

## Analysis of Treated Wastewater Produced from Al-Lajoun Wastewater Treatment Plant, Jordan

WALEED MANASREH\*, ATEF S. ALZAYDIEN and MALAHMEH .M

Department of Chemistry,  
Mutah University, P.O. Box 7, Jordan.  
*manasreh\_w@yahoo.com*

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**Abstract:** Assessment of treated wastewater produced from Al-Lajoun collection tanks of the wastewater treatment plant in Karak province was carried out in term of physical properties, its major ionic composition, heavy metals and general organic content, for both wastewater influent and effluent. Sampling was done in two periods during (2005-2006) summer season and during winter season to detect the impact of climate on treated wastewater quality. Soil samples were collected from Al-Lajoun valley where the treated wastewater drained, to determine the heavy metal and total organic carbon concentrations at same time. The study showed that the treated wastewater was low in its heavy metals contents during both winter and summer seasons, which was attributed to high pH value enhancing their precipitations. Some of the major ions such as  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{HCO}_3^-$ ,  $\text{Mg}^{2+}$  in addition to biological oxygen demand and chemical oxygen demand were higher than the recommended Jordanian guidelines for drained water in valleys. The treated wastewater contained some organic compounds of toxic type such as polycyclic aromatic hydrocarbons. Results showed that the soil was low in its heavy metal contents and total organic carbon with distance from the discharging pond, which attributed to the adsorption of heavy metals, total organic carbon and sedimentation of suspended particulates. From this study it was concluded that the treated wastewater must be used in situ for production of animal fodder and prohibit its contact with the surface and groundwater resources of the area specially Al-Mujeb dam where it is collected.

**Keywords:** Wastewater, Heavy metals, Soil, Ions, Organic content, Al-Lajoun .

### Introduction

Jordan is characterized by Mediterranean climate, hot and dry in summer and cold in winter. Jordan people are suffering from water shortage due to its location in the semi-arid climate zone, and very limited rainfall amount, falling in the winter season and extended from November to April 2005-2006.

Jordan has endured deficits in water resource since the early 1960s, because about 85% of the total amount of water is lost by annual evaporation where it ranges from 1600 to 4000 mm/year<sup>1</sup>. This leaves only small amount of surface and groundwater to enter the water supply. During the last few decades, water shortage increased due to population growth, industrialization, irrigation projects and improving standards of living not only have led to increasing water use, but also to deteriorating water quality as a result of the various human activities<sup>2</sup>. Therefore, the government of Jordan is trying to utilize every drop of water available in the country.

One of the major sources of water for agricultural purposes in Jordan is the treated wastewater, which provides a constant and reliable supply of water use through the year. Treated wastewater contains beneficial nutrients for crop growth that substantially reduce crop fertilizer requirement<sup>3</sup>.

Using this type of water requires close examination of the effect and implication of salt, pollutants and nutrients. It is high in organic content and plant nutrients and, in theory, makes a good fertilizer. However, most developed countries regulate its use because it also can contain a multitude of metals, organic pollutants, and pathogens<sup>4</sup>. Over time, they argue, metals such as copper, zinc, lead, and cadmium could build up in soil sediments to levels high enough to damage agricultural soils. In Jordan several wastewater treatment plants were constructed to treat sewage sludge for major cities, it has been estimated that around 75.64 million m<sup>3</sup>/year, of water could be retrieved from sewage treatment plants<sup>5</sup>.

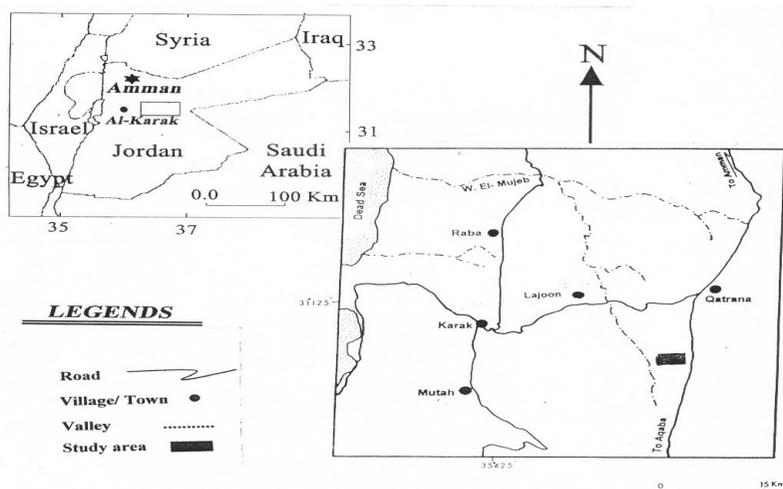
In Karak province/south of Jordan there are four wastewater treatment plants used to reclaim wastewater for agricultural proposes especially in dry season. It has been estimated that the demand (273,937 m<sup>3</sup>/year) which is utilized to irrigate 250,000 squar-meter<sup>6</sup>.

Most of the wastewater treated in this plant is generated from municipal wastewater and industrial activities. The treated wastewater is discharged along Al-Lajun valley to the north of wastewater treatment plant. Another portion of the treated wastewater recharges the groundwater along the valley and the rest ends up in the Dead Sea<sup>7,8</sup>.

The system under investigation (liquid waste disposal site) was in operation since 2004, which is located about 30 km to the east of the city of Karak (Figure 1). According to the design, a layer of 30 cm of sand was placed underneath a High-Density Polyethylene (HDPE) liner at the bottom of the six ponds. All ponds are lined at the bottom and all sides by an HDPE liner of 2 mm thickness, which is welded together, (MWI and BGR, 2005). The treatment system consists of six ponds: two anaerobic ponds (15.5 m × 60 m × 5 m), two facultative ponds (77 m × 152.5 m × 2 m) and two maturation ponds (67 m × 30 m × 2 m). Principally, in the waste stabilization pond system, anaerobic and facultative ponds are designed for BOD removal, and maturation ponds for pathogen removal (MWI and BGR, 2005). The design of the upper anaerobic ponds was based on a wastewater inflow rate of 600 m<sup>3</sup>/day in summer, and 750 m<sup>3</sup>/day in winter season.



**Figure 1.** Al-Lajoun wastewater disposal sites.



**Figure 2.** Study area.

The objective of this study is to assess the treated wastewater quality produced from Al-Lajoun liquid disposal site in term of major anionic composition, heavy metal content, organic pollutants, and physical parameters such as pH, electrical conductivity, and Temperature. In addition to investigate the sediments quality along the disposal site in terms of heavy metals and total organic carbon (TOC).

## Experimental

Certified standard solutions of cations (1000 mg/L) and anions (1000 mg/L) were supplied by Dionex, California. Standard solution of heavy metals (1000 mg/L and 10  $\mu$ g/L) was purchased from Perkin-Elmer, USA. Standard solution of polycyclic aromatic hydrocarbons (PAH) (ng/ $\mu$ L) was purchased from Promochem, Germany. Solvents (*n*-Hexane, Acetone, Dichloromethane, Iso-propanol) were of residual grade from Merck and Riedel-de Haen, Germany. All other chemicals were of analytical grade from Fluk, Switzerland, AVONCHEM, UK, TEDIA, USA, Merck and Riedel-de Haen, Germany.

## Sampling

### *Wastewater*

Wastewater Samples were collected on daily basis for five weeks period from the septic tanks wastewater disposal site from influent as well as from the wastewater effluent. This study covered two periods, the first sampling activities were carried out during June to September 2005, and the second period covered the period from December to February 2005-2006.

The samples were filtered through 0.2 mm pore size membrane in order to remove insoluble particles, and stored in polyethylene bottles under cold condition (4 °C). Each sample was divided into two portions, one for major anions analyses. The other portion was acidified with few drops of concentrated HNO<sub>3</sub> for cations and heavy metals analyses. Analyses were done a short period after collection to prevent any change in ionic composition.

### *Sediment*

A total of 42 sediment samples were collected along the wastewater drainages system using polyethylene bags. The first sets of samples were collected during June to September 2005 and the second was extended from December to January 2005-2006.

The location of samples were carefully selected to represent the possible distribution of pollutants in the area, the length of sampling area was 800 m<sup>2</sup> which divided into four equal sites (1, 100, 400 and 800 m<sup>2</sup>). The samples were dried at 104 °C and sieved through 2 mm, and 0.630 mm sieves.

#### *Wastewater samples*

A portable pH-meter model WTW 525, and a portable EC-meter model WTW LF 320, Germany were used to measure the pH and electrical conductivity of the collected wastewater samples. These tests were done on site, as these values might change when transported to the laboratory.

The bicarbonate was determined as follows: 10 mL of collected wastewater sample was transferred into Erlenmeyer flask, and one drop of methyl orange indicator was added. Carbonate was determined by titration with 0.01 M HCl until the appearance of green color. The test was done on the same day of sampling as its concentration might change due to precipitation of carbonates.

The ammonia test was done as follows: Samples were filtered and transferred to 5 mL test tubes, 2 mL of Nessler's reagent and two drops of EDTA were added, and swirled to mix. The sample was left for 10 minutes until the color developed to yellow and concentration was determined using a Spectrophotometer (MILTON ROY, Spectronic 20D) at 415 nm.

The chemical oxygen demand (COD) is used as measurement of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by strong chemical oxidant. COD was determined according to the standard procedure (APHA, 1998).

The biological oxygen demand (BOD<sub>5</sub>) test measures the amount of oxygen used by the microorganisms as they utilize the substrate (food) in wastewater. The dissolved oxygen (DO) is measured at the beginning of the test and recorded, during the five days, microorganisms in the sample break down complex organic matter in the sample using oxygen in the process. After five-day dark incubation period, the DO is again determined; the BOD is then calculated on the basis of the reduction of DO and the size of the sample. This test is an estimation of the availability of food in the sample (organisms that take up oxygen) expressed in terms of oxygen use samples are incubated for standard period of five days, because a fraction of the total BOD will be exerted during this period. BOD<sub>5</sub> was determined according to the standard procedure<sup>9</sup>.

Heavy metals (Pb, Cd, Cu, Zn, Cr, Fe and Co) were analyzed using a Perkin- Elmer Atomic Absorption Spectrophotometer model Analyst 300 with Standard Graphite Furnace model HAG 800 equipped with AS-72 Auto sampler. (PerkinElmer, Germany). Certified standard solutions for each heavy metal were used as stock standard, and used to prepare the working standard and built up the calibration curves. The detection limits of the atomic absorption spectrophotometer were: 0.005 Fe, 0.001 Zn, 0.001 Cu, 0.01 Pb, 0.001 Cd, 0.01 Co and 0.003 Cr mg/L. and that for the graphite furnace were: 0.01Cr, 0.01 Cd, 0.02 Pb and 0.03 Co µg/L.

The anion (F<sup>-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, PO<sub>4</sub><sup>3-</sup> and SO<sub>4</sub><sup>2-</sup>) were analyzed using DIONEX (DX-100) ion chromatography (IC) with a conductivity detector model CDM-2 from DIONEX, USA. Analytical column was an AS4A-SC ion exchange (4 x 250 mm ID) with an AG4A-SC guard column (4 x 50 mm ID) was used for the separation of the major anions, and ASRI anion self-regeneration suppressor. The standard mixture of five anions of 1000 mg/L (DIONEX, California) was used to prepare the working standards. The injection volume was

25  $\mu\text{L}$ , and the flow rate 2.0 mL/min. the eluent was an aqueous solution consisted of 1.8 mM  $\text{Na}_2\text{CO}_3$  and 1.7 mM  $\text{NaHCO}_3$ . The detection limit (DL) of element was based on peak to noise ratio (3:1). Following are the DL (ppm): 0.025 F<sup>-</sup>, 0.1 Cl<sup>-</sup>, 0.1 NO<sub>3</sub><sup>-</sup>, 0.1 PO<sub>4</sub><sup>3-</sup> and 0.4 SO<sub>4</sub><sup>2-</sup>.

Major cations were analyzed on the same instruments, which was described for the anion analysis. Standard mixture of four of cations ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$ ) of 200, 400 and 1000 mg/L, respectively, were used to prepare working standards based on the following concentrations of  $\text{Na}^+$  (0.2, 0.5, 1.0, 2.0, 4.0, 8.0 and 15.0 mg/L). The detection limit (DL) of element was based on peak to noise ratio (3:1). Following are the DL (ppm): 0.1, 0.1, 0.4 and 0.4, of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$ , respectively.

### *Sediment samples*

The Total Organic Carbon (TOC) of the sediment samples was determined according to the procedure, given elsewhere<sup>10</sup>. A 0.5 g of dried sediments sample was transferred into a microwave digestion vessel (Milestone, Ethos 900). 4 mL conc. nitric acid and 1 mL conc. perchloric acid was added to the sample. Then digestion vessels were capped and placed it in the microwave oven. After the end digestion program, the digestion vessel was removed from the microwave oven and allowed to cool at room temperature. The cap was removed and the content of the digestion vessel transferred into a simple filtration apparatus and the final volume of the sample was adjusted with 1%  $\text{HNO}_3$  to 25 mL using polyethylene volumetric flask.

Heavy metals were determined by using Perkin-Elmer Flam Atomic Absorption Spectrophotometer model analyst 300. The detection limits of the analyzed elements are given in the earlier section (Wastewater samples).

The organic compounds in sediment samples were determined using GC/MS analysis after liquid-liquid extraction. Wastewater samples (200 mL) were extracted two times with total amount of 150 mL dichloromethane using a separatory funnel. The organic phase was entangled with aqueous phase after separation, by the formation of emulsions. This problem was solved by extracted organic phase two times with 100 mL of *n*-hexane, and dried the extract with sodium sulfate anhydrous, and filtered through a plug of cotton into 500 mL round bottle flask. The samples were concentrated to 1 mL using rotary evaporator at 40 °C. The sulfur removal was done by using tetra butyl ammonium sulfate (TBAS) method<sup>11</sup>.

The chromatographic separation was carried out using a GC-MS model, Clarus 500. The fused silica capillary column a 30 m x 0.25 mm *i.d* x 0.25  $\mu\text{m}$  filmHP-5(Perkin-Elmer, USA). Chromatographic conditions: 1  $\mu\text{L}$  with split ration 1:50, the column temperature was 60 °C, and hold for 5 min, then programmed at ramping rate 10 °C/ min to 280 °C and hold for 10 min. Helium used as a carrier gas with flow rate 1.5 mL/min. the injector and transfer line temperature were at 250 °C and 200 °C, respectively.

### *Quality Control*

In order to assure the quality of the analytical results and to estimate the precision and accuracy of the data, many operations were performed during analysis such as:

- a) Standard and blank solutions were used for calibration the instrument and building up the calibration curves.
- b) Analysis of duplicate samples. To determine the RSD for methods of analysis.

- c) Analysis of standard reference material SRM (IAEA-soil 7), and comparison of the obtained results with the certified values. .
- d) Periodic analysis of standards in order to verify the reliability of measuring instruments. If the measured is not accurate the calibration curve was again built up.

## Results and Discussion

### *Temperature, pH and electrical conductivity (EC)*

The temperature of wastewater samples ranged from 10 to 15.2 °C with an average 12.7 °C in winter season (Table 1 and Table 2) and varied from 22.4 °C to 28.4 °C with an average 25.55 °C in summer season. The variation is due to climatic conditions of hotter summer season than winter season and not due to treatment processes.

The pH value of the different wastewater samples effluent in winter and summer seasons was ranged from 6.0 to 8.1 with an average value of 7.1. While for influent was ranged from 6.2 to 8.9 with an average 7.9 Table 1 and Table 2. The pH value in wastewater effluent was not low; although partial degradation of organic pollutants releasing CO<sub>2</sub> that converts to the weak carbonic acid upon contact with the water. This can be due to high content of carbonates in the investigated site buffering the wastewater to this pH values.

The electrical conductivity (EC) values of wastewater effluent samples did not show a significant variation between different seasons although the arid climatic conditions enhance evaporation as well as an increase in salinity<sup>8</sup>.

The EC value of wastewater effluent samples in summer season ranged from 3776 µS/cm to 4080 µS/cm with an average 3926 µS/cm, while for influent ranged from 3546 µS/cm to 3970 µS/cm with an average 3789 µS/cm. The EC value of wastewater effluent samples in winter season ranged from 3941 µS/cm to 4156 µS/cm with an average 4000 µS/cm, while for influent ranged from 3780 µS/cm to 4110 µS/cm with an average 3953 µS/cm, Table 1 and Table 2. The slight difference in EC between influent and effluent can be due to evaporation during the long treatment process period.

**Table 1.** Physicochemical parameters for wastewater effluent in summer season.

Variable	Influent				Effluent			
	N	Min	Max	Average	N	Min	Max	Average
Temp. °C	24	22.4	28.4	25.5	24	22.4	28.4	25.5
pH	24	6.52	8.92	7.90	24	6.0	8.1	7.1
EC, µS/cm	24	3546.0	3970.0	3789.0	24	3776.0	4080.0	3926.0
Na <sup>+</sup> , ppm	24	493.0	1093.0	729.0	24	851.0	1288.0	1050.0
K <sup>+</sup> , ppm	24	80.0	110.0	92.0	24	119.0	176.0	144.0
Ca <sup>2+</sup> , ppm	24	65.0	99.0	82.0	24	81.0	118.0	102.0
Mg <sup>2+</sup> , ppm	24	61.0	82.0	71.0	24	80.0	120.0	99.0
NH <sub>4</sub> <sup>+</sup> , ppm	24	250.0	460.0	321.0	24	172.0	278.0	220.0
Cl <sup>-</sup> , ppm	24	807.0	1167.0	1011.0	24	973.0	1199.0	1100.0
F <sup>-</sup> , ppm	24	0.0	1.5	0.6	24	0.0	0.4	0.2
NO <sub>3</sub> <sup>-</sup> , ppm	24	0.0	253.0	73.0	24	77.0	224.0	120.0
SO <sub>4</sub> <sup>2-</sup> , ppm	24	105.0	182.0	153.0	24	140.0	345.0	174.0
PO <sub>4</sub> <sup>3-</sup> , ppm	24	96.0	170.0	133.0	24	120.0	216.0	177.0
HCO <sub>3</sub> <sup>-</sup> , ppm	24	1128.0	1220.0	1165.0	24	1054.0	1497.0	1339.0

**Table 2.** Physicochemical parameters for wastewater effluent in winter season.

Variable	Influent				Effluent			
	N	Min	Max	Average	N	Min	Max	Average
Temp. °C	24	10.0	15.2	12.6	24	10.0	15.2	12.6
pH	24	6.2	8.9	7.9	24	6.0	8.1	7.1
EC, µS/cm	24	3780.0	4110.0	3953.0	24	3941.0	4156.0	4000.0
Na <sup>+</sup> , ppm	24	745.0	1045.0	895.0	24	863.0	1341.0	1071.0
K <sup>+</sup> , ppm	24	119.0	180.0	143.0	24	111.0	184.0	145.0
Ca <sup>2+</sup> , ppm	24	87.0	122.0	106.0	24	89.0	124.0	110.0
Mg <sup>2+</sup> , ppm	24	81.0	120.0	99.0	24	85.0	123.0	102.0
NH <sub>4</sub> <sup>+</sup> , ppm	24	214.0	455.0	316.0	24	102.0	319.0	217.0
Cl <sup>-</sup> , ppm	24	1022.0	1413.0	1237.0	24	1011.0	1381.0	1185.0
F <sup>-</sup> , ppm	24	0.0	1.8	0.7	24	0.0	1.9	0.4
NO <sub>3</sub> <sup>-</sup> , ppm	24	61.0	180.0	107.0	24	74.0	207.0	123.0
SO <sub>4</sub> <sup>2-</sup> , ppm	24	98.0	182.0	170.0	24	90.0	194.0	178.0
PO <sub>4</sub> <sup>3-</sup> , ppm	24	122.0	298.0	185.0	24	122.0	288.0	179.0
HCO <sub>3</sub> <sup>-</sup> , ppm	24	1097.0	1198.0	1101.0	24	1084.0	1225.0	1186.0

*N: number of samples*

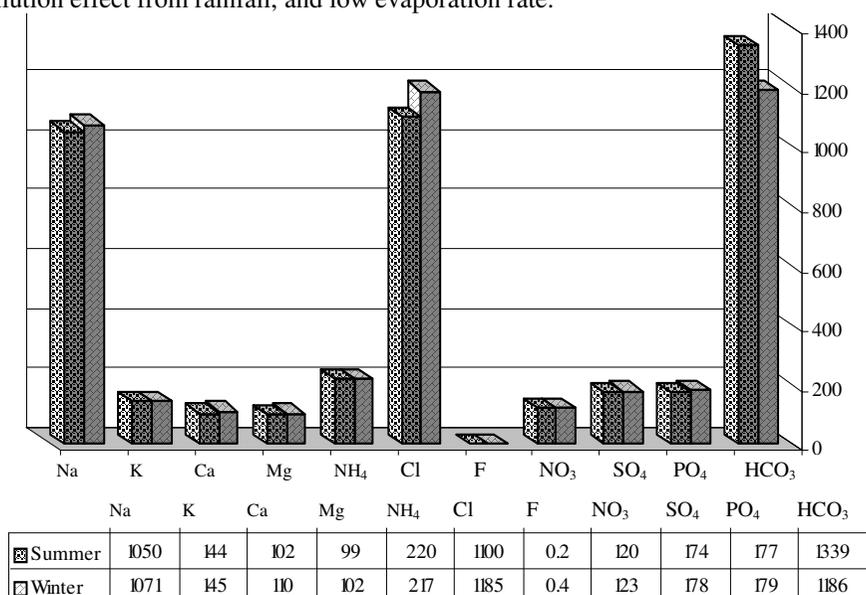
**Table 3.** Statistical difference between the average concentration of the major cations and anions in wastewater effluent for both seasons.

Ions	Season	N	Mean, ppm	S.D	t	df	Sig
Na <sup>+</sup>	Summer	24	1050	124	0.68	46	0.49
	Winter	24	1071	134			
K <sup>+</sup>	Summer	24	144	15.4	0.26	46	0.79
	Winter	24	145	15.8			
Ca <sup>2+</sup>	Summer	24	102	10.5	2.3	46	0.02
	Winter	24	110	11.2			
Mg <sup>2+</sup>	Summer	24	99	10.2	-0.74	46	0.46
	Winter	24	102	10.7			
NH <sub>4</sub> <sup>+</sup>	Summer	24	220	26.9	0.25	46	0.42
	Winter	24	217	58.7			
Cl <sup>-</sup>	Summer	24	1100	66.2	2.6	46	0.001
	Winter	24	1185	102			
F <sup>-</sup>	Summer	24	0.20	0.09	2.4	46	0.002
	Winter	24	0.40	0.11			
NO <sub>3</sub> <sup>-</sup>	Summer	24	120	47.0	48	46	0.62
	Winter	24	123	43.0			
SO <sub>4</sub> <sup>2-</sup>	Summer	24	174	39.0	2.3	46	0.002
	Winter	24	178	30.0			
PO <sub>4</sub> <sup>3-</sup>	Summer	24	177	36.6	0.20	46	0.07
	Winter	24	179	33.2			
HCO <sub>3</sub> <sup>-</sup>	Summer	24	1339	113	2.1	46	0.002
	Winter	24	1186	36			

*N: number of samples; Sig at ≤ 0.05*

*Major anions and cations*

The concentration of major ionic composition of wastewater effluent in summer and winter seasons are summarized in Table 3. The average concentration of cations and anions in winter season was slight higher than summer season, which could be due to the decrease of water demand during winter seasons, which decrease the dilution of cations and anions in wastewater (Figure 3). The results in Table 1 show that the average concentration of cations and anions in effluent wastewater was higher than influent in summer season; this can be attributed to the evaporation effect during summer seasons (Figure 4). But no variation was observed between influent and effluent in winter season (Table 2); this can be attributed to the dilution effect from rainfall, and low evaporation rate.



**Figure 3.** The average concentration of the major cations and anions for wastewater effluent for both seasons.

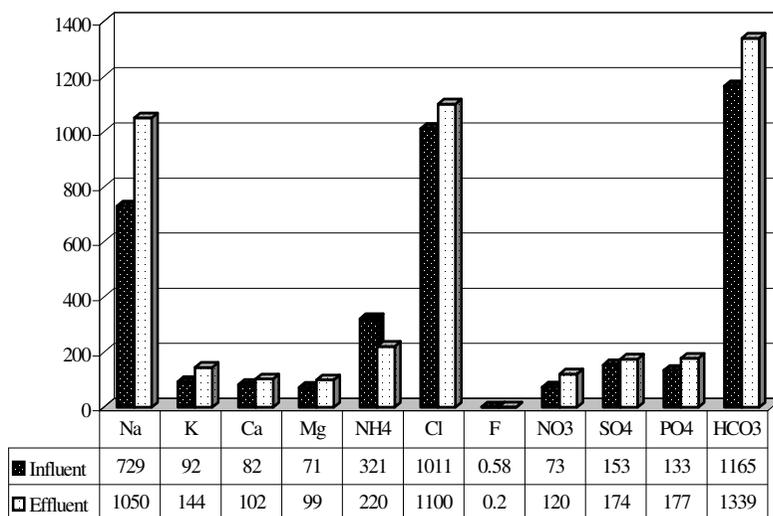
A chloride ion is one of the higher anion in the wastewater treatment plant. Chloride concentration was higher in winter than summer, it ranged from 1011 ppm to 1381 ppm with an average value of 1185 ppm in winter, and from 973 ppm to 1199 ppm with an average value of 1100 ppm in summer season.

The high chloride concentration in wastewater might be due to human excrement as well as to detergent<sup>7</sup>. The average concentrations of chloride for wastewater effluent in both seasons were higher than Jordanian standard 892/2002 (350 ppm).

The average concentration of phosphate in winter and summer seasons were 179 ppm and 177 ppm, respectively. This high concentration may be due to the use of detergents rich in phosphate. Such high phosphate in wastewater enhances growing of algae in its ultimate disposal sites which is the fresh water Mujeb Dam. But it is useful when the treated wastewater used for agriculture.

Nitrate is a well-regulated pollutant worldwide due to its toxicity and hazardous effect when it is used for drinking purposes. The NO<sub>3</sub><sup>-</sup> is reduced by anaerobic bacteria to NO<sub>2</sub><sup>-</sup>, nitrite (NO<sub>2</sub><sup>-</sup>) oxidize Fe<sup>2+</sup> to Fe<sup>3+</sup> to react with the hemoglobin causing methemoglobinemia.

Nitrite reacts with amines in the diet to produce carcinogenic compounds known as *N*-nitrosamines ( $R_2NNO$ )<sup>12</sup>. Nitrate in wastewater may originate from many sources, inorganic (mineral) as well as organic such as fertilizer, and sewage sludge<sup>13</sup>.



**Figure 4.** The average concentration of the major cations and anions for influent and effluent wastewater in summer season.

The average concentration of nitrate in wastewater in summer season was ranged from 77 to 224 ppm with an average 120 ppm, and ranged from 74 to 207 ppm with an average 130 ppm in winter season. This concentration is highest than Jordanian standards (892/2002) for wastewater, the maximum concentration limit of nitrate in discharged in valleys 45 ppm. Nitrate increases in effluent wastewater by decrease the concentration of  $NH_4^+$ . However, such high  $NO_3^-$  level is not harmful when it is used for irrigational purposes.

Carbonate exists in aqueous solution on three forms. In strongly basic condition by form carbonate ion,  $CO_3^{2-}$ , predominates, in weakly basic conditions bicarbonate ion,  $HCO_3^-$  is prevalent, in acid conditions, aqueous carbon dioxide,  $CO_2(aq)$ , is the main form. Therefore, in the collected samples only  $HCO_3^-$  was detected due to dominated pH value. The concentration of bicarbonate in summer ranged from 1054.0 to 1497.0 ppm with an average 1339.0 ppm, and ranged from 1084.0 to 1225.0 ppm with an average 1186.0 ppm in winter season. The main source of carbonate in the investigated area is the fresh water used at source where it was recorded to be rich in carbonate due to carbonate lithology of the aquifers. High bicarbonate or carbonate content in wastewater reacts with  $Ca^{2+}$  and  $Mg^{2+}$  to precipitate insoluble lime ( $CaCO_3$ ,  $MgCO_3$ ), when the samples are left for a long period before analysis.

The cations of  $Ca^{2+}$  and  $Mg^{2+}$  are directly connected to the pH value. The higher  $Ca^{2+}$  content, the less the negative impacts of  $Na^+$  and  $Cl^-$ . The concentration of  $Ca^{2+}$  in summers ranged from 81.4 ppm to 119.7 ppm with average 102.4 ppm, and ranged from 89.0 ppm to 124.0 ppm with average 109.8 ppm in winter season. These values are comparable with fresh water in the investigated area<sup>14</sup>. The average concentration of  $Mg^{2+}$  for wastewater effluent in summer season 99.0 ppm and 102.0 ppm in winter season, these values was higher than Jordanian standard 60.0 ppm.

$\text{Na}^+$  and  $\text{Cl}^-$  are the major salinity parameters in water as their concentrations are generally reflected in the EC value. The most probably source in wastewater treatment plants is salt use at home where significant correlation coefficient exists between  $\text{Na}^+$  and  $\text{Cl}^-$  ( $R=0.94$  for winter:  $R=0.95$  for summer) as the type of wastewater used here is municipal wastewater.

### Heavy metals

Heavy metals in wastewater come from industries and municipal sewage, and they are one of the main causes of water and soil pollution. Accumulation of these metals in wastewater depends on many local factors such as type of industries in region, people's way of life and awareness of the impacts done to the environment by careless disposal of wastes. Therefore the presence of heavy metals in wastewater is not only of great environmental concern but also strongly reduces microbial activity, as a result adversely affecting biological wastewater treatment processes. Moreover the toxicity of heavy metals in wastewater was shown to be dependent on factors like metal species and concentration, pH, wastewater pollution load and solubility of the metal ions. Wastewater is known to be a major source of pollution with heavy metals<sup>15</sup>.

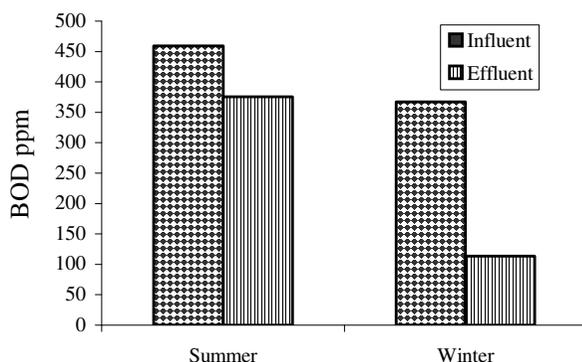
The data in the chemical characteristics of heavy metals content of Fe, Zn, Pb, Cu, Cr, Co and Cd are given in Table 4. The average concentration of heavy metal in winter season were higher than summer season, which could be due to the less use of water during winter seasons that decrease the dilution of heavy metals in wastewater (Figure 5).

**Table 4.** Statistical difference between the average concentration of the trace metals in wastewater effluent for both seasons.

Metals	Season	N	Mean, $\mu\text{g/L}$	S.D	t	df	Sig
Fe	Summer	24	196.70	56	-2.3	46	0.002
	Winter	24	267.60	63			
Zn	Summer	24	173.00	120	-0.56	46	0.57
	Winter	24	194.50	60			
Pb	Summer	24	20.60	6.82	-0.31	46	0.75
	Winter	24	21.80	5.33			
Cu	Summer	24	17.50	6.73	-2.2	46	0.001
	Winter	24	29.10	12.50			
Co	Summer	24	14.30	2.92	-0.09	46	0.92
	Winter	24	14.50	5.86			
Cr	Summer	24	1.20	0.70	-3.1	36	0.003
	Winter	24	2.80	1.60			
Cd	Summer	24	1.80	0.39	1.65	33	0.10
	Winter	24	2.52	1.30			

*N*: number of sample; *Sig* at  $\leq 0.05$

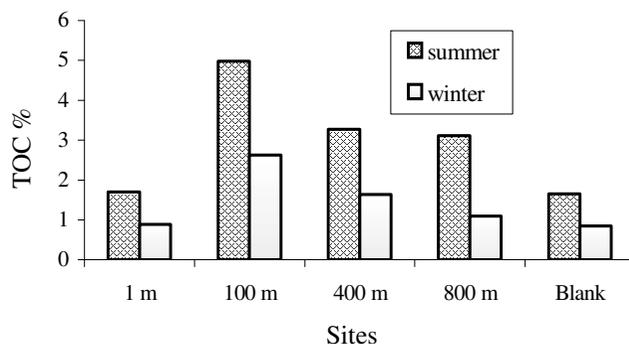
As given in Table 5, concentration of heavy metals in effluent wastewater were low, which can be due to enhancing precipitation under high pH value<sup>16</sup> (Figure 6 and Figure 7), table bounded to the sludge<sup>17,18</sup>, and most probably ends in the sediments<sup>14</sup>. Similar findings were also reported on treated wastewater in Karak, Jordan<sup>14</sup>. High pH conditions are associated with the removal of trace metals from the aqueous to the solid phase, but the reverse effect occurs with increasing acidity<sup>19</sup>.



**Figure 5.** The average of BOD<sub>5</sub> (ppm) in wastewater for both seasons.

**Table 5.** The average of COD (ppm) in wastewater for both seasons.

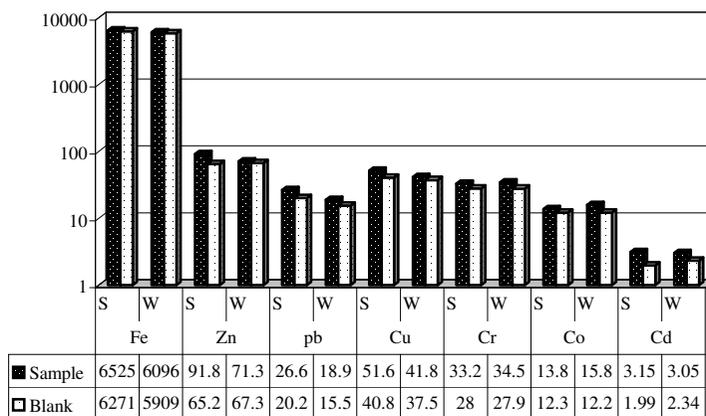
Number of samples	Summer		Winter	
	Influent	Effluent	Influent	Effluent
1	1118	1040	1000	480
2	672	575	1260	640
3	1046	746.8	1205	600
4	976	760	1105	550
5	1120	1038	1089	488
Mean	987	832	1132	552



**Figure 6.** Individual distribution pattern of total organic carbon (TOC %) in sediments for summer and winter seasons in different sites.

The results showed high concentration of Cr in wastewater, the concentration of Cr in summer ranged from 0.0 to 2.0  $\mu\text{g/L}$  with an average 1.2  $\mu\text{g/L}$  and ranged from 1.0  $\mu\text{g/L}$  to 6.0  $\mu\text{g/L}$  with an average 2.8  $\mu\text{g/L}$  in winter seasons. Chromium enters the environment from industries during plating operations, fossil fuel combustion and waste incineration.

The maximum average concentration of copper for wastewater effluent in summer and winter seasons are shown in Table 4 and Table 5. The concentration in the summer season ranged from 7.0  $\mu\text{g/L}$  to 39.0  $\mu\text{g/L}$  with an average value of 17.5  $\mu\text{g/L}$ , and in the winter season from 12.0  $\mu\text{g/L}$  to 68.0  $\mu\text{g/L}$  with an average value of 29.1  $\mu\text{g/L}$ . Copper enter the environment of wastewater treatment plants from pipe connections, corrosion of building materials, algicides, fungicides, pesticides produced from washing of vegetables and fruits at home<sup>20</sup>.



**Figure 7.** Heavy metals (ppm) in summer and winter seasons, for < 0.630 mm sizes of particles. (S: Summer season W: Winter season).

The concentration of lead in wastewater effluent ranged from 9.0 µg/L to 30.0 µg/L with an average value of 20.6 µg/L for summer and from 10.0 µg/L to 30.0 µg/L with an average value of 21.8 µg/L for winter season. Lead was present in the environment from pipelines and pipes connections used to transport fresh water at home. Beside other sources, such as industrial work shops<sup>21,22</sup>.

In wastewater effluent the Zn concentrations were high in both seasons, and ranged from 50.0 µg/L to 353.0 µg/L with an average value of 173.0 µg/L in summer, and ranged from 102.0 µg/L to 288.0 µg/L with an average value of 194.5 µg/L in winter season. Zinc can enter the environment from wear from tyres, brake pads, combustion of lubrication oils, activity of smelters, corrosion of building materials and metal objects<sup>20</sup>.

The Fe concentrations are shown in Tables 2 and 3. The results showed high concentration of Fe in wastewater in both seasons as well as in the influent and effluents wastewater. The average concentration of Fe in summer season ranged from 101.0 µg/L to 294.0 µg/L with an average value of 196.7 µg/L. However, in winter season the Fe concentration ranged from 130.0 µg/L to 394.0 µg/L with an average value of 267.6 µg/L. Iron enters into the site from the use of iron in many parts at source cooking house ware, as well as in different parts of food.

Cobalt concentration ranged from 9.0 µg/L to 20.0 µg/L with an average of 14.3 µg/L for summer season and ranged from 4.0 µg/L to 19.6 µg/L with an average concentration of 14.5 µg/L. In both seasons the maximum concentration for Co was reported in the wastewater effluent was less than Jordanian standard (893/2002), the standard of Co for irrigation and wastewater discharged in the valleys is 50 µg/L.

**Biological Oxygen Demand (BOD<sub>5</sub>) and Chemical Oxygen Demand (COD)**

The biological oxygen demand defined as the amount of oxygen used for biochemical oxidation by activities of aerobic bacteria usually in five days at 20 °C<sup>23</sup>.

The BOD<sub>5</sub> test is a very important parameter for the determination of pollution stage of wastewater, in order to evaluate the efficiency of wastewater treatment system, industrial waste and any type of water pollution. The BOD<sub>5</sub> value of wastewater effluent ranged from 183 to 520 ppm with an average value of 375.8 ppm for the effluent in summer season, and ranged from 306 to 510 ppm with an average value of 459.2 ppm for influent in summer season

(Table 6). In winter season it was much lower that it ranged from 277 ppm to 420 ppm with an average value of 366.6 ppm in the influent at winter season and from 89 to 140 ppm with an average value of 113.6 ppm in the effluent during winter season. This may be attributed to contribution of rain water falling on the area during winter season. The values for wastewater does not comply with the 300 ppm for irrigation, except effluent in winter season, and also does not comply with the standard for discharge in valleys 60 ppm. There are significance variation in winter season between effluent and influent due to the rainfall

**Table 6.** Average heavy metal concentrations in ppm from different fractions of sediments in winter season along stream flow in the investigated area in addition to blank sample.

Site	Heavy metal in winter season													
	Fe		Zn		Pb		Cu		Cr		Co		Cd	
	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg
1 m	4918	6604	79.04	60.05	18.43	21.71	39.87	41.85	35.40	28.71	16.33	16.32	3.07	5.02
100 m	6315	6706	80.04	65.05	19.18	23.76	51.63	46.88	40.04	27.47	16.57	16.45	3.28	5.19
400 m	6454	8236	66.84	61.24	19.40	22.30	39.72	40.60	34.01	25.81	15.33	15.26	3.19	6.94
800 m	6697	8923	59.36	64.07	18.60	20.11	35.94	36.83	28.73	22.20	15.00	14.67	2.67	4.25
Mean	6096	7617	71.32	62.60	18.90	21.97	41.79	41.54	34.54	26.04	15.80	15.67	3.05	5.35
Blank	5909	6853	67.25	55.17	15.49	12.83	37.53	32.64	27.90	20.41	12.22	10.12	2.34	3.51

*Aren = Grain size <0. 63 mm Arg = Grain size 2 mm to 0. 63 mm*

The chemical oxygen demand is defined as the amount of oxygen required by organic material in water for oxidation by strong oxidant. This test is used to measure the pollution level in water.

The COD value for the wastewater effluent ranged from 575 ppm to 1040 ppm with an average of 832 ppm. While for influent ranged from 672 ppm to 1120 ppm with an average of 987 ppm in summer season Table 7. But the average COD value for effluent is 552 ppm, and 1132 ppm for influent, in winter season, thus the wastewater treatment plant was capable to remove only 15% of COD during summer season and up to 53% during winter season. The high reduction of COD during winter season could be due to mixing of effluent water with rain water and not due to treatment process. This value for wastewater does not comply with the Jordanian standard 893/2002, value of 500 ppm, for irrigation. In addition, wastewater discharged in the valleys 150 ppm.

**Table 7.** Average heavy metal concentrations in ppm from different fractions of sediments in summer season along stream Flow in the investigated area in addition to blank sample.

Site	Heavy Metal in summer season													
	Fe		Zn		Pb		Cu		Cr		Co		Cd	
	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg	Aren	Arg
1 m	4271	11525	80.00	63.63	26.87	28.94	41.92	32.32	33.90	32.3	14.40	15.70	2.96	5.30
100 m	4475	11966	104.82	68.04	27.11	33.25	58.32	43.32	35.50	36.27	16.12	20.20	4.67	8.55
400 m	8369	12450	92.81	54.03	25.40	27.74	55.95	42.65	32.40	33.62	12.32	16.00	3.18	8.85
800 m	8985	14077	89.52	58.80	27.02	28.97	50.20	33.05	26.80	33.50	12.33	14.87	1.81	10.11
Mean	6525	12505	91.77	61.11	26.59	29.74	51.59	37.81	33.15	33.91	13.78	16.69	3.15	8.20
Blank	6271	10583	65.21	56.81	20.24	18.22	40.81	33.4	27.97	25.95	12.25	10.16	1.99	4.41

*Aren = Grain size <0. 63 mm; Arg = Grain size 2 mm to 0.630 mm*

## Sediment

### Total organic carbon (TOC)

The results of TOC in sediment samples showed, that TOC ranged from 1.70% to 4.98%

with an average 3.27% for summer, and from 0.88% to 2.62% with an average 1.56% for winter. The total organic carbon in site 2 which is located at 100 m from the treated wastewater discharging site ranged from 4.41% to 5.52% with an average value of 4.98% for summer, and ranged from 1.25% to 4.45% with an average value of 2.62% for winter season, it was noticed that site two (100 m) had a TOC value higher than other sites with about 2-3 times, which due to the accumulation of organic carbon in sediment.

From the results, we can note that samples for summer season have contained organic matter by 3 folds higher than for winter season. That might be explained in the winter sampling periods came after excess rainfall quantities. Therefore, wash out of pollutants from residential areas has been taken place during the first rainfall event, and then the pollutants washed out from the sediments during wet season<sup>24</sup>.

### *Heavy metals*

The principal concerns about heavy metals are their persistency in the environment as they do not generally degrade, volatilize or decay by photolysis<sup>25</sup>, and their ability to become concentrated in living tissue (bioaccumulation) thus threatening predators at the head of the food chain. As well as ultimately causing the death of aquatic organisms, some metals exert sub-lethal effects on aquatic organisms and predators such as birds and mammals<sup>26</sup>.

The average contents of heavy metals in sediment of the investigated area showed a higher heavy metal concentration than reference site. The heavy metal concentrations in winter season are lower than for to summer season in all sediments samples, this due to the rainfall quantities, which washed out the soil reducing the heavy metals concentration in all analyzed samples.

The effluent water from Al-Lajoun wastewater disposal site (LWWDS) is, undoubtedly, among the major factors contributing to metal pollution in the investigated area, in addition, lithology of the stream bedrock contributes, to enrichment of some heavy metals such as iron.

A general decreasing trend of all heavy metals, except iron, with distance from the source of treated water was observed (except site one (1 m) it is consider washing site). This could be due to precipitation of these metals from the liquid phase, near the source under prevailing high pH conditions, leading to an increase in concentration in the solid phase. In addition, calcareous soil that exists in the investigated area may decrease heavy metal problems<sup>27</sup>.

The concentration of Cu was ranged from 36.40 ppm to 65.00 ppm with an average 51.59 ppm and ranged from 34.84 ppm to 55.15 ppm with an average 41.79 ppm for fine particles in summer and winter seasons, respectively. But the concentration in grain particles was ranged from 28.60 ppm to 44.60 ppm with an average 41.45 ppm, and from 35.98 ppm to 74.70 ppm with an average 37.81 ppm for summer and winter seasons, respectively. The higher concentration of Cu in fine sediment particles during summer season than winter season could be due to meteorological conditions as well as that it is probably attached to the organic matter generated from the sewage<sup>20</sup>.

The concentration of Cr was ranged from 24.85 ppm to 38.31 ppm with an average 33.15 ppm, and from 25.00 ppm to 42.60 ppm with an average 34.54 ppm for fine particles in summer and winter seasons, respectively. But the concentration in grain particles was ranged from 31.10 ppm to 37.50 ppm with an average 33.91 ppm and ranged from 20.40 ppm to 29.55 ppm with an average 26.04 ppm for summer and winter seasons, respectively. This is due to higher concentration of iron during summer season under prevailing dry condition.

From the results obtained we infer that, there is no variation in Pb concentration with season as well as with grain size. The average concentration of Pb was 26.59 ppm and 18.90 ppm for fine particles in summer and winter seasons, respectively. But the average concentration in grain particles was 29.74 ppm in summer and 21.97 ppm in winter season.

The average concentration of Zn was higher in the fine particles than coarse particles which are due to higher surface area of the former size. The concentration of Zn was ranged from 70.75 ppm to 118.75 ppm with an average 91.77 ppm and ranged from 55.00 ppm to 93.30 ppm with an average 71.32 ppm for fine particles in summer and winter seasons, respectively. But the concentration in grain particles was ranged from 48.52 ppm to 73.37 ppm with an average 61.11 ppm and ranged from 55.68 ppm to 69.85 ppm with an average 62.60 ppm for summer and winter seasons, respectively.

The concentration of Cd was ranged from 1.70 ppm to 5.25 ppm with an average 3.15 ppm, and from 1.75 ppm to 9.05 ppm with an average 3.05 ppm for fine particles in summer and winter seasons, respectively. But the concentration in grain particles was ranged from 4.85 ppm to 12.00 ppm with an average 8.20 ppm and ranged from 2.85 ppm to 9.55 ppm with an average 5.35 ppm for summer and winter seasons, respectively. High concentration may be due to from rocks agricultural use of sludge, fertilizers and pesticides, and corrosion of galvanised metals, smelting operation and sludge disposal, *e.g.*, the source is most probably from household activities at source.

The concentration of Fe was ranged from 3100 ppm to 10030 ppm with an average 6525 ppm and ranged from 3700 ppm to 7215 ppm with an average 6096 ppm for fine particles in summer and winter seasons, respectively. But the concentration in grain particles was ranged from 9100 ppm to 14408 ppm with an average 12505 ppm and ranged from 5579 ppm to 9110 ppm with an average 7617 ppm for summer and winter seasons, respectively. High concentration may be due to the lithology of the stream bedrock contributes, such as basalt<sup>28</sup>.

### *Organic compounds*

The non-target GC-MS results identified some organic constituents of LWWDS. The detected compounds were classified into 16 different groups based on the functional group and chemical structure. Common compounds in LWWDS were found: alkanes, alkenes, acids, esters, ketons, phenols, amines, amides, phenylalkanes, alcohols, ethers, phosphate, chlorinated hydrocarbons, sulfides, aldehydes and polycyclic aromatic hydrocarbons. Most of these compounds were normal constituents for municipal wastewater. Furthermore, some carcinogenic compounds were identified such as phenols and polycyclic aromatic hydrocarbons.

These results were in agreement with another study that identified 16 carcinogenic compounds in wastewater of Karak province<sup>29</sup>. Also the phenolic compounds were in agreement with Batarseh who identified them in wastewater and sludge in a different wastewater treatment plants in Jordan<sup>5</sup>.

Some of the detected compounds in full scan analysis were confirmed via retention time (Rt) comparison using standard solution, such as polycyclic aromatic hydrocarbons (PAH) and phenols. Polycyclic aromatic hydrocarbons the main input of toxicology compound from the combustion of fossil fuels. Alkanes may originate from aquatic organisms as well as from mineral oil pollution. Alcohols, such as cholestanol may be due to multiple biogenic sources. Phenylalkanes was found in wastewater, may be due from detergent sources<sup>30</sup>.

## Conclusions

1. The wastewater effluent from Al-Lajoun disposal well affects both surface and ground water of the investigated area with time.
2. The average concentration of heavy metals, anions and cations in winter season was slight high than summer season, which could be due to less use of water during winter seasons, which decrease the dilution of cations and anions in wastewater.
3. The average concentration of heavy metals in wastewater effluent for both seasons was lower than influent, this is due to the high pH value enhancing its precipitation, and the heavy metals will be adsorbed on the sludge. The ionic composition in wastewater effluent for summer season was higher than influent, this is due to evaporation effect during summer seasons. Such variation was not significant between influent and effluent in winter season.
4. Heavy metals in wastewater were mostly of anthropogenic origin, and their concentration was below the national guidelines due to precipitation under basic pH.
5. The average concentration of  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$  and  $\text{HCO}_3^-$  in wastewater effluent for both seasons was higher than Jordanian standard, 2002.
6. The quality of the wastewater effluent of both seasons fall under the category  $\text{C}_4\text{-S}_3$ . Wastewater of high salinity and sodium content could cause a serious environmental damage of the discharge area (ecosystem).
7. The full scan analysis showed the LWWDWS was contaminated with toxicity organic compound such as PAH.
8. Heavy metals and TOC in sediment for winter was lower than summer season, this attributed to impact of rainfall during winter seasons.
9. The average concentration of heavy metals and TOC decreased with distance. That might be explained to natural purification of wastewater occurred downstream, which due to the adsorption of heavy metals and TOC and sedimentation of suspended particulates.

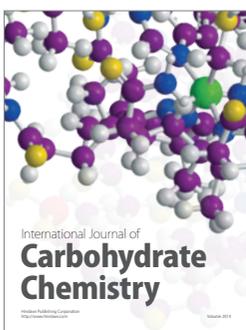
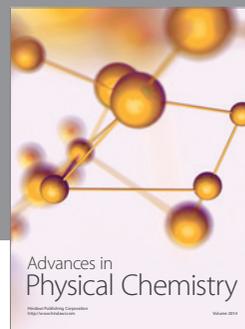
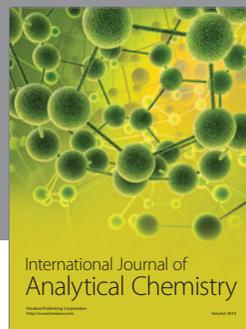
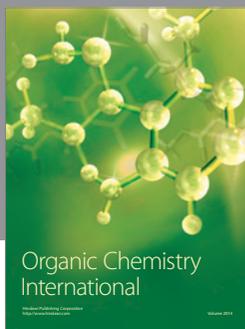
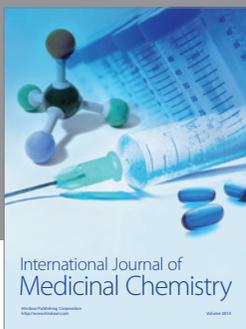
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