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RECLAIMED WASTEWATER TREATMENT AND REUSE IN JORDAN: POLICY AND PRACTICES

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BACKGROUND

The Hashemite Kingdom of Jordan is an arid to semi arid country, with a land area of approximately 89,400 km^2. Its topographic features are variable. A mountain range runs from the north to the south of the country. Land slopes gently to the east of this range to form the eastern deserts, but to the west the ground slopes steeply towards the Rift Valley, which extends from Lake Tiberius in the north, at an elevation of -220 m below see level, to the Red Sea at Aqaba.

Figure 1. Map of Jordan

The scarcity of water in Jordan is widely seen as the single most important restriction on the country's sustainable economic growth, particularly given the increasing population, which was nearly 5.5 million in July 2003 and growing at a yearly rate of 2.78%. About 70% of the population is urban, with 2 million living within the Greater Amman area.

The country's annual water demand currently exceeds 1 billion m^3 and is projected to rise to over 1.3 billion m^3 by 2005, having nearly doubled since the mid-90s. Jordan's renewable water resources can supply around 750 million m^3/year, leaving an annual deficit which has grown steadily, despite the huge programme of investment in the water sector, from 222 million m^3 in 1995 to a predicted 251million m^3 by 2011. The current annual allowance of 200m^3 per capita lags significantly behind other countries in the region, being around 65% less than that available in Israel and Syria and 85% less than Egypt.

Water resources consist primarily of surface and ground water resources, with treated wastewater being used on an increasing scale for irrigation, mostly in the Jordan Valley. Renewable fresh water resources are estimated at about 850 million cubic meters (MCM) per year, including water added by the Peace Treaty. About 125 MCM per year is expected to be available from fossil aquifers and through desalination by the year 2005, making the annual freshwater stock about 975 MCM per year.

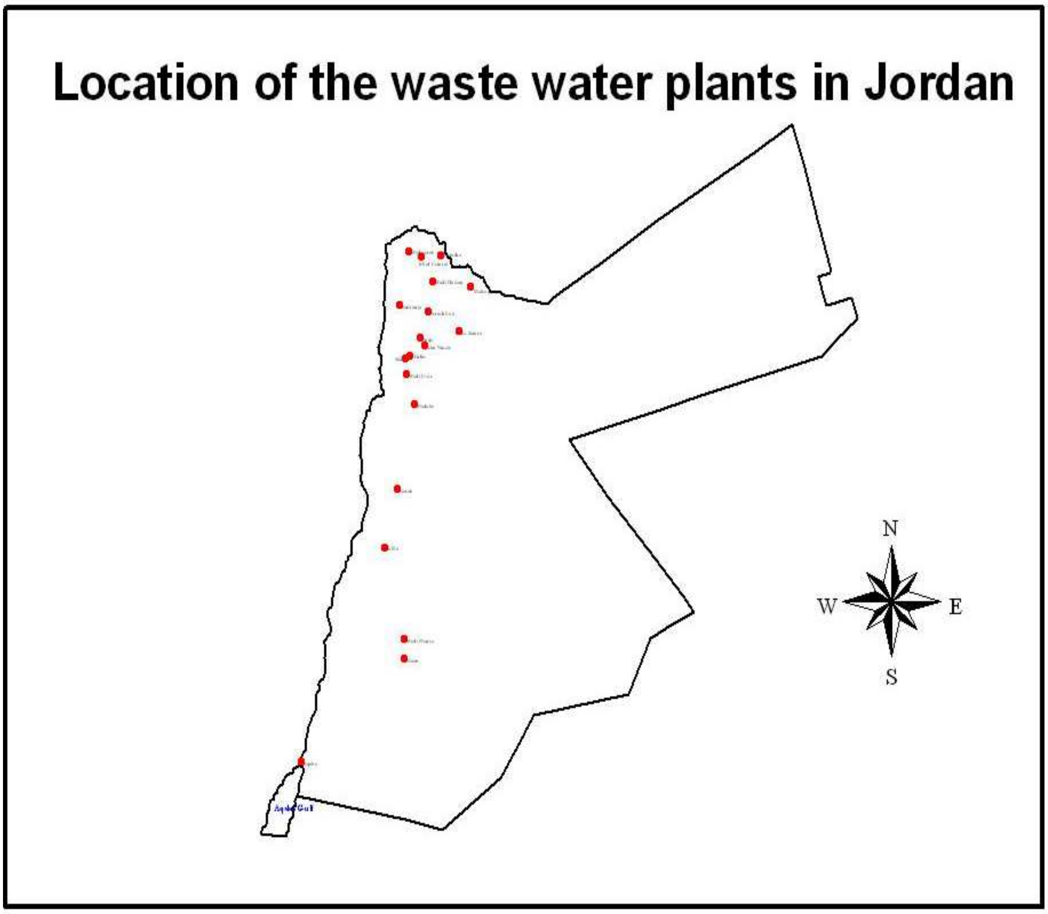
Treated wastewater generated at nineteen existing wastewater treatment plants (Fig. 2) is an important component of Jordan's water resources. Due to the terrain and the concentration of the urban population above the Jordan Valley escarpment, the majority of treated wastewater is discharged into various watercourses and flows to the Jordan Valley where it is used for irrigation. About 85 MCM per year (2003) of treated wastewater are effectively discharged today into the watercourses or are used directly in irrigation.

Wastewater quantity is increasing with the increase of population, increase in water use and the development of sewerage systems. Thus, by the year 2020 when the population is projected to be about 9.9 million and when the percentage of the population with sewerage service will have increased from the current 50 percent today to percentages that will cover most of the townships and cities of the country, about 240 MCM per year of wastewater are expected to be generated.

DEVELOPMENT AND STATUS OF WASTEWATER SECTOR

Wastewater collection has been practiced in Jordan in a limited way since 1930 in the town of Suit. Some treatment was achieved by utilizing primitive physical processes. Mostly, however, septic tanks and cesspits were used with grey water often discharged to gardens. This practice resulted in major environmental problems, especially groundwater pollution. The pollution problems were complicated by the rapid urban growth. The population in the capital city of Amman, for example, increased from 50,000 in 1940 to 800,000 in 1985.

Modern technology to collect and treat wastewater was introduced in the late sixties when the first collection system and treatment plant was built at Ain Ghazal (AGTP) utilizing the conventional activated sludge process. The system consisted of a sewage network that runs by gravity to the lowest point in Amman, where the treatment plant was located and built. The treatment plant was designed to handle an average flow of 60,000 m^3/d with a BOD_5.



loading of 18,000 kg/d, for a population of 300,000. The design effluent standard was BOD_5 20 mg/l. The treated effluent was discharged to Seil Zarqa.

However, due to the high strength of the raw sewage i.e. the BOD_5 of the incoming sewage was greater than 600 mg/1, the effectiveness of the activated sludge process was drastically reduced. Nevertheless, AGTP continued to operate under high organic overloading conditions, which resulted in major operational and environmental problems. As a result, AGTP produced odours that were a source of public nuisance to the surrounding areas. The quality of the effluent of AGTP deteriorated the quality of surface, ground and irrigation water in the region.

Since the year 1980 and during the International Drinking Water and Sanitation Decade (1980-1990), the Government of Jordan carried out significant and comprehensive plans with regard to the different issues of wastewater management primarily related to the improvement of sanitation. About 75% of the urban population and 52% of the total population (at that time) gained access to wastewater collection and treatment systems. This has raised the sanitation level, improved public health, and strengthened pollution control of surface and groundwater in the areas served by wastewater facilities. Presently, there are 19 treatment plants serving most of the major cities and towns in the country. Thirteen facilities are conventional mechanical treatment plants and six employ waste stabilization ponds. About 2.5 million people (nearly 50% of the population) are served by sewerage systems and the effluent quantity is estimated at about 85 million cubic meters per year.

The characteristics of wastewater in Jordan are somewhat different from other countries. The average salinity of municipal water supply is 580 ppm of TDS, and the average domestic water consumption is low (around 70 l/c/day country wide). This results in very high organic loads and in a higher than normal salinity in wastewater. This is particularly applicable to wastewater treated in waste stabilization ponds (85% of the total generated wastewater), where part of the water is lost through evaporation, thus increasing salinity levels in the effluents. In addition, high organic loads impose operational problems where the plants become biologically overloaded with only a portion of their hydraulic loads.

Given the low level of industrial discharges to sewage treatment plants, wastewater in Jordan is comparatively low in toxic pollutants such as heavy metals and toxic organic compounds. It is estimated that 10% of the biological load comes from industrial discharges.

The major receiving streams for wastewater have very low flow with wastewater comprising a significant portion of stream flow. These streams are not used for bathing or fishing. Much of Amman's wastewater treated effluent is discharged in the Zarqa River and is impounded by the King Talal Dam where it gets blended with fresh flood water and is subsequently released for irrigation use in the Jordan Valley.

It is worth mentioning that the increased supply of water to Jordan's cities came about at the expense of spring flows discharging into such streams as the Zarqa River, Wadi Shueib, Wadi Karak, Wadi Kufrinja and Wadi Arab. The flow of freshwater in these streams dried up as a result of increased pumping from the aquifers, and the flow was replaced with the effluent of treatment plants, a process that transformed the ecological balance over time.

Varieties of crops are grown using irrigated wastewater including citrus, vegetables, field crops and bananas. Soil characteristics vary widely from sand to clay. Principal concerns in the use of wastewater for irrigation include its salinity, chloride concentrations, and the presence of faecal coliforms and nematode eggs. Concerns about heavy metals, has not been substantiated but is an area of public concern warranting monitoring.

The Jordanian standards and regulations which specify the quality of the treated effluents allowed to be discharged into wadis or destined for reuse in agriculture, require a secondary level of treatment. Quality specifications follow the WHO guidelines for the safe use of treated effluent in irrigation.

PRESENT REUSE OF WASTEWATER

Irrigation Water Quantities

Table 1 shows the present requirement, resources and deficit of irrigation water in Jordan. Demand is subdivided in main regions (Jordan Valley and Up/Midlands). In 1999 total quantity of irrigation water was about 630 MCM per year (including reuse of treated effluent from treatment plants). The average specific irrigation water demand is roughly 1400 m^3/year/donum in the Jordan Valley and 900 m^3/ year / donum in the Up / Midlands.

Table 1. Total requirement, resource and deficit in irrigation water in Jordan, 1998 (MOWI/WB)

	Unit	Upland/Midland	Jordan Valley	Total
Freshwater	MCM/year	303	253	556
Treated effluent	MCM/year	11	56	67
Total resources	MCM/year	314	309	623
Total requirement	MCM/year	371	460	831
Deficit	MCM/year	57	151	208

Table 2 gives an overview of the irrigation efficiency for surface, sprinkler and drip irrigation, which underlines the meaning, and necessity of an appropriate irrigation method in case of scarcity of water resources, as is the case in Jordan. However, the table indicates that about 60% of the irrigated areas rely on drip irrigation systems.

Table 2. Present irrigated area and overall irrigated efficiency in Jordan (1 donum = 0.1 ha)

Crop	Irrigated area (donum)			Total irrigated area (Jordan)	Jordan Valley	Highlands / Disi / Mudawara
	Surface	Sprinkler	Drip			
Efficiency%	42	68	70			
Vegetables	50,000	13,700	242,000	305,700		
Fruit trees	112,000	---------	105,000	217,000		
Green houses	--------	---------	25,000	25,000		
Field crops	--------	90,500	---------	90,500		
Total	162,000	90,500	372,000	638,200	300,000	330,000

Present Reuse of Treated Wastewater

Table 3 shows the effluent quality the existing wastewater treatment plants with regard to four parameters relevant in the view of the reuse of treated wastewater for irrigation purposes. However, it has to be mentioned that only a few data on fecal coliforms and helminth eggs are available and, therefore, the assessment on the suitability for agricultural irrigation is limited.

Table 3. Effluent quality and suitability for agricultural irrigation (existing treatment plants)

Treatment plant	Effluent quality				Suitability for agricultural irrigation
	Fecal coliforms (1/100ml)*	Helminth eggs (eggs/L)*	BOD5 (mg/L)**	TDS (mg/L)**	
Abu Nuseir	<1,000 (by chlorin.)	>1	17	823	Restricted irrigation
Aqaba	4,700 up to 1 mio.	0	111	879	Restricted irrigation
As Samra	140,000	0	118	1,258	Restricted irrigation
Baqa	2,500	0	80	1.093	Restricted irrigation
Fuhis	15,000	0	11	669	Restricted irrigation
Irbid (Centre)	2,000	>1	51	No information	Restricted irrigation
Jerash (East)	No information	0	33	1,132	Restricted irrigation
Karak	>1,600	0	46	896	Restricted irrigation
Kufranja	No information	0	65	935	Restricted irrigation
Ma'an	16 mio. In Oct 1999	0	118	945	Restricted irrigation
Madaba	>15,000	0	282	1,439	Restricted irrigation
Mafraq	>15,000	0	197	1,284	Restricted irrigation
Ramtha	>15,000	0	239	1,546	Restricted irrigation
Salt	>15,000	0	11	666	Restricted irrigation
Tafielah	No information	0	35	798	Restricted irrigation
Wadi Arab	1,000	0	10	No information	Unrestricted irrigation after chlorine
Wadi Essir	1,600	0	50	1,084	Unrestricted irrigation after chlorine

* Data of 1999 or before, if not available for 1999
** Data of 1999

With respect to the quality criteria of treated wastewater according to Jordanian Standards 893/1995 none of the effluent fulfils the standards for unrestricted use for irrigation. Generally, the limiting water quality parameter is the content of fecal coliform count. For some of treatment plants the effluent approaches the limit of 1,000 fecal coliforms for unrestricted use, but a stable microbiological water quality is not recognizable. For safety reasons a chlorination of effluent should be provided, if used for unrestricted irrigation.

At present restricted irrigation by treated wastewater is practiced at agricultural land close to the treatment plants (inside or in the vicinity pf the plant) and downstream of it along the wadis serving as receiving water for the effluent. About 15,700 donums of cereal, fodder, forest trees and fruits are irrigated. WAJ and the Ministry of Health (MOH) control the reuse, if the irrigated land is inside the treatment plant area, while the Ministry of Agriculture (MOA), MOH and the General Corporation for Environmental Protection (GECP) is responsible for the control outside of the treatment plant area.

Wastewater effluent is reused for unrestricted irrigation at 91,000 donums of agricultural land in the Jordan Valley after mixing with freshwater. Related areas are mostly in the Middle and Southern Valley. Out of this area some 58,000 donums of vegetables are irrigated. Generally, the dilution takes by part of effluent to 3 parts of freshwater. The Jordan Valley Authority (JVA) and the MOH supervise restricted irrigation commonly.

In total more than 100,000 donums are irrigated by treated wastewater effluent of the existing treatment plants (Table 4). Presently, total annual treated effluent quantity reused for irrigation is roughly estimated to 85 MCM. Taking into account total applied irrigation water of 597 MCM/year, the reuse of treated effluent for irrigation purposes is in order of 14%.

Table 4. Areas presently irrigated by treated wastewater in donums (1 donum = 0.1 ha)

Irrigation	Type of crop				Total	Supervision
	Cereal and Fodder[1]	Forest trees[2]	Fruits[3]	Vegetables[4]		
Restricted irrigation close to treatment plant	1,770	3,190	1,700	0	6,660	WAJ & MOH
Restricted irrigation downstream of treatment plant	2,000	500	6,500	0	9,000	MOA, MOH & GECP
Unrestricted irrigation after mixing with freshwater[5]	6,500	1,000	25,000	58,500	91,000	WAJ & MOH
Total	10,270	4,687	33,197	58,500	106,654	

[1] Barely, sudan grass, alfalfa, maize (forage)
[2] Acacia, cassorina, eucalyptus etc.
[3] Olive, citrus, banana and others
[4] various vegetables
[5] Mixing in Jordan Valley

Area of restricted irrigation close to the treatment plants composed as shown in Table 5. The share of As Samra dominates with about 50% of the irrigated areas. Irrigated crops are fodder, olive trees and forests. Fodder is irrigated in particular in As Samra, Kufranja, Madaba, Mafraq and Ramtha. The largest areas of olive trees and forest irrigated are close to As Samra and Aqaba.

Table 5. Areas (donum) and type of crops irrigated on-site at the treatment plants (restricted irrigation)

Plant	Fodder	Olives	Forests	Total
Abu Nuseir		5	2	7
Aqaba		50	1,500	1,550
As Samra	300	1,500	1,500	3,300
Baqa			5	5
Fuhis		10	10	20
Irbid (Centre)		2	5	7
Jerash (East)			5	5
Karak		10	15	25
Kufranja	70	10	10	90
Ma'an	50	20	50	120
Madaba	600	10	20	630
Mafraq	250	30	15	295
Ramtha	500	5	15	520
Salt		10	5	15
Tafielah		15		15
Wadi Arab				
Wadi Essir		20	30	50
Total	1,770	1,690	3,187	6,654

Limits of Irrigation Reuse: Soil Salinity

This problem may develop as a consequent of using saline water or applying excessive non-saline water without providing adequate artificial drainage if natural drainage is not sufficient to percolate excess water deep beneath the root system. In some cases, salinity may develop as a result of using non- saline water, if the volume of irrigation water was not sufficient to meet the leaching requirement of that area. As an example, the drip application of good quality irrigation water in arid areas may lead to salinity build-up due to the absence of natural leaching of the accumulating salts by rainwater.

Salinity per se does not have an adverse affect on soil properties, particularly soil structure. In fact, increasing salinity of irrigation water maintains structural stability. Deterioration in soil structure may develop when utilizing non-saline water of relatively intermediate or high sodicity (SAR>10). In the Jordan areas of soil types other than the vertisols (formerly known as the red Mediterranean soils), deterioration in soil structure may take place even when employing irrigation waters of both low salinity and sodicity (SAR<5). It is for this reason; salinity and sodicity of irrigation waters are considered hand-in- hand in modern approaches. However, these two parameters represent one aspect of the criteria assessment process. Other factors affecting evaluation water quality criteria are:

1. Soil clay content and type: as clay content increases soil becomes more sensitive to the dispersive effect of irrigation water. In addition, the most labile soils are these rich in montmorillonite clay.
2. Soil content of easily weather able minerals like carbonate and gypsum: these soils tend to dissolve some salts of divalent cat ions leading to the enhancement of the subsurface structure against breakdown tendency.
3. Soil content of organic matter: Organic matter enhances stability of soil structure.
4. Soil content of oxides and hydroxides of Al and Fe: These components have a stabilizing effect too.

On the other hand, increasing soil salinity increases crop salt injury and, thus reduces crop yield, if salinity exceeds a certain threshold level. Crop salt tolerance is evaluated by the threshold salinity below which no reduction of crop yield is observed. When soil salinity exceeds the threshold level, relative crop yield declines.

Other Reuse of Treated Wastewater

At present, no industrial reuse worth mentioning is known. Some factories may reuse part of the industrial water on a small scale and mainly for cooling purposes.

Generally, aquifer recharge is not common in Jordan due to the restrictions given by existing regulations, the high demand of irrigation water and the general water scarcity. However, aquifer recharge is practiced to a certain extend by the treated effluent of the Aqaba Wastewater Treatment Plant. It was decided to avoid any discharge into the Gulf to protect the aquatic environment and the quality of seawater. Therefore, the treated wastewater of the plant is partly evaporated and infiltrated at the plant site and partly reused for agricultural irrigation. It is estimated that out of the total inflow to the plant:

1. 25% is evaporated in the facultative and maturation ponds,
2. 30% is used for irrigation, and
3. 35% is evaporated and or infiltrated in ponds.

In several unsealed ponds (downstream of maturation ponds) of a total surface of 200,000 m^2 the treated wastewater is evaporated and infiltrated into the groundwater. These ponds are mostly arranged in series so that the water quality is by far better than the one measured at the outlet of the maturation ponds.

CONSIDERATION ON SECTOR POLICY

The Ministry of Water and Irrigation prepared a Water Strategy for Jordan. It was adopted by a joint session of the Board of Directors of both the Jordan Valley Authority (JVA) and the Water

Authority of Jordan (WAJ). The Council of Ministries approved the strategy in 1997. Under the strategy, the Ministry and its two authorities formulate a series of the following policies.

Irrigation Water Policy

The policy paper No. 2 “Irrigation Water Policy” of February 1998 details the long-term objectives outlined in the Water Strategy of Jordan. It states water related issues of resources development: agricultural use, resource management, technology transfer, water quality, efficiency, cost recovery, management and other issues. In the following paragraphs such issues are summarized, which are of particular significant for the reuse of treated wastewater for agricultural irrigation.

Under the heading “Resource development and use” it is outlined that wastewater is a resource and cannot be treated as “waste”. It shall be colleted and treated to obtain a water quality that allow its reuse in irrigation unrestricted by health and public health considerations or unduly constrained by high salinity contents. After satisfying the local municipal and industrial needs from uncollected water resources, water resources shall be allocated to agricultural production including livestock. This means that in case of reuse of treated wastewater priority should be given to industrial use in comparison to agricultural use.

Advanced methods as drip irrigation, micro-sprinkler irrigation are favoured over less efficient methods. Night application of irrigation water, especially in the dry season, shall be encouraged to reduce evaporation losses. Programs shall be prepared to raise the public and farmers’ awareness of the availability of irrigation water, its rational and economic use and on the impacts of its quality.

Under the title “Irrigation water quality” it is said, where marginal quality water, such as treated wastewater effluent, is a source of irrigation water, care should be taken, to the maximum extend possible, to have the quality improved to standards that allow it to use for unrestricted irrigation. This can be achieved through blending with fresher water sources.

The water price shall at least cover the cost of operation and maintenance, and, subject to some other constraints, it should also recover part of the capital cost of the irrigation water project. The ultimate objective shall be full cost recovery subject to economic, social and political constraints. Part of the capital cost shall be recovered through the application of a one-time charge against irrigation rights. This is applied as a rate per unit area of the irrigated farm. The size of the portion thus recovered shall not be less than half the irrigation network development cost.

Wastewater Management Policy

The following paragraph summarizes present policy as stated in the Policy Paper No. 4 “Management of Wastewater” of June 1998.

In order to develop a Wastewater Management Policy, the following represent the key issues under consideration:

1. Provision of adequate wastewater collection and treatment facilities for all the major cities and towns in Jordan.
2. Protection of the environment and public health in the areas affected by the proposed systems, especially, surface waters and ground waters.
3. Consideration of treated effluents as a source for irrigation reuse.
4. Improvement of the socioeconomic conditions in the areas to be served by the proposed systems.

The policy focuses on the management of wastewater as a water resource and includes, amongst other, development, management, wastewater collection and treatment as well as the reuse of wastewater and sludge in the agriculture, pricing, selected priority issues, standards and regulations.

Wastewater shall be collected and treated in accordance with WHO and FAO Guideline as the basis for effluent quality requirements for reuse in irrigation. The use of treated wastewater in irrigation (unrestricted irrigation) shall be given the highest priority and shall be pursued with care.

Industrial wastewater shall be recycled as much as possible within the factories. Industrial shall treat the remainder of wastewater to meet the standards/regulations set for the ultimate wastewater reuse for its disposal through the collection system and/or into receiving environment.

Sludge from treatment plants shall be used for power generation, if proven technically, economically and financially feasible. It shall be processed so it may be used as fertilizer and soil conditioner for agricultural purposes.

Generally, the “polluter pays” principle shall be applied. Wastewater charges, connection fees, sewerage taxes and treatment fees shall cover at least the operation and maintenance costs. The ultimate aim is for full cost recovery. Treated effluent shall be priced and sold to end users at a price covering the operation and maintenance costs of delivery.

Through private sector participation, management of infrastructure and services shall be transferred from the public to private sector, in order to improve performance and upgrade the level of services.

Water Utility Policy

According to the Water Utility Policy of July 1997 the Government intends through private sector participation, to transfer infrastructure and services from the public to the private sector, in order to improve performance and ensure the delivery of services to the population. The private sector shall be involved through management contracts, concessions and other forms in water utilities. Private sector activities shall be continually monitored and assessed. In accordance with formulated Water Utility Policy, WAJ has embarked on a course of increasing private sector participation for both capital investment and management of services.

The Ministry will set municipal water and wastewater charges at a level, which will cover at least the cost of operation and maintenance. It will also move towards the recovery of all part of capital costs of water infrastructure.

Under point 6 of the Water Utility Policy paper it is said that the Ministry intends to raise the effluent quantity of wastewater treatment plants from 60 MCM per year 1997 to a volume of 200 MCM in the year 2020. In light of this, the Ministry is developing a wastewater master plan, which will establish targets for providing wastewater collection systems and treatment facilities to not yet serviced areas throughout the country.

Privatization of Jordan’s water sector has started with as water and wastewater management contract (support by World Bank) for Greater Amman. Contract was awarded to LEMA, a consortium of Suez Lyonnaise des Eaux- Montgomery Watson Arabtech Jardaneh. The consortium has started work in 1999. The contract comprises retail water supply including wastewater collection for the Greater Amman area. It does not include pre-treatment in Ain Ghazal, conveyance of wastewater to the plant in As Samra and its treatment by this plant.

RECOMMENDATIONS FOR IMPROVEMENT OF EXISTING WASTEWATER TREATMENT AND DISPOSAL

General

Non-operational treatment of facilities should be repaired as soon as for two main reasons, i.e. to improve the treatment efficiency and to avoid further harm to the existing facilities. For example the trickling filters in Irbid Central Treatment Plant needs urgent repair to reach required treatment efficiency to fulfill the requirement set ion the Jordanian Standard JS893/1995 for wastewater effluents.

Obviously, the *coverage (connection rate to the collection network) may be increased* by the construction of new house connections within the existing sewered areas to optimize the use of the existing collection network. Potential of increase seems possible in particular in those towns, where at the same time the sewer lengths per connected capita is high and coverage rates are low. This is in particular in the towns of Fuhis, Mafraq and Tafielah. For these towns (but also for the others) it should be studied whether and how the more houses may be connected to the already existing sewer network. It has to be mentioned that the degree of use (hydraulic) of the treatment plants of Fuhis and Mafraq are rather low 42 and 53% respectively. Therefore, it is supposed to increase wastewater quantity collected, treated and finally available for reuse without major investments.

Presently, not the total effluent of treatment plants is reused for agricultural irrigation. A certain quantity is still discharged unused to the receiving water (wadis). In addition, the local reuse of effluent *should be improved and maximized* to avoid additional losses of effluent along the flow in the watercourses.

There are several treatment plants operating close or above their design capacity. Adequate measures are undertaken for all of these plants except of the *extension of overloaded plant of Ma'an*. Due to the fact that Ma'an Treatment Plant operates hydraulically at 10% more than its design capacity, this plant calls for urgent upgrading/expansion.

Institutional

According to the policies and strategies the reuse of wastewater for irrigation purposes is one of the declared political objective. However, until now there is no clear attribution of the responsibility for implementation and operation of wastewater reuse facilities. Usually, the reuse facilities including irrigational infrastructure (if any) were implemented as part of the wastewater project under the responsibility of the MWI. On the other hand the MOA is responsible for agricultural irrigation and irrigation water quality. It carries out research projects in field of wastewater reuse and its effect on crops. So, *existing overlapping and/or vacant responsibilities* in matter of wastewater reuse for irrigational purposes should be cleared away.

Design

All sewerage systems are designed as separate systems. Nevertheless, a certain quantity of storm water (e.g. through uncovered manholes or wrong connections) penetrates into the sewage collection network. Therefore, every sewerage system should dispose of a *storm water overflow structure* to divert the discharge exceeding the hydraulic capacity of the treatment plant.

The degree of use of a treatment plant should be between 50 and 100%. For example the plant of Jerash is used by less than 50% even the extended plant is in operation since 1990. In this case efforts should be undertaken to *increase the connection rate* of the houses to the sewerage network.

Adequate design criteria should be established for every project based on general experience. For example the depth of 5m for a maturation pond (e.g. Jerash) is not adequate, if the pond shall serve for tertiary treatment.

The efficiency of several primary or secondary settlings tanks is not satisfactory, because only a portion of the related overflow weirs is charged. *Vertically adjustable overflow weirs* would allow easily solving the problem. Triangular openings of fixed weirs have to be deepened to reach a regular charge of the settling tank (e.g. Jerash).

In case of wastewater stabilization ponds an *overflow weir to stabilize the water leveling the upstream pond* should control the discharge from one pond to the next. Some of the pond systems dispose only of connection pipes close to the bottom, which allows to a broad range of water levels leading to miss-manipulations (e.g. Ramtha).

Ponds have to be designed in a manner that *dead zones of the water surface* are avoided. This criterion is important for the design of the pond's form and arrangement of the inlet and outlet structures (e.g. Jerash).

The recently prepared studies on wastewater treatment recommend *sand filtration as tertiary treatment* in order to improve effluent's quality for agricultural reuse. Granular media filtration involves the passage of water through a bed of filter media with resulting deposition of solids. Eventually, the pressure drop across the bed becomes excessive or the ability of the bed to remove suspended solids is impaired. Cleaning is then necessary to restore operating head and effluent quality. The time in service between cleanings is termed the run length. Filter run lengths are between 8 and 48 hours. The head loss at which filtration is interrupted for cleaning is called the terminal head loss (about 1.8 to 4.5 m) and this is maximized by the judicious choice of media sizes.

Gravity filters operate either using the available head from the previous treatment unit, or by pumping to a split box after which the wastewater flows by gravity to the filter cells. Pressure filters utilize pumping to increase the available head. Normally filter systems include multiple filer compartments. This allows for the filtration system to continue operating while one compartment in being backwashed.

A filter unit generally consists of a containing vessel, the filter media, structures to support the media, distribution and collection devices for influent, effluent and backwash water flows, supplemental cleaning devices and necessary controls for flows, water levels and backwash sequencing. Backwash sequence can include air scour or surface wash steps. Backwash water can be stored separately or in chambers that are integral parts of the filter unit. Backwash water can be pumped through the unit or can be supplied through gravity head tanks.

Generally, filtration is applied to remove residual biological flocks in settled effluents from secondary treatment and removal of residual chemical-biological flocks after alum, iron or lime precipitation in tertiary or independent physical-chemical wastewater treatment. Efficiency of filtration is highly dependent on consistent pretreatment quality and flow modulations. Increasing solids loading will reduce run lengths.

As can be concluded from the facts outlined above sand filtration is a cost intensive, susceptible technology requiring qualified staff in comparison with polishing by maturation ponds as tertiary treatment step. In Jordan where tertiary treatment is applied to improve effluent quality for reuse in agricultural irrigation, the following reasons do not favor the application of sand filtration:

1. Filter head loss may need pumping upstream or downstream of the filters.
2. Filer cleaning equipment (air blower and pumping for backwash water) requires energy.
3. Initial investment and reinvestment cost (for electromechanical equipment) are high.
4. Operation and maintenance of filters is costly due to requirements of energy, spare parts for electromechanical equipment, additional staff etc.
5. Operation and maintenance of filters requires well trained staff.
6. Growth of algae at surface of the filters could lead to difficulties for filter operation.
7. Filtration will reduce the content of suspended solids to 5-20 mg/l. However, elimination of microbiological pollutants (fecal coliform counts) will be limited and will not be enough to reach 1,000 fecal coliforms per 100 ml as required for unrestricted irrigation.
8. Backwash water (about 5-10% of the through put) has to be either returned to the head of the plant increasing the hydraulic load accordingly or discharged in the receiving water leading to a loss of water for reuse.

Taking into account the presented specific conditions, water polishing by maturation ponds seems the preferable solution for tertiary wastewater treatment instead of sand filtration. However, if the MWI or the WAJ insists to use sand filtration, it is recommended to apply at one treatment plant sand filtration (as pilot project) and gain some practical experience with the operation of sand filtration units rather than to implement such facilities in every new treatment plant.

Operation

Every type of treatment plant has a *specific mode of operation*. To each treatment plant belongs a manual, where the mode of operation is described. The specified instruction has to be followed. This is in particular true e.g. for the plants in Ramtha and Mafraq. At these plants the ponds are more or less operated as holding tanks.

In general, all inlets and outlets of ponds have to be used in order to get a regular charge of the entire water surface i.e. to avoid dead zones of ponds, which reduce their efficiency (e.g. Karak).

Most of the treatment plants are overstaffed and the share of staff cost for wastewater treatment amounts to some 40% of the total cost for operation and maintenance. If the staff members would be reduced the cost for operation and maintenance could be reduced by 20%.

In addition to the more technical recommendations the following recommendations concern the wastewater sector, i.e. sewage collection, treatment and reuse:

1. Responsibilities for implementation and operation of wastewater reuse schemes (in particular, as far as local reuse close to the related treatment plant is concerned) have to be clearly attributed to one authority.
2. Environmentally safe reuse of treated wastewater from treatment plants should be actively promoted by a research and extension effort coordination between WAJ, JVA, and the MOA, working with farmers' groups.
3. A wastewater treatment and reuse management strategy has to be formulated to guide a more commercial approach to the use of reclaimed water for irrigation and other purposes.
4. The proposed wastewater strategy shall be developed with full consideration of the environmental impacts of wastewater, and provide for expansion of the sewerage system where this can be economically and financially justified, taking into account the benefits of reuse and environmental improvement.
5. A strategic plan and priority investments be developed for the reclamation and reuse of wastewater.
6. Capacity and efficiency of wastewater treatment plants, especially Al Samra should be augmented to meet projected wastewater quantities of adequate quality for agricultural and/or industrial reuse.

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