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WASTEWATER TREATMENT AND WATER REUSE TECHNOLOGIES FOR SUSTAINABLE WATER RESOURCES: JORDAN AS A CASE STUDY

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Abstract

Due to the escalating water demands, in addition to sever water shortage, Jordan has done the most, making reuse a priority in their national water resources strategy. The waste stabilization ponds (WSP) represent the most economical method for wastewater treatment. For these reasons, many treatment plants were built in Jordan Since 1984 where more than 78% of all wastewater discharges had been treated in WSP. Recently, most of these plants were changed to mechanical technologies. The present study aims to evaluate the efficiency of the existing wastewater treatment technologies and to determine the necessity of modified systems. In addition, 80 samples of wastewater collected from the wastewater treatment plants (WWTP) inlet and outlet, analysed for BOD, COD, TSS, and NH_4 parameters. Ramtha WWTP was chosen a case study to assess the environmental impact of using modern technologies. Results indicated that the existing treatment plants are facing over hydraulic and organic loads, which cause significant deterioration in their efficiencies. Most of the plants are incapable to achieve the required standards for water reuse. The modern technologies provided high removal efficiencies, better control of odours, operation flexibility, and lower environmental load. Modern treatment technologies can create additional water resources, which is very important parameter in Jordan's water budget. Adequate design, using modern treatment technologies, enacting stricter regulations and better management of urban and rural waste will create more than 200 million cubic meter per year of treated water, which can be reused for irrigation.

Keywords: wastewater, treatment, water reuse, wastewater technologies, reuse standards

1. INTRODUCTION

In last few years, Jordan suffered from variable and heavy migration, lead to dramatic population growth rate side by side with rapid economic development. The issue of increasing the water demand floated

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significantly, in the light of the limited and decreasing available water resources. Jordan is considered among the lowest per capita countries in terms of water resources. The available water from renewable sources will be less than 80 m^3/capita/year by the year of 2025, which is far lower than the international recognized water poverty line indicated as 1000 m^3/capita/year [1]. Therefore, the Government of Jordan had to look for new sources for water to compensate the great drop between the increasing demand and the obtainable water resources. Wastewater reuse could be an alternative solution to achieve for this purpose [2].

Currently, the reuse of reclaimed wastewater is an international practice, which is promoted the development of wastewater and secondary effluent treatment technologies [3-5]. In addition to the principal objective of wastewater treatment in prevent pollution of the receiving watercourse, and protect human health and the environment it aims to achieve the required water quality for reuse. Reclaimed wastewater is applied on soil, on cultivated as well as marginal areas in various facilities, in irrigation, industry, and for ground water recharge [6-9]. The integrated and safe application of the reuse of reclaimed wastewater dictates the development of a comprehensive environmental plan. All parameters relative to such reuse should be taken into consideration including qualitative characterization of wastewater as well as examination of physical-chemical and environmental properties of all applications on soil, plants, building installations, and pipes [1]. The degree of required treatment is determined by the beneficial uses of the receiving stream, lake, and reuse for different purposes [11]. Therefore, the investigation of the characteristics of the reclaimed wastewater is necessary for evaluating its suitability for reuse.

Jordan is regarded as a leading country in the region in terms of wastewater treatment activities. Jordan hosts as many as 23 municipal treatment plants distributed all over the country and serving major towns and cities. Wastewater treatment plants provide service to about 68% of the Jordanian population. The total inflow to all the 23 plants 300,000 m^3/d, of which about 250,000 m^3/d inflows to As-Samra wastewater treatment plant (ASTP) which is regarded as the main treatment plant [1]. Jordanian standards for reclaimed wastewater (JS893/1995) try to regulate both water reuse and environmental discharges. Jordanian standards allow discharging treated wastewater to valleys and streams when it meets the specific criteria for many parameters such as BOD, COD, TSS, Ecoli bacteria, and Helminthes eggs. In the present time, the reclaimed wastewater is used for restricted agriculture either near the plants or downstream after mixing with natural surface water [12]. In Jordan each year more than 75 million m^3 of the reclaimed water representing about 10% of the total national water supply is used directly or indirectly. This percentage is expected to increase the share to more than 15% within the next 30-35 years [13, 14]. Therefore, water reuse is considered an attractive option for increasing the available water resources of Jordan [1, 12, 13].

As the water demand have grown, it has become more important to produce cleaner wastewater effluents. The demand for cleaner discharges could be achieved through using modern technologies to remove pollutants from wastewater treatment plants [15]. New technologies have made growing numbers of wastewater treatment alternatives available. International cooperation and joint efforts in this sector are necessary to set up common goals and strategies and to determine how the environmental work should proceed to be most efficient. When considering technology transfer between countries, which aims at improving management frameworks, it is important to recognize the differences between host and donor countries. Many environmental projects in Jordan, especially in the wastewater treatment sector, are supported -financially and technically- by developed countries. In order to optimize the benefits of this cooperation, it is important to import the modern technologies from these developed countries. This paper aims to evaluate the efficiency of the existing wastewater treatment technologies and to determine the necessity of modified systems.

2. METHODOLOGY

The Water Authority of Jordan (WAJ), carry regular measurement campaigns performed for all wastewater treatment plants [16] collect daily samples, carries out detailed data of wastewater characteristics, operating procedures, including the adopted method of treatment for all plants in Jordan. The samples analysed in this study represent sampling data from raw and treated sewage collected from the inlet and outlet of the treatment plants. Calculating and analysing the overall efficiency indicators based on monthly concentration average for each plant.

Eighty samples were taken from As-Samra (ASTP), Irbid (ITP), Ramtha (RTP), and Wadi Hassan (WTP) wastewater treatment plants to determine the characteristics of wastewater. The selected plants treat about 85% of the Jordanian domestic wastewater and provide service to more than four million inhabitants [16]. Ramtha wastewater treatment plant was chosen as a detailed case study to assess the environmental impact of using such modern and advanced technology.

BOD and COD parameters are considered as sensitive parameters usually used to determine the characteristics of any municipal wastewater. However, total suspended solid (TSS), ammonium (NH_4) and phosphorus (P), which are used for comparison purposes, are not less importance. Representative samples were collected very carefully to avoid any possible contamination or contact with air using ice-bounded plastic containers. The adopted samples collection procedure took into consideration the frequency at different sessions in order to obtain the best compassion on the light of the variable conditions. The collected samples were directly transferred to Al-Huson University College laboratory, Al-Balqa Applied University and stored at 4^oC in a refrigerator. The analyses of the collected sample were performed and conducted within 24 hours form the time of collection. Samples collected, preserved, transported, incubated, prepared and analysed in accordance with the Standards Methods for Examination of Wastewater and Water [17].

3. RESULTS AND DISCUSSIONS

3.1 The used technologies

Among the 23 municipal wastewater treatment plants of Jordan, four only are stabilization ponds, were as 16 use mechanical techniques, whereas three are used for the treatment of delivered domestic septic wastes. Table 1 shows the adopted technologies used for treatment of wastewater in Jordan. Seventy eight percent of the collected wastewater is treated naturally using stabilization ponds techniques, depending on the activity of algae and bacteria and other plants found in ponds. Such activities consumer replenish with the increasing of temperature and sunshine period. Therefore, the treatment is strictly climate dependent, with remarkably low efficiency of the plants, particularly in winter season. Almost all the active stabilization ponds in Jordan are over loaded from hydraulic and organic load point of view, which is considered an additional reason for efficiency degradation [18]. The activated sludge possess many advantages in less space areas than lagoon and higher removal efficiency with minimum flies and odours concentrations. However, the activated sludge processes are more costly to operate in comparison with attached growth and lagoon process, probably due to higher energy combustion required to run the aeration system [15]. Despite the fact that the construction, operating, and maintenance costs are considerably lower, yet the use of pond systems is restricted to areas with plentiful land available.

Table 1. Served areas and treatment facilities and applied technologies in wastewater treatment plants in Jordan

No.	Plant Name	Treatment Type	Design Hydraulic Load	Actual Hydraulic Load	Region
1	Al-Khirba Al-Samra Treatment Plant	Activated Sludge & Centrifuge	367,000	330,000	Parts of Amman, Zarqa Governorate, Ruseifa, Hashmiya, Hattin Camp, Shlner
2	South Amman Treatment Plant	Activated Sludge & Centrifuge	52,000	12,500	South Amman
3	Irbid Central (Fuara) Treatment Plant	Activated Sludge + Biological Filter	11,300	6,363.7	Irbid City
4	Old Aqaba Treatment Plant	Natural Treatment	-	-	Aqaba City
5	Aqaba Mechanical Treatment Plant	Activated Sludge	-	-	Aqaba City
6	Salt Treatment Plant	Activated Sludge	7,700	4,481.7	Salt City
7	Jerash Treatment Plant	Aeration Basins + Activated Sludge	-	-	Jerash City, Souf Camp
8	Mafraq Treatment Plant	Natural Treatment	1,800	1,990.8	Mafraq City
9	Ein Al-Basha Treatment Plant	Activated Sludge + Biological Filter	14,900	-	Baqaa Camp, Safout, Ein Al-Basha, Suwaylih
10	Karak Treatment Plant	Umhoff Tanks + Biological Filter	785	1,550.5	Karak City, Al Marj, Al Thalaja
11	Al-Lajoun Treatment Plant	Mechanical Treatment	1,000	518	Karak by Tankers
12	Muta Al-Adnaniya Treatment Plant	Activated Sludge	-	-	-
13	Abu Nusair Treatment Plant	Activated Sludge	4,000	2,357.6	Abu Nusair Housing
14	Tafilah Treatment Plant	Umhoff Tanks + Biological Filter	1,600	870	Tafilah City
15	Ramtha Treatment Plant	Activated Sludge	-	3,392.6	Ramtha City
16	Ma'an Treatment Plant	Activated Sludge	-	-	Ma'an City
17	Madaba Treatment Plant	Activated Sludge	7,600	4,711.3	Madaba City
18	Kufranjeh Treatment Plant	Activated Sludge	1,900	3,930.5	Kufranjeh, Anjara, parts of Ajloun
19	Wadi Al-Seer Treatment Plant	Natural Treatment with Aeration Basins	4,000	3,113	Baidar Wadi Al-Seer
20	Fuhais and Mahis Treatment Plants	Activated Sludge	2,400	1,791.8	Fuhais and Mahis Cities
21	Wadi Al-Arab (Duqra) Treatment Plant	Activated Sludge	-	-	-
22	Wadi Musa Treatment Plant	Activated Sludge	-	-	-

23	Wadi Hassan Treatment Plant	Activated Sludge	-	-	Al-Na'ima, Martyr's Camp
24	Al-Akider – Liquid Waste Landfill Treatment Plant	Natural Treatment	-	-	Tankers from the Northern Sector
25	Tel Al-Mantah – Liquid Waste Landfill Treatment Plant	Activated Sludge + Biological Filter	400	290	Tankers from Deir Alla Area
26	Al-Marad Treatment Plant	Activated Sludge	-	-	-

It is worth mentioning that in Jordan, all the operating waste stabilization ponds should be converted to mechanical mode such as activated sludge, MBR, or SBR [18]. In order to obtain better water quality and higher treatment efficiencies, the developed countries used modern technologies such as sequencing batch reactor (SBR), and membranes. For example, in Germany, treatment plants operating as activated sludge mode represent about 56%, adopt stabilization ponds occupy about 13%. Yet 4% of the treatment plants using sequencing batch reactor methods (SBR), whereas, 2% as trickling filters and 25% operated by either wetland and membranes or other multiple methods techniques [19]. Significantly, SBR technology gained reputation through the past years because of the single tank design and simplicity of automation. Several international studies indicated that the productivity and flexibility of such technology, due to its capability of treat different kinds of effluents under different conditions [20]. Membrane technologies are expected to become the chief treatment technologies in the coming near future. Taking into account that membrane techniques cost of modules drops. Therefore, membrane techniques become progressively more feasible, especially in the case of large capacity systems [21].
In the developed countries, the construction process of any newly developed treatment facility, the preferred technology is designed on the bases of the expected effectiveness. Modern technologies are used such as membrane or multi treatment stages of high quality in case of sensitive water bodies [19].

3.2 Efficiency of wastewater treatment plants

The existing wastewater treatment plants are facing overloads due to news connections and continuous expansion of the served urban areas. The efficiency of these plants may depreciate, and the effluent water may become less complying with reclamation standards. The average removal efficiencies of BOD, COD, NH_4, and TP are 93.8, 89.8, 58.9, and 24% respectively. According to the Jordanian standards (JS893), 14 plants could not achieve the allowable effluent limit of BOD, COD, and TSS. Majority of the operating treatment plants do not have any clear process to remove nitrogen contents leading to higher concentration of ammonium on these plants effluent. Concerning NH_4 limitation, only five plants meet the terms with Jordanian standards of water discharged to the streams.

Based on flow parameter, only 21.8% of the influent flow is treated effectiveness and match the Jordanian standards. Result also indicates that the generated organic load by 78% of the population is not condensed to the allowable limit. Mechanical treatment plants (trickling filter and activated sludge) obtained higher BOD,COD, TSS elimination efficiency, while lower efficiency was achieved by waste stabilization ponds (As-Samra, Mafraq and Maan) as shown in figures 1-3.

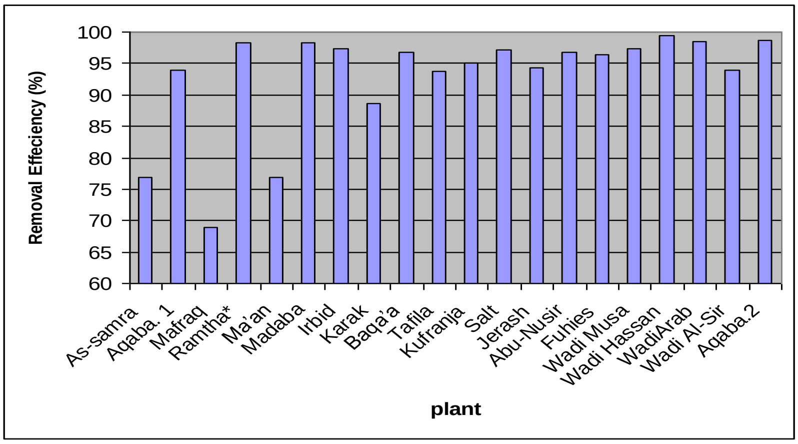

Fig. 1. Efficiency of wastewater treatment plant for BOD removal

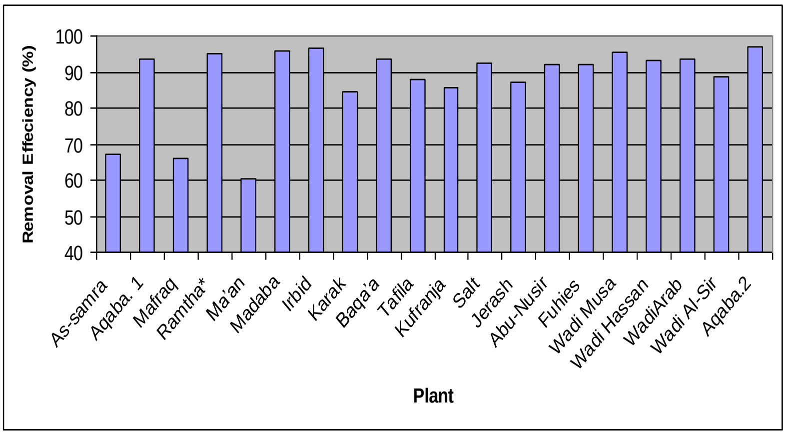

Fig. 2. Efficiency of wastewater treatment plant for COD removal

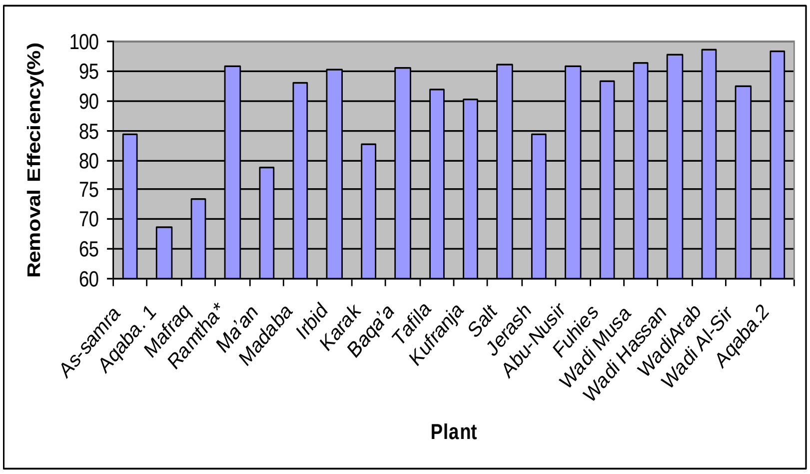

Fig. 3. Efficiency of wastewater treatment plant for TSS removal

3.3 Environmental pressure of WWTP

Jordan does not have regional or local rivers, so the effluent from most wastewater treatment plants is discharged to wades surrounded on both sides by land used for agriculture, and joins surface water flowing into natural streams. Because the receiving streams have very low flow, the high quantity with low quality of treated wastewater discharged from the centralize treatment plant cause high environmental load on these streams. About 76% of the treated wastewater is discharged to the Zarqa River, which is mixed with other river's tributaries along the river leading to significant improvements in its quality, yet the expected pollutants concentration remain higher than the allowable Jordanian standards [22, 23]. The discharged water from the treatment plant could travel for a long distance to reach the final use locations, so this water stays in contact with the environment for a long time. For example the discharged from As-Samra plant flows about 40 km to reach the King Talal dam which causes significant deterioration in the environmental systems along the river. In addition to the effect of the discharged water on the surface environment, it has a significant effect on groundwater quality in the receiving basin [23-26].

3.4 Water reuses efficiency process

The amount of the treated and collected wastewater is estimated to increase considerably with the drastic growth of population, quick urbanization, and development of sanitation service coverage. The treated wastewater increased from 59 million cubic meters (MCM) in 1994 to more than111 MCM in 2006 [16], represents about 15% of agricultural water requirements. The increase in water demand in the light of the limited resources enforced Jordan to overlook for new water resources techniques in order to decrease the breach between the available sources and the required demand. Treated wastewater reuse is considered as a promising option to achieve this goal. Conducted studies indicated that the effluent from activated sludge treatment plants obeys the Jordanian standards for unrestricted uses while it is not appropriate for unlimited irrigation and further advance treatment is required before reuse [1]. Most of the activated sludge plants consist of screening, settling chamber, sedimentation, biological aeration tank, secondary sedimentation, and disinfection. Some of the plants have infiltration system such as Ramtha and central Irbid treatment plants. According to the Jordanian Standards it is prohibited to use any reclaimed water for irrigating edible raw vegetables, but it is permitted to use it for irrigation of cooked vegetables, parks, playgrounds, fruit trees, field Crops, industrial crops and forest trees (JS893/2002). Table 2 illustrate the Jordanian standards for water reuse.

Table 2. Jordanian standards for water reuse

Parameter	Cooked vegetable, parks,	Fruit trees, landscaping.	Field crops, forest trees	Discharge to wadies, stream, water bodies	Groundwater recharge
BOD,	30	200	300	60	15
COD	100	500	500	150	50
DO	>2	-	-	>1	>2
TSS	50	150	150	60	50
pH	6-9	6-9	6-9	6-9	6-9
NO_3	30	45	45	45	30
TN	45	70	70	70	45
E.Coli.	100	1000	-	1000	<2.2
Intestinal helminths Eggs	≤1	≤1	≤1	≤1	≤1
All in mg/l, except pH in unit, E.Coli in MPN/100ml, Intestinal Helminth in egg/l.					

Annual report of the Jordan Water Authority indicates that the treated wastewater is actually reused to irrigate about 1000 hectare of restricted (forest, fodder, industrial crops, and grains) and unrestricted crops (vegetable eaten raw, public parks) respectively [16]. Most of the treated water is discharged to the wades and then used for irrigation in the downstream areas after it is mixed with other sources, while small amount is reused within the plant's vicinities. In 2020, the treatment plants treat more than 200MCM, of which 196MCM are reused represents 98% of the treated water. In all plants, water is reused directly within the plant vicinity or indirect downstream of the plant [27].

3.5 Possibilities of using of modern treatment technologies

Results indicated that the discharged wastewater from treatment plants is not appropriate for unlimited irrigation and it needs further advance treatment to fulfil the requirements. Advanced treatment could be achieved by modern technologies. The following points explain the importance and necessity of modern technologies in wastewater treatment plants [28, 29].

1. The present situation with low treated water quality, a high quantity of pollutants are discharged to a certain location and travels long distance which cause contamination for soil, water, and ecosystem especially in Zarqa basin. Modern technologies can improve treatment efficiency and minimize the pressure on the receiving watercourse and environment [29-32].
2. Modern technologies of stabilization ponds will create additional water resources, which is very important in Jordan's water budget. Adequate design, treatment, and management of municipal waste will create more than 200 MCM/y of treated water. As wastewater is purified to higher degrees, deploying such advanced treatment processes may lead to use the effluents more safely for urban, landscape and domestic agricultural irrigation, industrial cooling and processing, recreational uses and water recharge. Adequate treatment could be achieved by many applied technologies such as the SBR and MBR. Both technologies (MBR and SBR) showed high performance in wastewater treatment plants, and the effluent water is suitable for reuse. SBR has lower energy consumption in comparison with MBR, while MBR require smaller area. Regarding sludge retention time, MBR system requires less than SBR, and it is considered as a cost effective. For this reason, water authorities are looking to apply SBR in the new plants [31-34].
3. Advanced treatment technologies can be breathing room for conservative secondary biological treatment to further stabilize oxygen-demanding substances in the wastewater, or in order to eliminate nitrogen and phosphorus through modern technologies such as SBR [14, 33, 34].
4. Land-dwelling techniques implement nutrients limited in wastewaters. By using terrestrial or land treatment systems, plant growth and soil adsorption convert biologically available nutrients into less forms of biomass, It is harvested for a variety of usages, such as alcohol manufacturing, methane gas generation and/or cattle feed enhancements. Land-dwelling treatment techniques include very slow rate subsurface infiltration; rapid infiltration methods and slow rate overland flow [14, 34].
5. Modern technologies can reduce the evaporated water from waste ponds and lagoons.

3.6 Case study of modern treatment plants: Ramtha wastewater treatment plant

3.6.1. Description of the old plant

The old plant at Ramtha utilized waste stabilization ponds (WSP) as treatment method to cope with influent raw wastewater. The WSP plant occupies 180,000 m^2 and lies within 2 km to the north of Ramtha city. The plant was constructed and put in operation in 1987. The plant was designed to serve a population of more than 28,000 inhabitants, with an estimated flow of 2340 m^3/d and a current organic load of about 7000kg/d. The WSP at Ramtha consisted of two trains in parallel, each consisting of one aerobic pond, three facultative ponds connected in series and two maturation ponds in series, all together to achieve the preliminary, primary, secondary and tertiary treatment of incoming wastewater. It was anticipated that the ponds would achieve an effluent quality in accordance to WHO guidelines: average BOD_5 = 30 mg/l, average SS= 30 mg/l and average, Faecal Coliform (FC) count < 1000/100 ml.

3.6.2 Performance of the old plant

After completion and during 1987 to 1988 the flow into the ponds was only 600 m^3/d. The flow increases slightly during 1989 and 1990 to reach a maximum of 1200 m^3/d. Water losses throughout the ponds were as high as 42%. Organic loadings fluctuated considerably throughout the following months of start-up. The specific characteristics of influent wastewater in year of 2000 is illustrated in table 3 .The plant, in general, has a performance below expectations in terms of efficiency and effluent quality. The quality of the treated effluent has deteriorated to a level where the long-term average of BOD_5 concentration regularly exceeds 260 mg/l and that for TSS more than 200 mg/l. These levels are by far above the levels of 50 mg/l required by Jordanian standard JS/893/1995. Removal efficiencies of BOD and TSS were 79 and 80% respectively. The efficiency of COD removal was about 75%. However, it is clear that the effluent contained very high concentrations of COD. Surprisingly a high concentration of ammonia was present in the effluent of the ponds, which means that no nitrification was taking place within the ponds. This attributed to a number of possible reasons, such as the strength of the received sewage and the lack of enough oxygen. It was noticed that Chlorophyll concentrations at the facultative ponds were very low, which reflect minimal algal production potential. This Phenomenon affected the metabolic processes in the system such as nitrification and BOD_5 removal. Due to the long retention times and large surface areas; evaporation losses can be very high. Depending on the soil conditions, infiltration losses can also be high, unless mitigated by using clay or synthetic liners. Odours and nuisance insects can also cause problems [28, 30]. It is clear that this method of wastewater treatment, especially at such high strength of wastewater and such existing weather conditions, is not recommended for Jordan. It is advisable to reconsider sewage treatment using other methods which better suit the prevailing characteristics of climatic conditions, organic loads and patterns of lifestyle in Jordan.

Table 3. Characteristic of influent wastewater at Ramtha treatment plant

Parameter	Unit	Concentration
BOD_5	mg/l	1,078
COD	mg/l	1,880
TSS	mg/l	1,170
PO_4-P	mg/l	25
NH_4 -N	mg/l	70
NO_3-N	mg/l	2
SS	mg/l	914
Sulphur as SO_4	mg/l	90
TOC	mg/l	220
pH – value	-	8.0
EC*	dS/m	1.8
Temperature	˚C	20.7

3.6.3 Description of the modified plant

From variety options to improve the performance of treatment at Ramtha plant, extended aeration process was selected. The Jordanian experience with this system and the literature referred that efficiency of this treatment method in treating domestic wastes is excellent. These systems can achieve very good BOD removal, generally more than 95%, they can function well under high temperature conditions, and require only a fraction of the land area in comparison with waste stabilization ponds [26, 27, 32-34]. The plant is designed for a design horizon of 20 years. The design data include quantities, qualities; design flow and loadings are as presented in table 4. The new design consists of following units: preliminary treatment, equalization ponds, extended aeration, settling tanks, polishing ponds, tertiary maturation ponds, filtration, chlorination.

Table 4. Design criteria for the modified plant

Description	Unit	Quantity
Daily average flow	m^3/d	5,400
Maximum monthly flow	m^3/d	7,200
Peak flow	m^3/d	13,500
Average BOD_5 loading	kg/d	5,400
Average influent BOD_5	mg/l	1,000
Average SS loading	kg/d	5,130
Average Influent SS	mg/l	950

3.6.4 Comparison between the old and modified plant

A) Comparison according to the treatment units

Table 5 illustrated the treatment units in both plants (old and modern). It is clear that the modern plant consists of many additional units, which will enhance its efficiency. Benefits of flow equalization include the elimination or minimization of shock loadings and therefore enhance the biological treatment, improvement of performance of secondary sedimentation process and improvement of filter process, which will all result in an improvement of effluent quality.

Table 5. Treatment units for the old and modified plant

Treatment unit	Old plant	Modern plant
Equalization tank	unavailable	available
Screen	mechanical and manual	mechanical and manual
Parshall flume	available	available
Grit removal unit	unavailable	available
Grease removal	unavailable	available
Biological treatment	aerobic, facultative ponds	extended aeration
Nitrogen removal	unavailable	available
Phosphorus removal	unavailable	available
Secondary settling	unavailable	available
Sludge thickener	unavailable	available
Sludge dewatering	unavailable	available
Polishing ponds	available	available
Filtration	un available	available
Chlorination	available	available
Odour control	unavailable	available
Septage receiving station	unavailable	

The object of grit removal is to eliminate the sand and other mineral particles from the wastewater, to protect pumps and other equipment against abrasion, and to avoid overloading of subsequent treatment processes. Particles of sand having 2.65 kg/l specific gravity and of 0.2 mm diameter and more will be removed from wastewater.

The two rectangular channels are to be used together at all times. During low flow, one channel only can be closed and cleaned for a very short time. Two circular units are installed to remove oil and grease. These units have a surface loading of less than 10 m/h and a retention time of more than 5 minutes. The wastewater is flowing tangentially in the unit and the effluent is discharged through a system from the base of the unit. Grease and oil is scrapped (removed) from the surface [31- 34].

The selected extended aeration process consists of aeration tanks, secondary clarifiers or settlement tanks and sludge recycle line. The aeration tanks have arrangements to enhance the removal of phosphorous and nitrogenous compounds. Circular surface aerators are used to supply the microorganisms in the activated sludge with the oxygen they require. Two circular settling tanks are attached to the aeration basins for the separation of mixed-liquor suspended solids from the wastewater. Thickening is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction. Drying beds are the most widely used method of sludge dewatering in Jordan. It is used to decrease the sludge volume by dewatering process. Dried sludge will be transported and disposed to land fill. Polishing ponds can remove nematode eggs and faecal coliform from secondary effluent through settlement. Rock filter operates by allowing pond effluent to travel through a submerged porous rock bed, causing suspended solids (SS in the effluent) and algae to settle out on the rock surface and into the void space [31-34].

B) Comparison according to the removal efficiency

Table 6 illustrates the removal efficiency of the old and modern plants. It is clear that the modern plant has higher removal efficiency for all considered parameters. The higher removal efficiency of the modified plant is attributed to the modern technology where excess air is available for organic matter removal. This system provides suitable conditions for nitrification and denitrification process, which explain the high removal of nitrogen.

Table 6. Quality of the effluent water for the old and modified plant (* Higher than in the influent)

Parameter	**Effluent concentration (mg/l)**		**Removal efficiency (%)**	
	Old plant	Modern plant	Old plant	Modern plant
BOD_5	260	10	79	99
COD	475	38	75	98
TSS	200	28	80	97
NH_4-N	70	2.5	*	96
PO_4-P	23	12	*	52
NO_3-N	2.1	5.8	*	*

C) Comparison according to the environmental impact:

The environmental impacts of the old and modified plants were considered based on two parameters: The First one is the capability of the plant to deal with seepage waste. The existing sewerage network facilities do not serve all residential areas of the city, and there are individual onsite septic holding tanks and cesspools built in each lot. Moreover, the people do not empty these septic tanks unless they run full. This practice cause nuisance for the people, pollute the soil and contribute to the pollution of ground water. The old plant was not comply to deal with seepage waste, so all these wastes are disposed in the landfill. The modified plant includes a seepage-receiving manhole for the disposal of sludge and seepage from these cesspools. This application decreased the highly effect of seepage waste on soil, health, water and environment [29, 33, 34].

The second considered parameter is the present of odour and insects problems. The odour problem of the old WSP plant was severe. No arrangements could be undertaken to reduce the production of odorous gases from open ponds. While by the new design a better control of odours is achieved, this can be accomplished by maintaining aerobic conditions by increasing the aeration rate controlling anaerobic microbial growth by pH control, installation of covers, collection hoods, and air-handling equipment for containing and directing odorous gases to treatment system. A chemical scrubber is installed in order to increase the efficiency of odour removal and to reduce the odour levels. This scrubber provides a contact between air and chemicals to provide better oxidation of the odorous gases. Waste stabilization ponds are invaded and colonized by insects and flies from natural breeding places. Flies, not only the housefly but also mosquitoes and a great variety of other flies, cause most problems. Waste disposal provides two attractive materials for the replenishment of insects, i.e., water rich in organic material. The number of these insects may increase to a level enough to cause a serious and definite irritation or even to risk health of workers on the plant itself and its immediate neighbourhood. Table 7 and 8 summarises the biological wastewater treatment techniques and wastewater treatment techniques in Jordan, respectivelly.

Table 7. Biological wastewater treatment techniques in Jordan

Technique	Process Description	Application Examples
Biological Filters	Water is distributed over the surface of the filter, allowing air to pass through the layers. Microorganisms form a biofilm on the media, decomposing organic material into CO_2 and water vapor.	Typically used in areas with medium organic load.
Rotating Biological Contactors (RBC)	Water contacts biomass on rotating plastic discs, forming a biofilm that decomposes organic material. Efficient for continuous treatment with minimal maintenance.	Used for municipal wastewater treatment plants.
Activated Sludge	Aerobic microorganisms decompose organic matter in aeration tanks. The process is enhanced by oxygen supply through mechanical aeration, promoting rapid microbial growth.	Widely used in large cities like Amman for high organic load treatment.
Natural Stabilization Basins	Also known as anaerobic lagoons, these large basins allow organic matter to decompose naturally over time, with microbes consuming the organic material under anaerobic conditions.	Suited for rural areas where land is available and operational costs need to be minimized.
Aerobic Treatment Basins	Similar to aerated lagoons, these involve the aerobic breakdown of organic materials facilitated by mechanical aeration, which introduces oxygen into the water.	Used in areas requiring efficient breakdown of organic matter with controlled aeration.
Anaerobic Digestion	In the absence of oxygen, microorganisms break down organic materials, producing methane and CO2. This process is beneficial for generating biogas while treating wastewater.	Applied in facilities aiming to utilize biogas for energy while treating high-strength waste.

Table 8. Summary of wastewater treatment techniques, benefits, and drawbacks

Technique	Description	Advantages	Disadvantages	Examples in Jordan
Activated Sludge	This process breaks down organic materials in wastewater using microorganisms in aeration tanks.	Extremely effective at removing organic particles and pollutants; adaptable to changes in wastewater volume.	Requires expert operation and continuous monitoring; high operational costs; produces significant sludge.	Al-Khirba Al-Samra Treatment Plant, South Amman, etc.
Trickling Filter	Sewage seeps through a media structure and starts microbial biofilms' breakdown of organic components.	Easy operation and low maintenance; uses less energy than activated sludge systems.	May have clogging and pest issues; sometimes additional treatment needed to achieve desired effluent quality.	N/A
Sequencing Batch Reactor	Wastewater is fed into a reactor, allowed to settle and aerate, and then discharged in a repeating sequence.	Removes nutrients effectively; saves space due to compact design; ideal for variable loads.	Complex control systems required; potential for odor emissions during operation.	N/A
Membrane Bioreactor	Combines membrane filtration with biological degradation to remove particulates and pathogens.	Produces high-quality effluent; effective solid-liquid separation; may reduce sludge discharge.	High operating and startup costs; membranes may foul, requiring maintenance.	N/A
Anaerobic Digestion	Microorganisms break down organic material in the absence of oxygen, producing biogas.	Generates biogas, a renewable energy source; less sludge production than aerobic systems.	Requires large tanks and longer processing times; less effective at pathogen removal.	N/A
Rotating Biological Contactor	Wastewater is passed over revolving discs covered in microbial biofilms which break down organic pollutants.	Energy-efficient; simple maintenance and operation; suitable for low to medium strength wastewater.	Mechanical failures possible; may require further treatment for significant pollutant removal.	N/A
Aerated Lagoons	Large shallow ponds that allow organic matter in wastewater to be broken down by microorganisms via aeration.	Low running and maintenance costs; adaptable to a range of wastewater types.	Requires large land areas; possible odor and pest issues; affected by weather variations.	N/A
Natural Treatment	Utilizes natural biological processes without mechanical aids, like constructed wetlands.	Environmentally friendly; low cost and minimal mechanical requirements.	Performance varies with environmental conditions; requires large areas.	Old Aqaba Treatment Plant

4. CONCLUSION

The operation of conventional waste stabilization ponds and the obtained effluent quality has shown very low efficiency regarding the removal of pollutants. The resulted quality of the effluents was not adequate for irrigation reuse. In addition, some environmental aspects are behind the rejection of this method of treatment. The modification of WSP of Ramtha was carried out as environmental arrangement. The produced effluents have good quality to suit the requirements. The demand for cleaner discharges could be achieved through using modern technologies to remove pollutants from wastewater treatment plants. Territory treatment is necessary to achieve a desirable water quality that could be reused for irrigation and industrial purposes.

REFERENCES

1. Al-Zboon, K and Al-Ananzeh, N 2008. Performance of wastewater treatment plants in Jordan and suitability for reuse. *African Journal of Biotechnology* **7**,15, 2621-2629.
2. Al-Kharabsheha, N M and Al-Zboon, K 2021. Wastewater treatment and reuse in Jordan, 10 years of development. **238**, pp.15–27. DOI: https://doi.org/10.5004/dwt.2021.27780.
3. Janga, N, Rena, X, Kimb, G, Ahnb, C, Choa, J, and Kima, I 2005. Characteristics of soluble microbial products and extra cellular polymeric substances in the membrane bioreactor for water reuse, Presented at the conference of Wastewater Reclamation and Reuse for Sustainability (WWRS2005), Korea.
4. Myszograj, S, Bocheński, D, Mąkowski, M, Płuciennik-Koropczuk, E 2012. Biogas, solar and geothermal energy - the way to a net-zero energy wastewater treatment plant: a case study. Energies 14, (21),1-15, DOI: 10.3390/en14216898.
5. Simon, T 2006. Reuse of effluent water—benefits and risks. *Agricultural Water management Journal* **80**, 1-3. https://doi.org/10.1016/j.agwat.2005.07.010.
6. Kalavrouziotis, I K and Apostopoulos, C A 2007. An Integrated Environmental Plan for the Reuse of Treated Wastewater Effluents from WWTP in Urban Areas. *Building and Environment Journal* **42** (4):1862-1868.http://dx.doi.org/10.1016/j.buildenv.2006.07.016.
7. Bushnak, A A 2003. Future strategy for water resources management in Saudi Arabia. In proceeding of: A Future Vision for the Saudi Economy Symposium, Riyadh.
8. Salgot, M, Huertasa, E, Weberb, S, Dottb, W and Hollenderb, J 2006. Wastewater reuse and risk: definition of key objectives. *Desalination* **187** (1–3): 29-40.
9. Ernst, M, Sperlich, A, Zheng, X, Ganb, Y, Hub, J, Zhao, X, Wang, J, and Jekel, M 2007. An integrated wastewater treatment and reuse concept for the Olympic Park 2008 Beijing. *Desalination Journal* **202** (1):293-301. http://dx.doi.org/10.1016/j.desal.2005.12.067.
10. Magalha˜es, J M, Silva, J E, Castro, F, E and Labrincha, J A 2005. Physical and Chemical Characterization of Metal Finishing Industrial Wastes. *Journal of Environmental Management*, **75**, (2):157-66. http://dx.doi.org/10.1016/j.jenvman.2004.09.011.
11. Hammer, M J 1996. Water and wastewater technology, third edition, Prentice –hall. Inc.
12. Bataineh, F, Najjar, M and Malkawi, S 2002. Wastewater Reuse, In: Water Demand Management Forum, Amman, Jordan.
13. Bdour, A and Hadadin, N 2005. Potentials and limitations of wastewater reuse in rural areas in Jordan: The reuse options in the Jordan Valley. *Journal of Agronomy* **4** (4) 315-322. http://dx.doi.org/10.3923/ja.2005.315.322.
14. McCornick P G, Hijazi A and Sheikh B 2007. Progression of Water Reuse Standards in Jordan. Available online: http://www.idrc.ca/en/ev-68342-201-1-DO_TOPIC.html.

15. EPA, Wastewater Treatment/Disposal for Small Communities. Cincinnati, Ohio, 1992. (EPA Report No. EPA-625/R-92-005).
16. Breulmann, M, van Afferden, M, Al-Subeh, A, Al-Mahamid, J S, Dorgeloh, E and Müller, R A 2021. National Framework: The Certification of Wastewater Treatment Systems with Capacities up to 5.000 PE in Jordan; Helmholtz Centre for Environmental Research–UFZ with Support of the Ministry of Water and Irrigation: Leipzig, Germany; Amman, Jordan, 252.
17. APHA, 1998. Standard Methods for the Examination of Water and Wastewater, 20th Ed. Washington, DC: American Public Health Ass. WPCF and AWWA.
18. Khurelbaatar, G, Al Marzuqi, B, Van Afferden, M, Muller, R A and Friesen, J 2021 Data Reduced Method for Cost Comparison of Wastewater Management Scenarios-Case Study for Two Settlements in Jordan and Oman. Front. *Environ. Sci*. **9**, 626-634.
19. Barjenbruch, M and AlZboon, K 2008. North –south gap in wastewater management, a comparison study for Germany and Jordan, GCGW conference, Istanbul, Turkey.
20. Mace S and Mata-Alvarez, J 2002. Utilization of SBR Technology for Wastewater Treatment: An Overview. *Ind. Eng. Chem. Res*. **41** (23), 5539-5553.
21. ESCWA, 2003. Economic and social commission for western Asia, wastewater treatment technologies: a general review, technical report E/ESCWA/SDPD/2003/6.
22. Al-Zboon, K 2005. Modeling of water quality in Zarqa River, international engineering conference, Mutah University, Jordan.
23. Mrayyan B and Hussein, I 2004. Integrated assessment of the control of wastewater pollution in Zarqa Governate, Jordan. *International Journal of Environment and Pollution* **22** (5), 580-596.
24. Abbassi, B, Al-Zboon, K, Radaideh, J and Wahbeh, A 2018. Using Constructed Wetlands To Improve Drainage Water Quality From Hydroponics Farms. *Irrigations and Drainage* **60** (3), 370-380. https://doi.org/10.1002/ird.580.
25. Manolis, L, Christina, Ki, Mihali,s L and Nicolas, K 2010. Treatment of unpleasant odours in municipal wastewater treatment plants Petros Karageorgos. *Water Science Technology* **61** (10), 2635–2644. https://doi.org/10.2166/wst.2010.211.
26. Petroselli, A, Giannotti, M, Arcangeletti, E, Palomba, F and Marras, T 2015. The Integrated System of Phytodepuration of Sile River Natural Park. *International Journal of Phytoremediation* **17** (11), 1038–1045. https://doi.org/10.1080/15226514.2014.964843.
27. Ministry of Water and Irrigation “Jordan Water Utilities Plants Inspection Report”, www.mwi.gov.jo/UPMU. 2022.
28. Abu-Awwad, A M 2021. Wastewater Treatment and its Reuse in Jordan. *Jordan Journal of Agricultural Sciences* **17** (3), 211-223.
29. Abualhaija, M 2023. Applying the quality and pollution indices for evaluating the wastewater effluent quality of Kufranja wastewater treatment plant, Jordan. *Water Conservation and Management* **7**, 6-11.
30. Jabr G, Saidan M and Al-Hmoud N 2019. Phosphorus recovery by struvite formation from Al Samra municipal wastewater treatment plant in Jordan. *Desalination and Water Treatment* **146**, 315-325.
31. Alawi, M A, Tarawneh, I N and Ghanem Z. 2018. Removal efficiency of PAH’s from five wastewater treatment plants in Jordan. *Toxin Reviews* **37** (2), 128-137.
32. Myszograj, S 2008. Study on susceptibility of domestic sewage to biodegradation under laboratory conditions, Scientific and Technical Conference on Water and Wastewater Basis for Environmental Protection (School of Quality Water 2008), Przemysl Chemiczny **87**, Issue 5, 527-530.
33. Al-Quraan, N A, Abu-Rub, L I and Sallal, A K 2020. Evaluation of bacterial contamination and mutagenic potential of treated wastewater from Al-Samra wastewater treatment plant in Jordan. *Journal of Water and Health* **18** (6), 1124-1138.

34. Płuciennik-Koropczuk, E, Jakubaszek, A, Myszograj, S, Uszakiewicz S 2017. COD fractions in mechanical-biological wastewater treatment plant. *Civil and Environmental Engineering Reports* **24** (1), 207-217. DOI: 10.1515/ceer-2017-0015.