therefore, there exists a symbiotic relationship between pond algae and pond bacteria.

***f.* Maturation Ponds:**

Maturation ponds are designed to receive treated effluent from facultative ponds. The removal of BOD5 in these ponds is small, and two ponds in series with a retention time of 7 days are usually needed. They are relatively shallow 1- 1.5m and are aerobic.The primary function of maturation ponds is the destruction of pathogens. Faecal bacteria and viruses die off because of the unfavorable environment in the maturation ponds. The rate of die-off increases with rise in temperature. Ultraviolet light penetration, high dissolved oxygen concentrations and the release of algal toxins have been suggested as direct causes of faecal coliform die-off in maturation ponds. It has been proved that a high pH > 9, as a result of rapid algal photosynthesis, is mainly responsible for faecal coliform die-off and that of bacterial pathogens. The eggs of helminths and the protozoan cysts have a relative density of about 1.1 mg/l, and with the long retention times in these ponds, they settle to the bottom.

The method of treatment using WSP is natural. No mechanical aerators are needed to produce oxygen, but rather oxygen is symbiotically produced by algae. No sludge recycling is needed. It was found that in spite of the long retention time needed, ponds will under the appropriate conditions, produce a very good effluent quality with a BOD5 removal > 95% and up to 6 $\log^{10}$ cycle reduction in faecal coliforms.

The first WWTP was constructed in Jordan in 1945 to serve the town of Salt, where cesspits were the form of waste water deposition. Naturally, the fouled water used to seep both to the surface and groundwater, negatively affecting the water quality in the area as well as transmitting various diseases. The springs supplying the town with drinking water were also polluted from the cesspool seepages. The WWTP of extended areation type served its purposes, and cesspools were abandoned, hence, the springs and wadi water qualities improved. The good quality of the treatment plant effluent allowed for its unrestricted use in irrigation along Wadi Shueib without any environmental or health hazards. The case of Salt repeated itself in Amman, lrbid and other towns and cities in Jordan. Treatment plants were then constructed, in sequence, especially from the eighties onward (Fig 1)

The first generation of WWTP of trickling filter and activated sludge types functioned properly without any major problems except for becoming overloaded with time. In 1985 waste water stabilization ponds were introduced into Jordan, Khirbet-es-Samra was constructed around 35 km northeast of Amman to serve Amman, Rusaifa and Zerka cities.

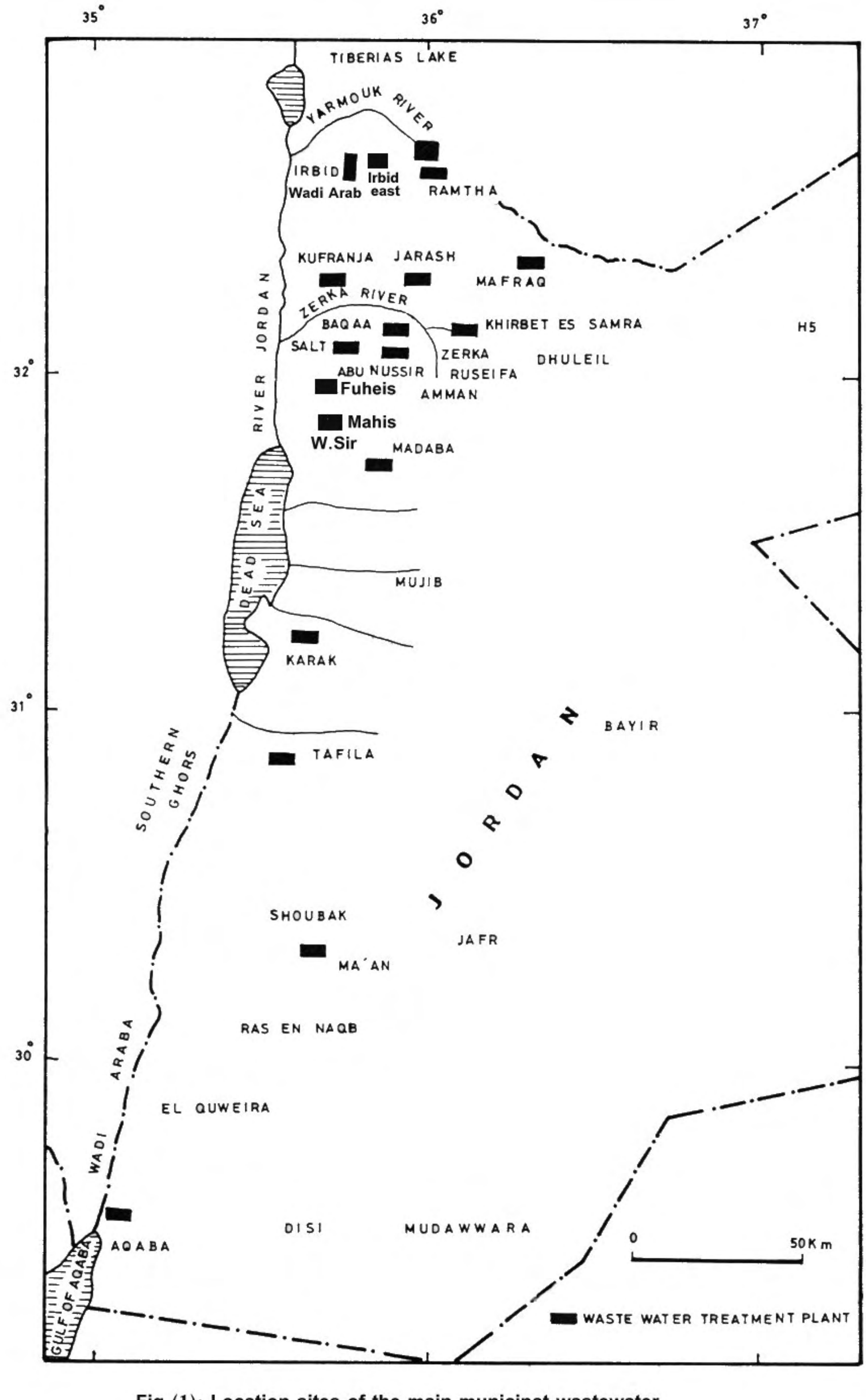

Fig (1): Location sites of the main municipat wastewater treatment plants in Jordan

Table 1 shows the main municipal wastewater treatment plants in Jordan and the used type of treatment. Due to limited efficiency of stabilization ponds as indicated by their effluents BOD5 Valves (Table 2) MOWI started a program to replace them by other types of treatment plant within this program Madabe stabilization pond treatment plant was replaced in the year 2002 by a mechanical activated sludge treatment plant

Science other WWTP were quantitatively overloaded due to increases in the population members as a result of natural growth and of forced migration into the country as well as due to increases in the members of house connections. Table 3 shows the design capacities of WWTP in Jordan and the amounts of wastewater reaching them. From that table it can be deduced that Irbid, Karak, Baqa'a, Khirbet-es-Samra, Madaba, Ramtha and to some extent Maan wastewater treatment plants are quantitatively overloaded None the less, the effluents of some of them such as Irbid and Baqaa are producing an effluent wilh low BOD5 values. But, stabilization ponds whether quantitatively under loaded or over loaded produce effluents generally with high BOD5 values of 83 mg/l up to 400 mg/l. With the exception of Karah and Kufranja WWTP all activated sludge and biofilters WWTP produce effluents with BOD5 Valves of less than 50 mg/l.

This shows that stabilization ponds treatment has not proven to be effective in Jordan.

Table 1: Main municipal treatment plants in Jordan and the types of treatment processes

Activated sludge	Biofiltralion	Stabilization ponds
Salt	Kark	Khirbed-es-samra
Jarash	Tafila	Aqaba
Abu Nusseir	Kufranja	Madaba*
Irbid	Baqa'a	Ramtha
Fuheis/ Mahis		Maan
Wadi Arab		Mafraq
		Wadi sir

* Madaba (WWTP) was replaced by a mew plant of activated sludge type of treatment

Table 2: Average biochemical characteristics of the effluents of the main municipal wastewater treatment Plants (WWTP) in Jordan (WAJ 2001). "all values in mg/l"

WWTP	BOD5	COD	TSS	TDS	NH4	PO4
Salt	30	136	143	935	28	14
Jarash	33	177	95	1144	75	39
Abu Nusseir	14.4	73	43	980	1	16
Irbid	44	237	96	993	90	20
Fuheis/Mahis	24.4	103	53	820	23	9
Wadi arab	13.5	73	53	1059	2	11
Karak	101	302	97	900	71	13
Tafila	45.1	391	91	851	45	15
Kofrauja	89	368	257	1002	82	16
Baqa'a	48.5	183	151	1192	14.6	13
Khirbet-es-samra	102	247	173	1246	73	16
Aqaba	91.3	485	210	993	44	9
Madaba	400	854	190	1626	96	15
Ramtha	197	1718	516	1216	159	-
Maan	83.5	482	190	1141	65	17
Mafraq	156	406	155	1153	100	13
Wadis sir	36.4	142	72	949	70	10

Table 3: Design capacities of WWTP in Jordan and their in flow loads

WWTP	Design capacity m^3/day	Inflows m^3/day (2001)
Salt	7700	3400
Jarash	3500	2070
Abu Nusseir	4000	1620
Irbid	1100	4610
Fuheis/mahis	2400	1220
Wadi arab	22000	5990
Karak	785	1230
Tafila	1600	710
Kufranja	1900	1890
Baqaa	4000	11185
Khirbet-es-samra	68000	170750
Aqaba	9000	8800
Madaba	2000	4270
Ramtha	1920	2340
Maan	1670	1890
Mafraq	1800	1850
Wadi sir	4000	1110
Total mcm/yr		**82.6**

IV. Institutional and Legal Framework

In Jordan three governmental agencies are involved in the management of the water sector, each of them with a variety of primary responsibilities: The Ministry of Water and Irrigation, the Water Authority of Jordan and the Jordan Valley Authority. The two authorities are headed by Secretary Generals who report to the Minister of Water and Irrigation. The three agencies are subject to the provisions of the Civil Service commission, the Audit Bureau, the Bureau of Supervision and inspection and Government procurement regulations.

Ministry for Water and Irrigation

The Ministry for Water and Irrigation (MWI) was established in accordance with Article 120 of the Constitution under by-law no. 54 of 1992. This regulation provides for the formal organisational structure of the Ministry rather than setting out its formal roles and responsibilities. The MWI supervise two Authorities, namely the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA). The responsibilities of the Ministry, however, are set out in Art.5 of the WAJ law, which states that the Ministry is responsible for all water and wastewater systems and related projects and shall set forth a water policy and submit it to the Council of Ministers for approval. The key functions actually undertaken by MWI include:

- Drafting and preparation of water sector policy;
- Water resources data collection and management, including preparation of the national water plan and advice on specific water abstraction proposals;
- Donor financing liaison;
- Management of large ‘strategic’ projects, particularly where international financing or PSP is involved; and
- Water sector legislation.

Water Authority of Jordan

The Water Authority of Jordan (WAJ) was established under the Water Authority of Jordan Law (No.18 of 1988) as an autonomous statutory body with financial and administrative independence (Art.3). This provides WAJ with the authority to enter legal proceedings, raise loans and sign contracts in its own right. WAJ is required to follow the rules that are binding on ministries, governmental authorities and official authorities (Article 4). Its staff is employed under the Civil Service Law (Article 13). As an autonomous statutory body, WAJ has its own financial accounts and the law requires that these be organised according to recognised accounting methods and shall be audited by qualified auditors (Article 18).

The following summarises WAJ's responsibilities under Art.6 of the WAJ law:

- Survey different water resources and determine ways, means and priorities for their implementation and use (except for irrigation);
- Set up plans and programs to implement approved water policies related to domestic and municipal water (i.e. supplied through public networks) and sanitation, including developing water resources, treating and desalinating water;
- Direct and regulate the construction of public and private wells, license well drilling rigs and drillers;
- Study, design, construct and operate wastewater projects;
- Draw terms, standards and special requirements in relation to the preservation of water and water basins, protect them from pollution;
- Carry out theoretical and applied research regarding water and wastewater;
- Issue permits to engineers and licensed professionals to perform water and wastewater works;
- Regulate the uses of water, prevent its waste and conserve its consumption.

Additional responsibilities can be conferred on WAJ by the Council of Ministers, upon the recommendation of the Minister for Water and Irrigation (Art.7). WAJ is established with a Board of Directors, chaired by the Minister for Water and Irrigation. Under Art.10, the Board's responsibilities may be summarised as:

- Setting forth a water policy for the Kingdom;
- Approving the water policy of the Kingdom and plans for the development and conservation of water resources;
- Submitting draft regulations to the Council of Ministers for approval;
- Obtaining loans, with the approval of the Council of Ministers;
- Making recommendations to the Council of Ministers concerning water tariffs; and
- Investing WAJ's funds and revenues, with the approval of the Council of Ministers.

The Secretary-General of WAJ, as Chief Executive of WAJ, is responsible for implementing WAJ's policies and plans and its day-to-day administration. The Secretary-General is responsible to the Minister for Water and Irrigation (Art.12).

Under Art.28, the Council of Ministers, on the recommendation of the Minister for Water and Irrigation, may assign any of the Authority's duties or projects to any other body from the public or private sector or to a company owned totally by the Authority. This may include transfers of project management, a lease or ownership.

The Jordan Valley Authority

Development in the Jordan Valley is governed by Law 19/1988, an extension of Temporary Low 18/ 1977 that created the JVA as the successor to four organisations previously responsible foe the overall development of the Jordan Valley. The 1988 low gives the JVA the legal mandate for developing the Jordan Valley and the area south of the Dead Sea. The responsibilities of the JVA are:

- Development of water resources for domestic, irrigation and industrial uses in the Jordan Valley area. Development of towns and villages.
- Design and construction of road networks, domestic water supply electricity and telecommunication networks and provision of tourist facilities.
- Implement social development infrastructure such as schools, health centers, housing government buildings, streets, parking lots etc.
- Provide agriculture support services such as packing and grading stations, marketing centers, processing factories, laboratories etc.

According the Law, the JVA will hand over projects to the appropriate regional or municipal authorities after the projects are completed. The Law describes the Authority as an autonomous corporate body with full authority in the allocation or usage of all surface and groundwater resources and authorization to fix water prices.

V. Reuse Standards

Standard JS 893:2002

Introduction

The Institution for Standards and Metrology is the national entity responsible for Issuing standards in Jordan. Standards are set by technical committees formulated by The Institution for Standards and Metrology from members representing main parties concerned with the subject. All concerned parties have the right to express their opinion and comments on the final draft of the subject standard during the notification period in order to make the Jordanian standards in harmony with international standards, to alleviate any technical boundaries facing trade and to facilitate flow of commodities between countries. Based on this, the permanent technical committee for water and wastewater No.17 has set the Jordanian Standard 893/1995 dealing with "Water-Reclaimed Domestic Wastewater" and recommended its approval as a Jordanian Technical base No. 893/2002 in accordance with article (11) paragraph (b) of the Standards and Metrology Law No. 22 for the year 2000.

Water: Reclaimed Domestic Wastewater

1. Scope

This Jordanian standard is purposely set to specify the conditions that the reclaimed domestic wastewater discharged from wastewater treatment plants should meet in order to be discharged or used in the various fields mentioned in this standard.

2. Standard References

The following standard references become conditions of this standard when referenced. When a documented reference is dated, the amendments after that date do not apply despite the fact that any contractual party depending on these references recommends using the latest edition of the listed references. In the case that the reference is not dated then the latest edition would prevail.

The library at the Institute for Standards and Metrology contains current standards.

- -Standard Methods for the Examination of Water and Wastewater APHA. 1998
- -Health Guidelines for the Use in Agriculture and Aquaculture, WHO. 1989.

3. Definition

The following definitions are used for the purpose of this standard:

3-1 Domestic wastewater

Is the water produced from domestic usages and it could contain industrial wastewater that comply in terms of quality to the ordinance issued by the official parties for the connection to the public sewer system.

3-2 Reclaimed Water

Is the treated wastewater to be reused according to the conditions of this standard provided it is not mixed with water from other sources.

3-3 landscape Areas

Is the green areas intended to be used for decoration and landscaping and not for recreational purposes.

3-4 Mechanical Treatment Systems

Systems that use mechanical processes for treating water such as the activated sludge system, the rotating biological contactors system, the biological filters system, and others.

3-5 Natural Treatment Systems

Systems that use natural processes for treating water by using aerobic or anaerobic ponds, maturation ponds or others.

3-6 Disinfection

Is a process for the removal or reduction of pathogenic and indicator microorganisms that can be found in the water by using disinfectants such as chlorine or chlorine dioxide or ultraviolet rays or the ozone or any other disinfectant approved by the official parties.

3-7 Industrial Crops

Crops used for industrial purposes such as wood trees and olive trees

3-8 Field Crops

Crops that are planted on large areas and harvested once a year and includes:

3-8-1 Forages

Crops planted in order to utilize its vital aggregate (stems and roots) such as berseem, sweet corn, sudan grass, Alfa Alfa, …..

3-8-2 Grains

Crops planted for its high content of carbohydrate and used in the nutrition of humans and animals and includes wheat, barely, oats, corn (white).

3-8-3 Legumes

Crops planted to utilize its seeds after drying such as lintel. Fenugreek and lupine.

3-8-4 Fibers

Crops planted in order to utilize its fibers such as cotton and linseed.

3-8-5 Oils

Crops planted to produce oil such as sesame, soya bean and olives.

3-8-6 Sugar

Crops planted to produce sugar such as sugar beet and sugarcane.

3-9 Cooked Vegetables

Vegetables that are usually eaten after cooking and includes: eggplant, squash, beans, cornflower, potato, okra, pees, broad beans, turnip, spinach, jew's mallow, artichoke.

3-10 Uncooked Vegetables

Vegetables that are usually eaten raw and includes the following: tomato, cucumber, Egyptian cucumber, pepper, cabbage, onion, carrot, radish, lettuce, parsley, mint, rocket (watercress), coriander, purslane, strawberry, watermelon and cantaloupe.

4. General Requirements:

4-1 The Reclaimed Domestic Wastewater standard has two primary components

a) Reclaimed water discharged to streams, wadis or water bodies.

b) Reclaimed water for reuse.

4-2. Reclaimed water must comply with the conditions stated in this standard for each of its planned end uses.

4-3 It is not permitted to dilute or mix reclaimed water discharged from wastewater treatment plants with pure water intentionally to comply with the requirement set in this standard.

4-4 Should reclaimed water be used for purposes other than those mentioned in this standard (such as for cooling or for fire distinguishing), special standards or guidelines are to be applied in each case after conducting the necessary studies taking into consideration the health and environmental dimension.

4-5 Official and specialized concerned parties overseeing the operation and development of wastewater treatment plants must always work towards improving the effluent quality to levels, maybe, exceeding those presented in this standard to ideally use the reclaimed water and protect the environment.

5. Standard Requirements:

5-1 Reclaimed Water to be discharged to streams, wadis or water bodies.

5-1-1 It is allowed to discharge reclaimed wastewater to streams or wadis or water bodies when its quality complies with the properties and criteria mentioned in table (1) and it is prohibited to discharge it into wadis draining to the gulf of Aqaba.

5-1-2 When reclaimed water passes on areas that are above or leading to ground water aquifers, measures must be taken to prevent the leakage of the reclaimed water to ground waters.

5-1-3 When discharging reclaimed water to streams, wadis or water bodies that are in direct contact with the public it is preferred to use any of the suitable types of disinfectants to protect the public health. When Chlorine is used, the free residual chlorine concentration shall not exceed 1 mg/l.

5-1-4 Natural treatment plants are permitted to exceed the specified values for *E Coli* numbers when water is discharged to wadis leading to storage dams where the water is stored and used totally for irrigation purposes. In the event that this water is used prior to reaching the dam, then the criteria specified for the reclaimed wastewater for the purpose of reuse and according to the nature of the end use must be applied.

5-1-5 Table **1 – Allowable limit for properties and criteria for discharge of water to streams or wadis or water bodies**

Parameters	Abbreviation	Unit	Allowable Limit
Group A			
Biological Oxygen Demand	BOD_5	mg/l	60*
Chemical Oxygen Demand	COD	mg/l	150**
Dissolved Oxygen	DO	mg/l	>1
Total suspended solids	TSS	mg/l	60**
pH	pH	mg/l	6-9
Nitrate	NO_3	mg/l	45
Total Nitrogen	T-N	mg/l	70
Escherishia Coli	*E. coli*	Most probable number or colony forming unit/100 ml	1000
Intestinal Helminthes Eggs	Intestinal Helminthes Eggs	egg/l	< or =1
Fat and grease	FOG	mg/l	8.0

Table 1. Continued

Parameters	Abbreviation	Unit	Allowable Limit
Group B			
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	25
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	$T\text{-}PO_4$	mg/l	15
Chloride	Cl	mg/l	350
Sulfate	SO_4	mg/l	300
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	200
Magnesium	Mg	mg/l	60
Calcium	Ca	mg/l	200
Sodium Adsorption Ration	SAR	-	6.0
Aluminium	Al	mg/l	2.0
Arsenic	As	mg/l	0.05
Berelium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2
Floride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5
Manganese	Mn	mg/l	0.2

Molibdinum	Mo	mg/l	0.01
Nikel	Ni	mg/l	0.2
Lead	Pb	mg/l	0.2
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.02
Mercury	Hg	mg/l	0.002
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

* For biological Treatment Plants or Treatment plants with polishing ponds BOD_5 is considered as the filtered BOD

** For biological Treatment Plants or Treatment plants with polishing ponds the allowable limits is twice this number

5-2 Reclaimed Water for reuse: This part of the standard consists of reusing reclaimed water for artificial recharge of groundwater aquifers and for irrigation purposes.

5-2-1 Reuse for the purpose of artificial recharge of groundwater aquifers. Reuse of reclaimed water for the purpose of artificial recharge of groundwater is allowed if its quality complies with the criteria mentioned in Table 2.

5-2-1-1 It is not permitted to artificially recharge ground water aquifers used for drinking purposes.

5-2-1-2 Technical studies must be performed before using reclaimed water for artificial recharge of groundwater aquifers used for irrigation purposes to verify that there is no effect on groundwater aquifers used for drinking purposes.

Table 2 – Allowable Limit for properties and criteria for use in artificial groundwater aquifers

Parameters	Abbreviation	Unit	Allowable Limit
Group A			
Biological Oxygen Demand	BOD_5	mg/l	15
Chemical Oxygen Demand	COD	mg/l	50
Dissolved Oxygen	DO	mg/l	>2
Total suspended solids	TSS	mg/l	50
pH	pH	mg/l	6 – 9
Turbidity		NTU	2
Nitrate	$\mathbf{NO_3}$	mg/l	30
Ammonia	NH_4		5.0
Total Nitrogen	T-N	mg/l	45
Escherishia Coli	*E. coli*	Most probable number or colony forming unit/100 ml	<2.2
Intestinal Helminthes Eggs	Intestinal Helminthes Eggs	Egg/l	< or =1
Fat and grease	FOG	mg/l	8.0

Table 2. Continued

Group B			
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	25
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	T- PO_4	mg/l	15
Chloride	Cl	mg/l	350
Sulfate	SO_4	mg/l	300
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	200
Magnesium	Mg	mg/l	60
Calcium	Ca	mg/l	200
Sodium Adsorption Ration	SAR	mg/l	6.0
Aluminium	Al	-	2.0
Arsenic	As	mg/l	0.05
Berelium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2
Floride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5
Manganese	Mn	mg/l	0.2
Molibdinum	Mo	mg/l	0.01

Nikel	Ni	mg/l	0.2
Lead	Pb	mg/l	0.2
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.02
Mercury	Hg	mg/l	0.1
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

5-2-2 Reclaimed water reuse for Irrigation

5-2-2-1 The item concerned with reclaimed water reuse for irrigation purposes consists of two main groups; standards group and guidelines group:

- Standards group: is the group of properties and standards that are presented in Table 3 and where operating parties must produce water complying to it and according to the usages mentioned in this standard.
- Guidelines group: The guidelines group shown in Table 4 is considered for guidance only and in case of exceeding it values the end user must carry out scientific studies to verify the effect of that water on public health and the environment and suggest ways and means to prevent damage to either.

5-2-2-2 It is prohibited to use reclaimed water for irrigating vegetables that are eaten uncooked (raw).

5-2-2-3 It is prohibited to use sprinkler irrigation except for irrigating golf courses and in that case irrigation should practiced at night and the sprinklers must be of the movable type and not accessible for day use.

5-2-2-4 When using reclaimed water for irrigating fruit trees, irrigation must be stopped two weeks prior to fruits harvesting and any falling fruits in contact with the soil must be removed.

Table 3 – Allowable Limit for properties and criteria for reuse in irrigation

Allowable limits per end use				
Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits	Fruit Trees, Sides of Roads outside city limits, and landscape	Field Crops, Industrial Crops and Forest Trees
		A	B	C
Biological Oxygen Demand	mg/l	30	200	300
Chemical Oxygen Demand	mg/l	100	500	500
Dissolved Oxygen	mg/l	>2	-	-
Total suspended solids	mg/l	50	150	150
pH	unit	6-9	6-9	6-9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70
Escherishia Coli	Most probable number or colony forming unit/100 ml	100	1000	-

Intestinal Helminthes Eggs	Egg/l	< or = 1	< or = 1	< or = 1

Table 4 – Guidelines for Reuse in Irrigation

Group B			
Fat And grease	FOG	mg/l	8
Phenol	Phenol	mg/l	<0.002
Detergent	MBAS	mg/l	100
Total Dissolved Solids	TDS	mg/l	1500
Total Phosphate	$T\text{-}PO_4$	mg/l	30
Chloride	Cl	mg/l	400
Sulfate	SO_4	mg/l	500
Bicarbonate	HCO_3	mg/l	400
Sodium	Na	mg/l	230
Magnesium	Mg	mg/l	100
Calcium	Ca	mg/l	230
Sodium Adsorption Ration	SAR	-	9
Aluminium	Al	mg/l	5
Arsenic	As	mg/l	0.1
Berelium	Be	mg/l	0.1
Copper	Cu	mg/l	0.2

Floride	F	mg/l	1.5
Iron	Fe	mg/l	5.0
Lithium	Li	mg/l	2.5(0.075 for citrus crops)
Manganese	Mn	mg/l	0.2
Molibdinum	Mo	mg/l	0.01
Nikel	Ni	mg/l	0.2
Lead	Pb	mg/l	5.0
Selenium	Se	mg/l	0.05
Cadmium	Cd	mg/l	0.01
Zinc	Zn	mg/l	5.0
Chrome	Cr	mg/l	0.1
Mercury	Hg	mg/l	0.002
Vanadium	V	mg/l	0.1
Cobalt	Co	mg/l	0.05
Boron	B	mg/l	1.0
Cyanide	CN	mg/l	0.01

6- Quality Monitoring

6-1 The Wastewater Treatment Plant Owner Party must ensure that the reclaimed water quality complies to the standards and according to its end use. And must carry out the required laboratory tests and document results in official logbooks and present them whenever requested by the governmental monitoring parties.

6-2 The operating party must take composite samples every 2 hr for a period of 24 hrs in accordance with the frequency indicated in Table 5. Monitoring parties can collect samples in any way found suitable.

6-3 The frequency of collecting samples for both the operating and monitoring parties is as indicated in Table 5.

6-4 Collecting, preserving, transporting and analyzing samples will be as stated in the Standard Methods for the Examination of Water and Wastewater issued by APHA and the federal American Association for Water Research and Pollution Control and any of its amendments or any other approved method if it is not mentioned in the above mentioned reference.

6-5 For natural treatment plants or for mechanical treatment plants with polishing ponds BOD_5 is calculated after filtration step.

6-6 In evaluating the quality of reclaimed water geometric mean is used for calculation of Thermotolerant coliforms or *Escherichia coli* results.

6-7 In evaluating the content of reclaimed water for total Nitrogen, the Geometric mean is used provided that at least 5 samples are included in the calculation.

6-8 Results of the Thermotolerant coliforms can replace those of the *Escherichia coli* when the *Escherichia coli* test cannot be performed due to the absence of technical capabilities.

6-9 When there is a need to define a standard value for a criterion not mentioned in this Standard then the Institution for Standards and Metrology must be contacted to take the proper action.

6-10 In case of epidemics the monitoring and operational parties must investigate the presence of intestinal pathogenic microorganisms that may be found in the water.

7- Evaluation Mechanism

7-1 For the purpose of evaluating the quality of reclaimed water as per the different uses mentioned in this standard the periods shown in Table 5 are approved.

7-2 When any value violate the standards set for discharge of reclaimed water to streams, wadis or water bodies an extra-confirmatory sample must be taken. If the two samples exceeded the allowable standard limits the concerned party will be notified in order to conduct the necessary correction measures in the shortest possible time. And if the violation persist for more than 3 months then the reuse of reclaimed water for that purpose should be stopped until the water quality stabilized.

Table 5 - Number of Reclaimed Water Samples to be collected for the purpose of quality control and evaluation, and the required chemical, physical and biological analysis to be done on the samples

Treatment Plants	Sampling Frequency		Evaluation Period
Type	Operating Party	Monitoring Party	
Mechanical	· Routine Tests: 8 samples / month (composite) · Physical & Chemical Properties: 3 samples /day (grab) · Intestinal Helminthes Eggs: 4 samples/month (composite) · Escherichia coli: 8 samples/month (grab)	· Routine Tests: 2 samples/month · Physical & Chemical Properties: 2 samples /month · Intestinal Helminthes Eggs: 2 samples /month · Escherichia coli: 2 samples /month	3 months*
Natural	· Routine Tests: 4 samples / month (composite) · Physical & Chemical Properties: 3 samples /day (grab) · Intestinal Helminthes Eggs: 2 samples/month (composite) · Escherichia coli: 4 samples/month (grab)	· Routine Tests: 1 samples / month · Physical & Chemical Properties: 1 samples /month · Intestinal Helminthes Eggs: 1 samples/month · Escherichia coli: 1 samples/month	6 months**

Table 5 – (Cont'd)

. Routine Tests: T-N, NH_4, TSS, COD, BOD_5, NO_3
. Physical & Chemical Properties: pH, DO, RCL_2, Turbidity, Temperature
* According to seasons (Dec – Feb) , (Mar – May), (Jun – Aug), (Sep – Nov)
** Winter and Summer (Summer: Start of May – Oct, Winter: Start of Nov – Apr)

VI. Public Awareness

Informing and educating water users in Jordan about the seriousness of water scarcity is a very important issue to overcome severe water shortage problem. Public awareness program should include all the public sectors starting from household, business and farm level. The program should include protection of water quality as well as rationalizing water consumption. The government believes that the public should be aware of the water scarcity and shortages so that any significant changes in water conservation and protection will be appreciated. In addition new legislations and laws can be enforced more easily.

In view of the above it is believed that the Jordanian Ministry of Water and Irrigation is the best institution to execute such a program and achieve the government objectives through direct involvement of the people within the program.

An active program had been designed and put in practice where policy implications are related primarily to how the Government will collaborate with non-governmental and other organizations at policy level. Furthermore, the other part of the program is an educational campaign put into effect to inform the public about the value of water for them and for the well being of the country for the sustainability of life, and for the economic and social development. Likewise facts, about water in Jordan need to be disseminated such as the cost incurred provide the service, and the mounting pressure of the population growth on the water resources. Economic measures may be adopted to reinforce public awareness.

The Public Awareness program includes significant community outreach where a forum is to be created between the organizations within the ministry of

Water and Irrigation trained staff and the community stakeholders where they can share and resolve local scale water issues. This forms as a link between the central government and local communities. The trained staff from the ministry has been involved in meetings with local community representatives to discuss water issues at various watersheds. The community stakeholders (representatives) were identified and are engaged in meetings addressing specific issues related to individual watersheds. This will provide a community based perspective on potential mitigation measures and pin point specific concerns each community they might have.

To disseminate public awareness various materials are used including:

- Newsletter articles
- Citizen guidebooks
- More newspaper coverage for water issues
- TV and Radio
- Websites
- Creating public educational places in libraries and town halls
- Developing signs in public areas
- Educating land-use decision makers
- Schools and universities

Developing and funding educational programs is the responsibility of the government, but stakeholder agencies should share some responsibility for education. The educational program is broadly based to the public but it contains also issues addressing specific audiences for specific issues.

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Annex 1: Average Inflows of wastewater treatment plants and pollution parameters in effluents (2003)

Wastewater Treatment Plant	Daily Influent m3/d	Yearly Influent MCM/yr	BOD5 Mg/l	COD Mg/l	TSS Mg/l	TDS Mg/l
Es samra	187000	68.5	123	577	101	1195
Central Irbid	8150	2.97	29.2	132	48	1020
Aqaba	10171	3.71	9.8	320	607	882
Salt	4248	1.55	18	72	26	630
Jarash	4360	1.60	29	171	86	570
Mafraq	2260	0.83	156	451	263	1210
Baqaa	12000	4.4	38	121	41	1357
Karak	1586	0.579	50	183	65	872
Abu Nusseir	2218	0.81	20	77	31	1091
Tafileh	841	0.31	38	159	58	831
Ramtha	3048	1.12	167	540	271	1270
Ma'an	2071	0.76	183	460	182	962
Madaba	4450	1.62	31	108	35	1172
Kufranja	2787	1.02	26.7	127	30	885
Wadies Sir	2545	0.93	32	168	52	815
Fuheis- Mahis	1976	0.72	14	56	16	566
Wadi Arab	6683	2.44	5.5	65	4.72	1426
Wadi Musa	885	0.33	7.9	43	16.8*	2518
Wadi Hassan	654	0.24	9.4	60	189	1260