

Effects of the Upgrading of Al-Ramtha - Northern Jordan, Wastewater Treatment Plant on Quality of the Effluent and Environment

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Abstract

The present study concludes that the wastewater generated in Al-Ramtha wastewater treatment plant is classified as strong in terms of the total dissolved solids (TDS) content, the total suspended solids (TSS) content, and the chemical and biochemical oxygen demands (COD and BOD₅). The efficiency of the plant in removing total dissolved solids (TDS) from wastewater is still low, while it is reasonably high in terms of suspended solids, COD and BOD removal. The upgrading which took place in 2003 added a significant improvement in the process of plant treatment regarding the selected parameters (COD, BOD and TSS). Regarding these parameters, the new plant effluent complies with Jordanian standards for irrigation parks, reuse for irrigation of cooked vegetables, fruits, and trees, and for fodder crops, but not with respect to TDS concentration of effluent used for irrigation purposes. The obtained concentrations of all analyzed metals indicate that the studied soils are uncontaminated with respect to Cd, Zn, Mn, Pb, Cu and Fe.

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1. Introduction

Wastewater is the water that carries the waste removed from residences, institutions, and commercial and industrial establishments. It can be subdivided on the basis of the levels of the major constituents into strong, medium and weak domestic wastewaters (Table 1) (FAO, 2008).

Table 1: Major constituents of typical domestic wastewater (FAO, 2008).

Major Constituents	Level of Major constituents and their concentration in mg/l		
	Strong	Medium	Weak
Total solids	1200	720	350
Dissolved solids (TDS)	850	500	250
Suspended solids	350	220	100
Nitrogen (as N)	85	40	20
Phosphorus (as P)	15	8	4
Chloride	100	50	30
Alkalinity (as CaCO ₃)	200	100	50
Grease	150	100	50
Biochemical Oxygen Demand(BOD ₅)	400	210	110

Currently available systems of treatment in Jordan need upgrades in capacity or supplementary systems. In the present study, Al-Ramtha wastewater treatment plant (WWTP) was selected to determine the effect of upgrading on the quality of effluent and whether the current effluent quality can be used in agriculture.

Al-Ramtha WWTP was constructed in 1988 on gently sloping plateau about 4km northwest of Al-Ramtha city, near the road leading to Turra (Fig. 1).

Wastewaters from homes, commercial buildings, hospitals (domestic sewage), etc. of about 70,000 people are collected via a collection system and flow to Al-Ramtha WWTP for treatment.

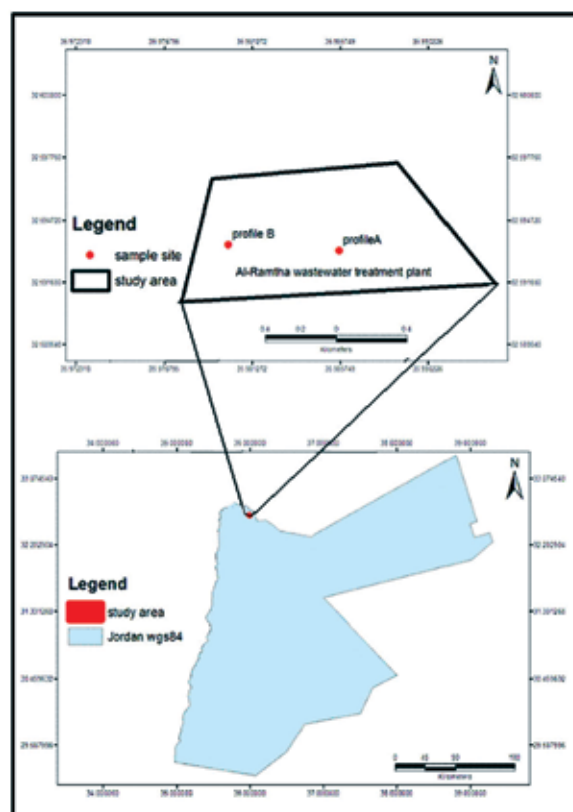


Figure 1: Location map of the study area.

In the old stabilization ponds plant, three stages were used. In the first stage, settleable organic materials are accumulated as sludge in the bottom of anaerobic ponds and decomposed to produce inorganic matter. In the second stage,

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facultative ponds which are divided into two zones upper aerobic and lower anaerobic, consumer and decomposer organisms mainly reduced organic material during two to three weeks to basic intracellular inorganic constituents. In the third stage, the shallow maturation ponds, where the water is light loaded with organic matter and contains dissolved oxygen; provide a high quality effluent (Parker, 1979; Rich 1980; Arceivala, 1981, and Gharaibeh *et al.*, 2000). After the upgrading in 2003 an activated sludge process is in use. The treatment is divided into pretreatment, where coarse solids and other materials are removed using screens, aerated greave and grit chamber, in the secondary treatment activated sludge in the aeration tank is used, and in the tertiary treatment residual particles and parasites are removed.

The hydraulic design capacity for the new plant is 5400 m³/d and operating capacity 3492 m³/d. All effluent has to be reused throughout the year in order to eliminate effluent discharge to the wadi downstream of the plant.

Evaluation of several options for reuse of the reclaimed water showed that agricultural reuse was the most suitable alternative. The proposed agricultural lands irrigated with the reclaimed water are around 1 Km² located adjacent to the WWTP.

The present research aims to achieve the main following goals:

- Determining of the effects of upgrading that was finished in 2003 on the quality of Al-Ramtha wastewater treatment plant effluent by measuring chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS) and comparing the results with data available before upgrading.
- Determining the new plant effluent suitability for agricultural irrigation and comparing the new plant effluent properties with Jordanian standards and the international standards.
- Investigating the environmental impact of effluent in its current quality on irrigated soil by measuring the concentration of some heavy elements (Cd, Fe, Cu, Pb, and Zn) and comparing it with soil samples from non- irrigated profile.

2. Methodology

A combination of both field and laboratory work were used to accomplish this study.

Field work

A) Sixteen water samples were collected from influent and effluent of the plant during the period from May to October 2009. The effluent samples used in analysis were taken from the plant after secondary treatment and before chlorination; the influent samples were taken from the plant inlet. The samples were preserved in bottles and transported to the laboratory for further analyses.

B) Soil samples were collected from two profiles: The first profile (Coordinates 35.985744° N and 32.593295° E) represents soil irrigated by effluent, and the second profile (Coordinates 35.98129° N and 32.593580° E) represents a reference from non-irrigated soil. Soil samples were preserved in polyethylene bags to minimize contamination then transported to the laboratory for further analysis.

Temperature, pH value and TDS were measured in the field by using thermometer, pH meter and conductivity meter, respectively.

Laboratory work

Laboratory work was carried out at the Faculty of Science at Yarmouk University and laboratories of the Ramtha Wastewater Treatment Plant.

A. Wastewater samples analyses

a) Suspended Solids (TSS)

A known volume of water sample was filtrated through a pre-weighed Whatman glass fiber filter (GFC), 47 mm in diameter. The filter was dried at 105°C and reweighed. The amount of suspended solids was determined from the increase in weight of Whatman glass fiber filter.

b) Chemical Oxygen-Demand (COD)

The Chemical Oxygen Demand is used as a measure of the oxygen equivalent of the organic and inorganic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The COD test was carried out by using Photolab S6 equipment (Fig. 2).

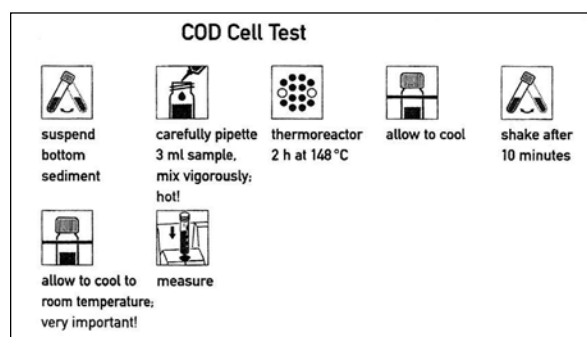


Figure 2: Process of measuring COD.

c) Biochemical Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen used by microbes to decompose organic matter in a wastewater. The sample is kept in a sealed container fitted with a pressure sensor. A substance that absorbs carbon dioxide (typically sodium hydroxide) is added in the container above the sample level. The sample is kept at 20 °C in darkness to prevent photosynthesis (and thereby the addition of oxygen) for five days. Oxygen is consumed, and carbon dioxide is released. The total amounts of gas, and thus the pressure, decrease because carbon dioxide is absorbed. From the drop of pressure, the sensor electronics compute and display the consumed quantity of oxygen.

d) Heavy metals chemical analysis

The (Nov AA300 "Analytic Jena") atomic absorption spectrophotometer (AAS) was used for the determination of Cd, Pb, Cu, Fe, Zn and Cr content in all analyzed water and soil samples.

B. Soil samples analyses

All soil samples were dried at 110°C, disaggregated, homogenized and sieved to discard coarse materials (>2mm). Representative subsamples were taken for each soil sample.

a) Heavy metals chemical analysis

The same as the analysis of heavy metals in wastewater.

b) Total Organic Matter Content (%TOM)

The percentage of organic matter in the soil samples was measured by titration method which is based on the oxidation of organic matter by potassium dichromate, followed by chemical titration with ferrous sulphate until the color flashes to green, as suggested by Loring and Rantala (1992).

3. Results and Discussions

- Properties of influent and effluent in the new plant

Data concerning Al-Ramtha WWTP were obtained from the Ministry of Water and Irrigation, and the chemical and physical analyses of the collected wastewater samples (Tables 5-7).

Data of chemical and physical analyses of the collected wastewater samples (Table 2) during the study period are divided into two groups (summer and winter).

- Physical properties of influent and effluent

The physical properties of interest here are the temperature and solids content of the wastewater. The waste water temperature is an important parameter because of its effects on type and rate of the biochemical reactions. The average influent wastewater temperatures in Al-Ramtha treatment plant is ranging from 15.4° to 20.4°C in winter, and from 21° to 26°C in summer (Table 2). The minimum temperature in winter is never less than 10°C. These temperature ranges are suitable for high bacterial activity. The temperature for optimal bacterial activity ranges from 25-35°C and this activity decreases to about the half when the temperature decreases by 10°C (Metcalf & Eddy1990).

The average effluent wastewater temperature ranges

from 15.17° to 22.8 °C in winter and from 25.4° to 27.9°C in summer (Table 2). The effluent temperature is significant because it can affect aquatic life upon discharge, and the sustainability of the water for beneficial uses. Also, oxygen is less soluble in warm water than in cold water.

The other important physical property of wastewater is the solids content. The average studied influent total dissolved solids range from 916 mg/l to 1176 mg/l in winter and from 1068 mg/l to 2068 mg/l in summer (Table 2). The average effluent total dissolved solids contents for the winter and summer range from 826 mg/l to 1400 mg/l and 806 mg/l to 1533 mg/l, respectively (Table 2). Accordingly, the treated wastewater is classified as strong wastewater (Table 1). The low efficiency of the used technologies in removing dissolved solids from wastewater is of concern because it affects the reuse of wastewater for agriculture.

In winter, the average influent of total suspended solid content (Silt, clay, algae, zooplankton, bacteria) of the studied wastewater is 628 mg/l, and in summer 725.8 mg/l (Table 2). Accordingly, this wastewater is classified as strong wastewater (Table 1). But the percentage removed of TSS from treated wastewater is 95.8% (Table 2) because solid particles precipitate throughout the treatment process, causing the water to become clear when it flows down and enters a reservoir.

Table 2: Summary of statistical information of influent and effluent wastewater parameters of Al-Ramtha WWTP after upgrading.

Parameter	Unit	Season	Influent				Effluent			
			Ave.	Std.	Max.	Min.	Ave.	Std.	Max.	Min.
Qave.	M ³ /day	—	3244	—	—	—	—	—	—	—
Temp	°C	Winter	18	1.7	20.4	15.4	18.19	2.35	22.8	15.7
		Summer	24.5	1.5	26	21	26.8	0.8	27.9	25.4
pH		Winter	7.6	0.27	7.95	7.2	7.2	0.48	7.88	6.28
		Summer	7.4	0.26	7.75	6.96	7.74	0.25	8.21	7.34
TDS	mg/l	Winter	1088.9	84.36	1176	916	1182.8	159.4	1400	826
		Summer	1379.9	318.8	2068	1068	1143.9	251.2	1533	806
TSS	mg/l	Winter	628	341.7	1374	192	26.8	16.8	66	10
		Summer	725.8	226	958	324	30.46	16.75	84	13
BOD ₅	mg/l	Winter	924.4	488	1708	229	11	4	20	5
		Summer	989	248	1310	580	13.45	5	20	5
COD	mg/l	Winter	1629.8	616.35	2590	799	58	34.6	156	24
		Summer	2259.6	849	3651	1156	69.38	33.4	121	25
COD/BOD ratio	—	Winter	1.76	1.26	3.48	1.5	5.3	8.65	7.8	4.8
		Summer	2.28	3.42	2.78	1.99	5.4	6.48	6.05	5

**** TDS: Total Dissolved Solids, TSS: Total Suspended Solids, BOD₅: Biochemical Oxygen Demand and COD: Chemical Oxygen Demand.
Std: Standard Deviation

- Chemical and biochemical properties of influent and effluent

The wastewater properties of interest here are the pH and the organic matter content; which include the biochemical oxygen demand (BOD₅), the chemical oxygen demand (COD), and the ratio of COD to BOD₅. The pH is an important parameter. Most biological life dislike pH outside the range 4 – 9. The well-being of microorganisms in the aerated tanks is of concern. Most bacteria cannot tolerate pH outside the range 4.0 - 9.5. Generally, pH for optimum bacterial growth lies in the range 6.5 - 7.5 (Sincero, 1996). The pH reported for Al-Ramtha treatment plant ranges from 6.28 to 8.21, (Table 2) they are well within the range favored by the bacteria.

Special consideration must be given to the organic matter content of the wastewater; it is characterized in terms of the biochemical oxygen demand (BOD₅), the chemical oxygen demand (COD), and the ratio of the COD to the BOD₅. The BOD₅ by definition is the quantity of oxygen required for the stabilization of the oxidizable organic matter present after five days of incubation at 20°C. It is the amount of Oxygen used by microorganisms to decompose organic matter.

The average, studied influent BOD₅ concentrations range from 229 mg/l to 1708 mg/l in the winter time and from 580 mg/l to 1310 mg/l in the summer time (Table 2). These numbers indicate that the wastewater being treated is classified as strong wastewater (Table 1). The percentage

removals of BOD₅ obtained for plant selected for the study averaged 98%.

The COD test measures the total organic content of a wastewater which is oxidizable by dichromate in acid solution (Eckenfelder, 1989). Certain aromatics such as benzene and straight chain carboxylic acids are not completely oxidized in the reaction, and on the other hand reduced substances, such as sulfides, sulfates, and ferrous iron, will also be oxidized and reported as COD.

The average influent COD concentrations of the studied wastewater range from 799 mg/l to 2590 mg/l in winter and from 1156 mg/l to 3651 mg/l in summer (Table 2).

These numbers indicate that the studied wastewater is strong (Table 1). Because the five-day BOD will represent a different proportion of the total oxygen demand for raw wastewater than for effluents, the COD/BOD₅ ratio will frequently vary for effluents as compared with untreated wastes (Table 2). The influent wastewater of the plant is characterized as containing high percentage of nonbiodegradable organic matter; which can be concluded from the ratio of COD/ BOD₅ (Table 2) which ranges from about 1.5 to about 3.48. These numbers are comparable to those presented by Metcalf and Eddy (1990) which state that the typical COD/BOD₅ ratio of domestic wastewaters is usually in the range 1.25 to 2.5. The COD/BOD₅ ratio becomes even more profound for treated effluents and ranges from 4.8 to 7.8. This indicates that the proportion of the nonbiodegradable content of treated effluent is relatively higher than that of raw wastewater and that the efficiency of BOD₅ removal is higher than that of COD removal.

Heavy Metals in influent and effluent in the new plant.

Cadmium (Cd) and Zinc (Zn)

The Cd and Zn concentration in all analyzed samples lies below the detectable limit of the atomic absorption spectrophotometer used. Thus, the effluent can be classified as uncontaminated with Cd and Zn.

Table 3: Mean and standard deviation of heavy metals concentration (ppm) in the influent and effluent of Al-Ramtha WWTP.

Heavy metals	Influent		Effluent	
	Mean of concentration	Stdev	Mean	Stdev
Cd	ND	ND	ND	ND
Zn	ND	ND	ND	ND
Pb	0.090	0.067	0.083	0.036
Mn	0.167	0.02	0.156	0.008
Cu	0.230	0.037	0.230	0.017
Fe	0.438	0.185	0.472	0.311

ND: not detect

Lead (Pb)

The concentration of lead in fresh water is less than 3 ppb (Wedepohl, 1969) and the upper limit of guideline values of Jordanian standard for Pb concentration of effluent used for irrigation is 5ppm. The average concentration of Pb in the influent is 0.090ppm and in effluent of the plant is 0.083ppm (Table 3 and Fig. 3A), so the plant effluent used for irrigation purposes can be classified as uncontaminated with Pb.

Manganese (Mn)

Manganese occurs primarily as Mn²⁺ in the rocks forming silicates. The relatively low manganese content in the carbonate minerals is often due to a low concentration of this

element in carbonate precipitating solutions such as sea water and other types of water (Talyor, 1983).

The upper limit of guideline values of the Jordan Institute of Standards and Metrology (JISM) for Mn concentration of effluent used for irrigation is 0.2ppm. The average concentration of Mn in the influent is 0.167ppm and in effluent of the plant is 0.156ppm (Table 3 and Fig. 3B), so the plant effluent used for irrigation purposes can be classified as uncontaminated with Mn.

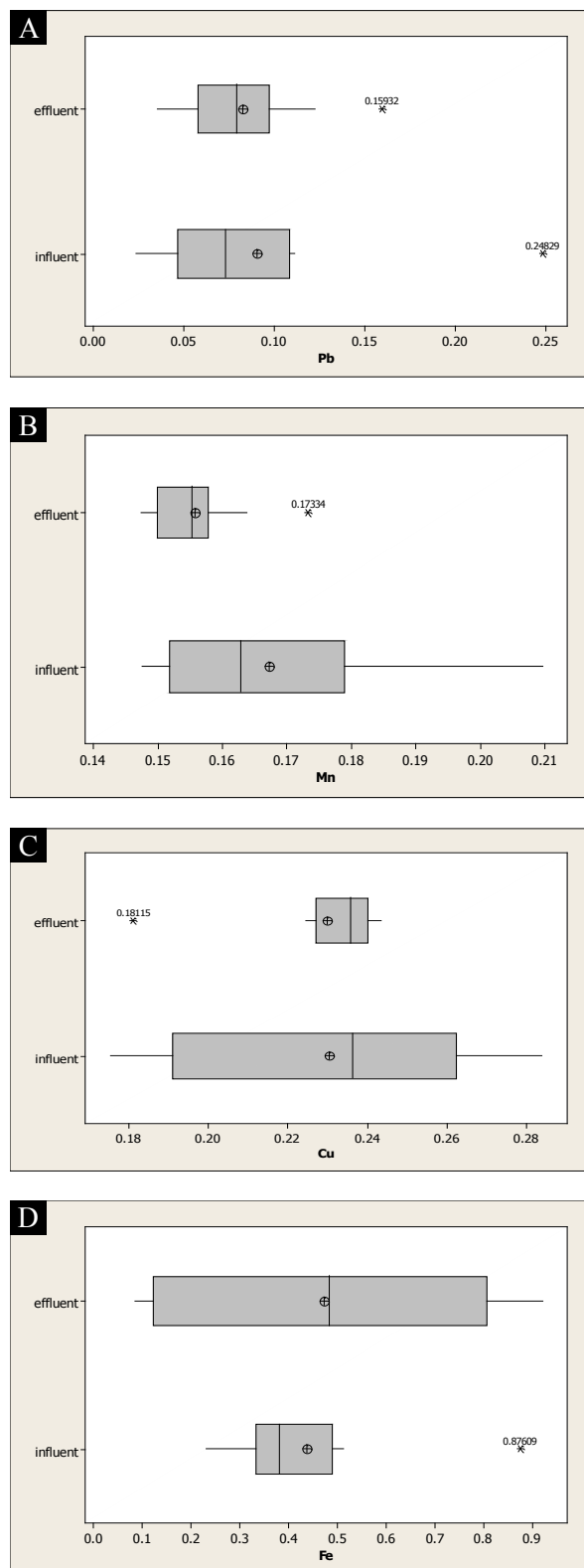


Figure 3: Box-plots show distribution of Pb(A), Mn (B), Cu (C) and Fe (D) concentrations in influent and effluent.

Copper (Cu)

Copper is widely distributed in nature in free state as well as in sulfides, arsenide, chlorides and carbonates.

The concentration of copper in fresh water is 3 ppb (Wedepohl, 1969) and the upper limit of guideline values of the Jordan Institute of Standards and Metrology (JISM) for Cu concentration of effluent used for irrigation is 0.2ppm. The average concentration of Cu in influent is 0.230ppm and in effluent of the plant is 0.230ppm (Table 3 and Fig. 3C), so the plant effluent used for irrigation purposes can be classified as slightly contaminated with Cu.

Iron (Fe)

Iron has several sources in sedimentary rocks. Iron minerals present in carbonate rocks are mostly ferric oxides formed by weathering.

The concentration of iron in river waters is 0.67ppm (Wedepohl, 1969). The upper limit of guideline values of the Jordan Institute of Standards and Metrology (JISM) for Fe concentration of effluent used for irrigation is 5ppm. The average concentration of Fe in influent is 0.438ppm and in effluent of the plant is 0.472ppm (Table 3 and Fig. 3D), so the plant effluent used for irrigation purposes can be classified as uncontaminated with Fe.

Soils

Total Organic Matter (TOM %) in Soil

The organic matter of soil consists of mixture of plant and animal remains in various stages of decomposition.

Organic matter of a soil affects its color; it increases its cation exchange capacity and accounts for 20-90% of the adsorbing power of the soil.

The organic matter contents vary between 4.74 to 8.16 % in profile A, and from 4.3 to 7.9% in profile B (Table 4). The highest values were obtained at the surface with decreasing tendency with depth (Fig. 4A).

Table 4: The average and range of the concentration of heavy metals and total organic matter (TOM %) in the soil profiles and normal soils.

Tom% & Heavy Metals (PPm)	Average of Conc.		Range of Conc.		Average concentration in normal soils
	Profile A	Profile B	Profile A	Profile B	
TOM %	6.8	6.5	8.16-4.75	7.9-4.3	
Cd	ND	ND	ND	ND	0.1
Mn	767.35	644.76	737.27- 856.12	550.31 - 696.46	850
Pb	0.029	0.012	0.008-0.067	0.002-0.03	14
Zn	0.059	0.042	0.02-0.11	0.03-0.08	70
Cu	0.04	0.03	0.02-0.07	0.014-0.043	45
Fe	6.03	5.73	5.79-6.2	5.51-5.98	55

** Profile A, obtained soil samples non- irrigated by the plant effluent.

** Profile B, obtained soil samples irrigated by the plant effluent.

** ND: Not detect.

Heavy metals in soils

Cadmium (Cd)

The Cd concentration in all analyzed samples lies below the detectable limit of the atomic absorption spectrophotometer used.

The studied soils can be classified as uncontaminated with Cd.

Manganese (Mn)

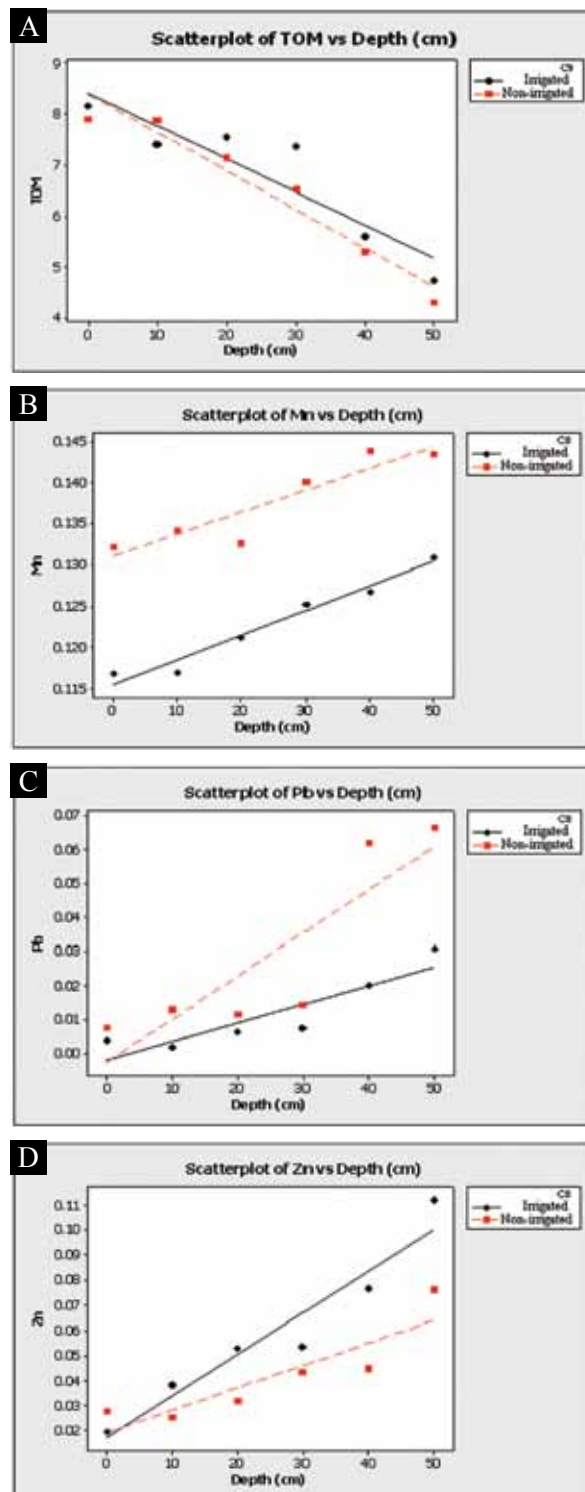
Normal soils have an average content of Mn that ranges from 100 to 4000ppm with a mean value of 850ppm (NAS, 1973). Manganese is generally considered to be one of the most important toxic metals in acid soils. Several investigators pointed out that pH had the greatest effect on the availability of Mn, followed in order by organic matter and moisture

(Christensen *et al.*, 1951).

The concentration of Mn in the analyzed soil samples ranges from 550.31 to 856.12ppm (Table 4). The concentration of Mn in profile A (non -irrigated by plant effluent) ranges from 737.27 at the surface to 856.12ppm at 30cm depth, and in profile B (irrigated by plant effluent) 550.31ppm at the surface and 696.46 ppm at 30cm soil depth (Fig.4B).

The analysis shows that the Mn – concentration in general increases with depth in both profiles and decreases with irrigation (Profile B). It indicates that Mn is gradually washed out of soil by percolating rain and irrigation.

The obtained Mn-values are within the range given for normal soils; therefore, the studied soils can be classified as uncontaminated with Mn.



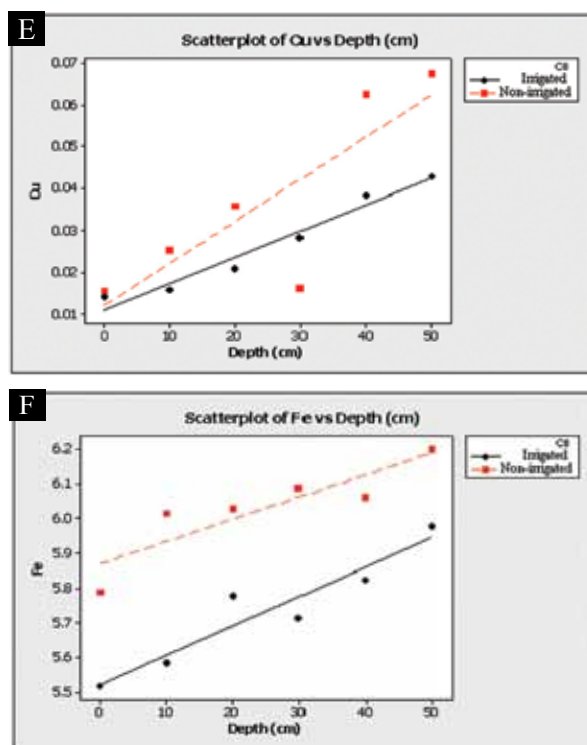


Figure 4: Variations of TOM(A), Mn(B), Pb(C), Zn(D), Cu(E) and Fe (F) in the studied profiles with depth.

Lead (Pb)

The average of Pb content in the earth's crust range from 13 to 16 ppm (Swaine, 1978).

Soils can have a wide range of Pb content, depending on a number of factors, such as the parent material and anthropogenic input (Adriano, 1986).

The concentration of Pb in the analyzed soil samples ranges from 0.002ppm to 0.067ppm (Table 4)

The increase tendency of lead with depth in both profiles (Fig. 4C) results from transport of lead from the surface probably at relatively lower pH to the bottom where higher pH-values are expected.

Comparison of the obtained Pb-values in the study area with Pb-values in normal soils indicated that the studied soils are uncontaminated with Pb.

Zinc (Zn)

The Zn-concentration in the study area ranges from 0.02 at the surface to 0.11ppm at 50cm depth in the non-irrigated soil, and from 0.03ppm at the surface to 0.08ppm at 50cm depth in the irrigated soil (Table 4 and Fig. 4D). This Soil can be classified as uncontaminated with Zn

Copper (Cu)

Copper is one of the important essential elements for plants and animals.

The average concentration of Cu in soils of the study area is 0.04ppm in profile A and 0.03ppm in profile B (Table 4 and Fig. 4E), so these soils can be classified as uncontaminated with Cu.

Iron (Fe)

The concentration of Fe in the analyzed soil samples ranges from 5.51 to 6.2ppm (Table 4). The concentration of Fe in profile A (non-irrigated by plant effluent) ranges from 5.79 at the surface to 6.2ppm at 50cm depth (average 6.03 ppm) and in profile B (irrigated by plant effluent) was 5.51ppm at the surface and 5.98ppm at 50cm soil depth (average 5.73

ppm).

The Paired T-Test analysis indicates significant difference in the Fe values between the two profiles as well as with the depth in the soil profile (Fig. 4F).

Generally, the Fe content of soils ranges from 10.00 to 100.00ppm (Mitchell, 1964). The distribution pattern of all measured elements shows an increasing tendency of the concentration with depth in irrigated and non-irrigated studied soils (Fig. 4F). This is probably caused by relatively increasing of pH with depth. However the obtained results are much lower than that given by Al-Ghazzawi (2009) for soils along Zarqa river and than that reported by Al-Kailani (2005) for soils irrigated by King Talal dam water. This can be explained by anthropogenic inputs to the Zarqa river, through the effluent of Khirbet Assamra and industrial waste discharged to the river.

The low values obtained in this study points to noncontamination of soils as well as the absence of anthropogenic heavy metals source in the area. The obtained results of heavy elements analyses in Al-Ramtha area are comparable with those reported by Rusan *et al.* (2006).

The effects of the upgrading of Al-Ramtha wastewater treatment plant

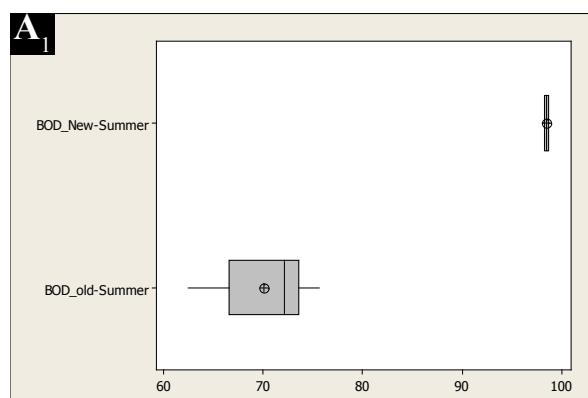
Different packages of Microsoft Office Word 2003, Excel 2003 and SPSS 8.0, chemical and biochemical data that covers ten years (2000-2009) have been used to find out the effect of upgrading that has been finished 2003 on the quality of the plant effluent.

BOD

The average percent removal of BOD in the old plant was 70.1% in summer and 67.94% in winter. This indicates that the effluent was not in agreement with the Jordanian standards, while the average removing of BOD in the new plant is 98.53% in summer and 98.5% in winter (Table 5 and Fig. 5A₁ & A₂). This complies with the Jordanian standards for reclaimed wastewater discharge to streams, ground water recharge, irrigation parks, reuse for irrigation of cooked vegetables, fruits, and trees, and for reclaimed wastewater reuse for fodder crops.

Table 5: The range, mean, and the standard deviation values (stdev) of the removing percentage of BOD for new plant and old plant in summer and winter seasons in the years 2000-2009.

Plant name	Seasons	Number of samples	Range of removing percentage	Mean	Stdev
New plant	summer	9	98.1%-99.3%	98.53%	0.35
New plant	winter	9	97.3%-98.9%	98.5%	0.49
Old plant	summer	9	62.5%-75.6%	70.1%	4.40
Old plant	winter	9	54.8%-75.3%	67.94%	6.43



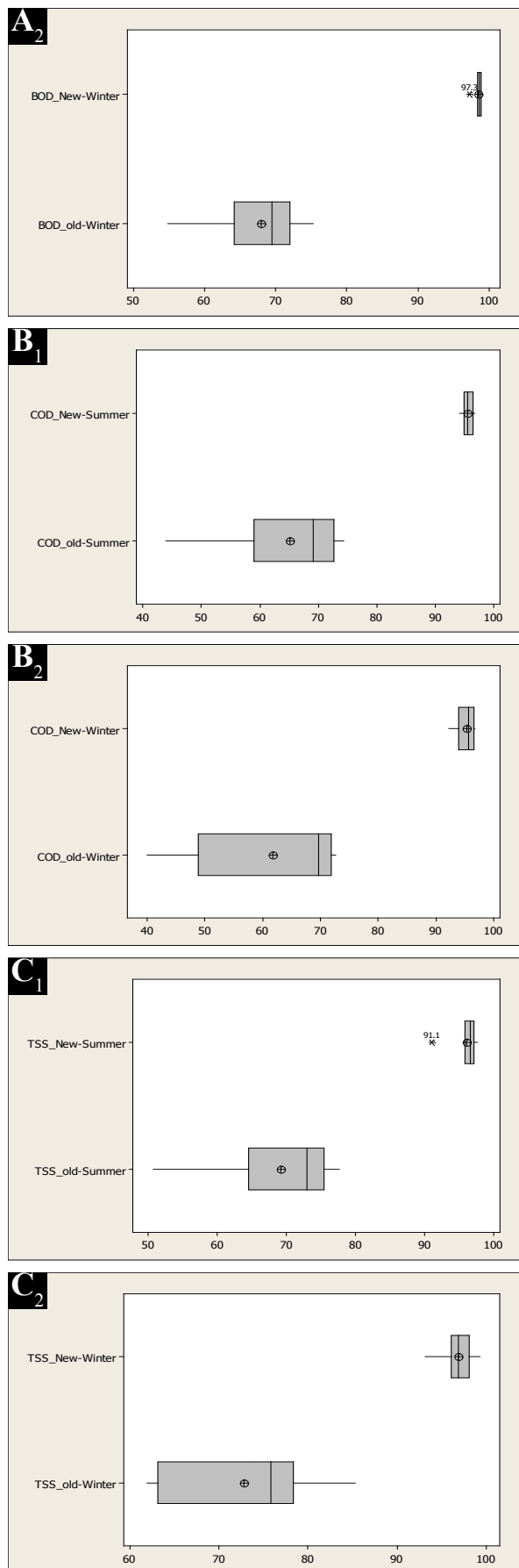


Figure 5: Box-plots show the removing percentages of BOD before and after upgrading in summer (A_1) and in winter (A_2), of COD before and after upgrading in summer (B_1) and winter (B_2) and of TSS before and after upgrading in summer (C_1) and winter (C_2).

COD

The average removal of COD in the old plant was 65.07% in summer and 61.67% in winter. The old plant effluent was not in agreement with the Jordanian standards, while the percentage removal of COD in the new plant is 95.53% in summer and 95.3% in winter (Table 6 and Fig. 5B₁ & B₂). The new plant effluent complies with Jordanian standards for reclaimed wastewater discharge to streams, ground water recharge, irrigation parks, reuse for irrigation of cooked vegetables, fruits, and trees, and for reclaimed wastewater reuse for fodder crops.

Table 6: The range, mean, and the standard deviation values of the removing percentage of COD for new plant and old plant in summer and winter seasons (2000-2009).

Plant name	Seasons	Number of samples	Range of removing percentage Of COD	Mean	Stdev
New plant	summer	9	94.1%-96.8%	95.53%	0.89
New plant	winter	9	92.3%-96.8%	95.3%	1.69
Old plant	summer	9	43.8%-74.3%	65.07%	9.81
Old plant	winter	9	39.9%-72.6%	61.67%	12.66

TSS

The average removal of TSS in the old plant is 69.17% in summer and 72.78% in winter. This indicates that the old plant TSS effluent was not in agreement with the Jordanian standards, while the average % removal of TSS in the new plant is 96.06% in summer and 96.86% in winter (Table 7 and Fig. 5C₁ & C₂). Therefore, the new plant TSS effluent complies with Jordanian standards for reclaimed wastewater discharge to streams, and water body, as also determined by Al-Zboon *et al.* (2008).

Table 7: The range, mean, and the standard deviation values of the removing percentage of TSS for new plant and old plant in summer and winter seasons (2000-2009).

Plant name	Seasons	Number of samples	Range of removing percentage	Mean	Stdev
New plant	summer	9	91.1%-97.7%	96.06%	1.97
New plant	winter	9	93.2%-99.3%	96.86%	1.75
Old plant	summer	9	50.6%-77.6%	69.17%	8.55
Old plant	winter	9	61.9%-85.3%	72.78%	8.32

4. Conclusions

1. The average temperature of influent wastewater in the treatment plant ranges from 15.4 to 20.4°C in winter, and from 21 to 26°C in summer. The minimum temperature in winter time is never less than 10°C; this is suitable for biodegradation of organic matter.
2. The wastewater generated in Al-Ramtha treatment plant is classified as strong in terms of total dissolved solid content, and the efficiency of the selected technologies in removing dissolved solids from wastewater is low. Also, the wastewater is classified as strong wastewater in terms of total suspended solid content, but the efficiency of the selected technologies in removing suspended solids is reasonably high (96.46%).
3. The treated wastewater is classified as strong wastewater in terms of BOD and COD contents, and the percent removals of BOD and COD are high.
4. The wastewater generated in Al-Ramtha is characterized as containing high nonbiodegradable organic matter, and there is a significant reduction of this matter in the treated wastewater in the treatment plant.

5. Regards to the selected elements in this study, the new plant effluent complies with Jordanian standards for irrigation parks, reuse for irrigation of cooked vegetables, fruits, and trees, and for reclaimed wastewater reuse for fodder crops, exception the upper limit of guideline values of the Jordan standards for TDS concentration of effluent used for irrigation purposes.
6. The effluent is not suitable for those vegetables that are eaten uncooked, such as tomato, carrot and green leaf vegetables.
7. The obtained concentration of all analyzed metals indicate that the studied soils are uncontaminated with respect to Cd, Zn, Mn, Pb, Cu and Fe (the soils are unpolluted in regarding to heavy metals).
8. The upgrading which took place on 2003 adds significant improvement in the process of plant treatment with respect to TSS, BOD and COD, but not with respect to TDS.

5. Recommendations

1. Construction additional treatment stage to reduced TDS in the plant effluent.
2. Further investigation is needed to study the effect of using treated water on food chain.
3. Organizing programs to increase the farmer's awareness for the right using of treated water, pesticides and fertilizers.

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References

- [1] Adriano, D.C., 1986. Trace elements in the terrestrial environmental. Springer Verlag. New York, pp. 533.
- [2] Al-Ghazzawi, 2009. Soil pollution with heavy metals in farms along the upper course of Zarqa River. Unpublished M.Sc. thesis, Yarmouk University.
- [3] Alkailani, A., 2005. Major and trace elements in soil profiles from selected Farms irrigated with King Talal dam water. Unpublished M.Sc. thesis, Yarmouk University.
- [4] 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.
- [5] Arceivala, S. J., 1981. Wastewater treatment and disposal: Engineering and ecology in pollution control. Marcel Dekker, New York. Pp. 53-600.
- [6] Christensen, P.D., Toth, S. J., and Bear, F. E., 1951. Soil scisoc amproc 15: 279-282.
- [7] Eckenfelder, W., 1989. Industrial water pollution control. McGraw-Hill Company, New York.
- [8] FAO, 2008. Wastewater treatment. Corporate Document Repository. Food and Agriculture Organization of the United Nations. <http://www.fao.org/docrep/T0551E/t0551e0b.htm>. 25/4/2008.
- [9] Gharaibeh, S., and Farhan, Y., 2000. Introduction to environmental science, Dar Ashoroq, pp. 415, (In Arabic).
- [10] Loring, D. H. and Rantala, T. T., 1992. Manual for the geochemical analysis of marine sediments and suspended particulate matter. *Earth science reviews*, Vol.32, pp.235-263, Elsevier Science Publishers b. V., Amsterdam.
- [11] Metcalf and Eddy, 1990. Wastewater engineering: Treatment, disposal, and reuse, McGraw-Hill Company, New York. pp. 56-118.
- [12] Mitchell, R. L., 1964. Trace elements in soil. In: *Chemistry of the soil*. Ed. F. E. Bear. ACS monograph No. 160. Reunhold Publishing, New York.
- [13] National Academy of Science (NAS), 1973. Manganese. NAS, Washington, D.C. pp. 191.
- [14] Parker, J.G., and Lyons, B.J., 1979. Factors influencing the treatment of food processing wastes by anaero-bic-aerobic lagoon systems. *Progress in water technology*, Volume 11, pp. 377-388.
- [15] Rich, L., 1980. Low-maintenance and mechanically simple wastewater treatment systems. McGraw-Hill, New York, USA, pp. 53-129.
- [16] Rusan, M., Hinnawi, S., Rusan, L., 2006. Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, 215: 143-152.
- [17] Sincero, A. and Sincero, G. 1996. Environmental engineering: A design Approach. Prentice Hall, New Jersey.
- [18] Swaine, D. J., (1978): *J. Royal Soc. new South Wales*, 111: pp. 41-47.
- [19] Talyor, J.H., 1983. The geochemistry of iron and manganese in the waters and sediments of bolstadford. *Estuarine, Costal and shelf science*, Volume 17, pp. 1-19.
- [20] Wedepohl, K. H., 1969. *Handbook of geochemistry*. Springer Verlag, New York. pp. 297-319.