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Assessment and Evaluation of Treated Municipal Wastewater Quality for Irrigation Purposes

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Abstract: The present study investigated the chemical composition of Petra Wastewater Treatment Plant effluent in southern Jordan. Twenty four Samples were collected over one year period from June 2008 to June 2009. The samples were analyzed for temperature, conductivity, dissolved oxygen, pH, major cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}), major anions (Cl^{-}, NO_3^{-}, HCO_3^{-}, SO_4^{2-} and PO_4^{3-}) and trace metals (B, Fe^{2+}, Cu^{2+}, Cd^{2+}, Cr^{2+}, Pb^{2+}, Zn^{2+} and Mn^{2+}). The pH value ranged from 6.52 to 8.14 with a median value of 7.51±0.50. The water quality was characterized by its high salinity hazard (C3) and low Sodium Hazard (S1) which can be considered as marginal for human consumption. The hydrogeochemical behavior is rather complicated and is affected by anthropogenic and natural sources. The positive correlation values between various parameters indicate that most of ions were resulted from the same lithological sources. The abundance of the major ions in water samples is in the following order: $HCO_3^{-}>Ca^{2+}>Cl^{-}>Na^{+}>Mg^{2+}>SO_4^{2-}>NO^{3-}>NH_4^{+}>K^{+}$. Moreover, concentrations of trace metals in treated wastewater were found to be low and within guidelines for irrigational purposes due to low level of industrial activities in the study area. According to the residual sodium carbonate, SAR and conductivity values, the studied water is suitable for agricultural purposes. Based on these findings, the effluents of Petra Wastewater Treatment Plant can be considered as possible additional resources for irrigation in Jordan.

Keywords: Assessment, irrigation, chemical elements, hydrochemical coefficient, jordan, wastewater treatment

INTRODUCTION

The wastewater is a combination of the water and carried wastes removed from residential, institutional and commercial establishments together with infiltration of water, surface water and runoff water (Al-Enezi *et al*., 2004). Water suitable for human consumption and irrigation is a scarce resource in the densely populated region of Middle East. Wastewater is a valuable source of nutrients and organic matter. Meanwhile, it may contain undesirable chemical metals and pathogens that pose negative environmental and health impacts (Alobaidy *et al*., 2010; Al-Hamaiedeh and Bino, 2010). The treated water is a potential solution for addressing the problems of poor quantity and quality of water in the region. The methods of wastewater treatment are first developed in response to the concern of public health and the adverse conditions caused by the discharge of wastewater to the environment (Jamrah, 1999). The restriction of available water observed in the last years in arid countries forced the decision makers to consider other sources of water in dry season for irrigation (Al-Shammiri *et al*., 2005). The characteristics of treated wastewater and sludge that affect its suitability for land irrigation and beneficial use include the presence of heavy metals, toxic organics, pathogens nutrient and organic content. The use of wastewater treated in irrigation has agronomic and economic benefits (Pescod, 1992; Shatanawi and Fayyad, 1996). It causes some problems such as; salinity, which causes soil problems and adversely affects yield quality beside, the ionic toxicities which also causes problems to both land and crops. Trace metals are sometimes found in wastewater. The use of water leads to accumulation of these metals in crops (Wang and Keturi, 1990; Pescod, 1992; Wong *et al*., 2001; Karvelas *et al*., 2003; Mireles *et al*., 2004; Al-Enezi *et al*., 2004; Wang *et al*., 2005). Urban effluents of wastewater always contain trace metals, while the concentration in the water is related to the source of the water and activities in the urban environment. Trace metals are widely used in industrial activities (Page and Chang, 1985; Smith *et al*., 1996). Major urban inputs to sewage water include household effluents drainage water, industrial effluents, atmospheric deposition and traffic related emissions

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Table 1: Major wastewater treatment plants in Jordan

Plant	Design capacity (m^3/day)	Current capacity (m^3/day)	Type of treatment
As-Samra	68000	130000	Waste stabilization ponds
Ramtha	1920	1600	Waste stabilization ponds
Irbid	11000	8500	Trickling filters-activated sludge
Kofranja	1918	1400	Trickling filters
Mafraq	1800	2000	Waste stabilization ponds
Jarash	3500	1500	Oxidation ditch
Baqa'a	6000	7000	Trickling filters
Abu-Nuseir	4000	1500	Rotating biological contactors
Salt	7700	4500	Extended aeration
Madaba	2000	3000	Waste stabilization ponds
Karak	786	1100	Trickling filters
Tafila	1600	1000	Trickling filters
Petra	1015	850	Mechanical treatment
Aqaba	9000	7500	Waste stabilization ponds

(vehicle exhaust, brake lining, tires and asphalt wear, gasoline and oil leakage). These are transported with storm water into the sewerage system (Wang *et al*., 2005; Karvelas *et al*., 2003; Sorme and Lagerkvist, 2002). Jordan is classified among the ten poorest countries in the world in terms of water resources (Lawrence *et al*., 2002). The climate is generally arid, with more than 90% of Jordan total area receives rainfall less than 200mm/year and more than 70% of the country receives less than 100 mm/year of rainfall (Salameh, 1996; WAJ, 2003). Treated waste water represents another essential element in the water strategy of the country approximately 95% of the total volume of treated wastewater has been utilized for irrigation (WAJ, 2008). The treated effluent of the major urban areas was added to the stock of irrigation water and, in 1999 constituted more than 20% of irrigation water resources in Jordan (WAJ, 2003). Jordan’s desperate need for water imposed a necessity for the use of treated waste water for irrigational purposes. Currently, several wastewater treatment plants were constructed to treat sewage from major sites in Jordan. The capacity of these plants has been estimated around 60 million m^3/year of treated water has been obtained as illustrated in Table 1 (Jamrah, 1999; WAJ, 2008).

This study presents one year study of wastewater contents carried two times every month in Petra city (June 2008 to June 2009). The main objective of this study is to study the suitability of the effluent wastewater treatment from Petra Wastewater Treatment Plant (PWTP) for irrigational purposes, without passing through tertiary treatments. This is achieved by examining the chemical composition of treated wastewater and the levels of toxic heavy metals in order to evaluate the effluents quality of water on the basis of its suitability for irrigation.

MATERIALS AND METHODS

Description of study area: The study area is situated in the southern part of Jordan (Fig. 1). The Petra region is situated between 30° 19¯ N and 35° 28¯E which is considered one of the great archaeological treasures in the world, undoubtedly; it is the most important famous attraction of Jordan. Petra region (50,000 populations) is about 250 km to the south of the capital Amman. Petra is now a UNESCO world heritage site that enchants visitors from all around the globe. Petra lies on the edges of the mountainous desert of the Wadi Araba. There is a considerable variation in the nature of the topography in the investigated area. The elevation drop vary from 1115 m above mean sea level in Wadi Musa center of Petra Region to maximum altitude of 1734 m above sea level at Jabel Al-Hisha, 6km north of Wadi Musa. Petra wastewater treatment is a mechanical treatment plant that used oxidation ditch followed by

Fig. 1: Location map of the studied area

Fig. 2: General view of the Petra Wastewater Treatment Plant location

settling units (Clarifiers) and polishing ponds. Nitrogen removal is included as a tertiary treatment (WAJ, 2003). The plant was constructed in 2001 with a design capacity of 1015 m^3/day, to serve the towns of Wadi Musa, Taiba and the villages of Um Saihoun and Beida. Water treated by this plant can be used for irrigated agriculture and some industrial uses (WAJ, 2003). However, the excess water during low irrigation practice is being discharge along the adjacent wadi. A general view of the plant site is given in Fig. 2.

Climate and geology: The investigated area in general considered as a very arid to semi-arid area, while it marked by sharp seasonal variation in both temperature and rainfall. It is about 80km from the sea and the annual rainfall is about 298 mm/year. Rainfall occurs only in the winter season, which is extended from November to April. The average temperature is 21.5ºC, with minimum values of 4.1°C in January and maximum of 38.0°C in July (Department of Meteorology, 2004). The maximum sunshine duration occurs in June with absolute values of 11.5 h/day, but the average minimum sunshine of about 4.8 h/day was recorded for December and January. The average relative humidity varies from 41 to 44.3% in the winter months and from 44.3 to 63.3% in the summer season. The prevailing wind direction is from westerly to northwesterly (Department of Meteorology, 2004).

The investigated area is located in the northwest part of the Arabian plate, where most of Jordan is located within the stable part of the plate. Upper Cretaceous carbonaceous facies dominated the central part of the country, whereas ancient basement (pre-Cambrian) and Cambrian Nubian sandstone dominated in the southern part of the country. Furthermore, the sandy facies within the carbonate rock increases south ward the country (Bender, 1974). Structurally, the area is intensively faulted and folded as a result of various tectonic activities. The basin is affected by many major faults and fault zones, these faults with directions E-W, WNW-ESE, N-S, NNE and NE-SW trending faults (Bender, 1974). Most of the fold in the basin is well seen in the upper cretaceous and tertiary carbonate rocks.

Sampling and analysis: Twenty four treated wastewater samples from Petra Wastewater Treatment Plant, were taken in rate of twice monthly from wastewater effluent along a time period of one year (June 2008 to June 2009). Two samples were used in this study, one sample was used for analysis of major anions and cations, while the other was acidified by adding 1ml of 50% ultra-pure HNO_3 after being filtered through a 0.45 µm pore size membrane filter in order to remove the insoluble particles. The water samples were collected in polyethylene bottles and the samples were transported to the laboratory within the same day of collection and then stored in a refrigerator at 4°C until the time of analysis. The samples were analyzed for pH, salinity, soluble cations and anions and trace metals. All glassware and polyethylene bottles were soaked in 20% HNO_3 for one day and rinsed several times with deionized water before use. The laboratory analyses were performed using Standard Methods for water and wastewater analysis, American Public Health Association (APHA, 1992). The pH values of the collected samples were measured for unacidified samples using 370 JENWAY pH-meters equipped with a combination glass electrode (Al-Khashman, 2006). Calibration was always carried out before measurement by using standard buffer solutions of pH 4.00 and 7.00. Dissolved oxygen values were measured in the field using field DO-meter (WTW equipment). TDS was measured by the TDS meter (Oakton Control Co, USA). Conductivity measurements were carried out with 470 JENWAY conductivity meter with temperature compensation (Al-Khashman, 2005). Concentration of NH_4^+ was determined spectrophotometrically using the Nessler method. Major anions (Cl^-, NO_3^-, PO_4^{3-} and SO_4^{2-}) were analyzed by 100 Dionex Ion Chromatography instruments equipped with AG4A-SC guard column, AS4ASC separating column, SSR1 anion self regeneration suppresser and conductivity detector. The samples were injected through 25 MI sample loop and eluted at 2.0ml min-I using 1.7 mµ $NaHCO_3$ and 1.8mµ Na_2CO_3. The system was calibrated with a certified standard from Dionex. Major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) were measured by 800 Varian flame Atomic Absorption Spectrophotometer. The concentrations of cations were determined using a CS12 analytical column, CG12 guard column, using 20mµ $CH_4SO_3^-$. The concentration of bicarbonate was determined by titration with 0.01 hydrochloric acid using methyl orange as indicator. Trace metals (B, Fe^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}, Cr^{2+}, Cd^{2+} and Pb^{2+}) were analyzed with Graphite Furnace Atomic Absorption Spectrophotometer (GF-AAS) using a Varian model GTA 100 instrument. The GF-AAS was calibrated using the method of the standard addition. The standard solution of the anions, cations and trace metals as well as blank samples was prepared with different concentrations. All standard solution were made daily by diluting the stock solutions with 0.01 M HNO_3 (Virkutyte and Sillanpåå, 2006), which was prepared from analytical grade HNO_3 solution obtained from Merck. A quality control procedure, including, recalibration of the instruments, analysis of triplicate samples and recovery test of standard reference material was used to control data quality (Momani, 2006; Al-Khashman, 2009). All chemicals and reagents used in this study were of analytical grade unless otherwise stated. Deionized water (Milli-Q 18.2µs/cm) was used for all dilutions.

Standard solution was prepared by diluting the stock solutions.

To prevent the sample contamination with trace metals, all the glassware , Pyrex and plastic containers were washed several times with soap, deionized water and treated with 0.01 M HNO_3 and finally rinsed with ultra-pure water. After analysis the accuracy of these standards were within ±7%.

Indictors of water quality for irrigation: Important irrigation water quality parameters include physical and chemical characteristics of water that are used in the evaluation of agricultural water quality. Parameters such as electrical conductivity (EC), pH, Sodium Adsorption Ratio (SAR) and adjusted SAR (adj SAR) and Exchangeable Sodium Percentage (ESP), Soluble Sodium Percentage (SSP) and residual Sodium Carbonate (RSC) were used to assess the suitability of water for irrigation purposes.

RESULTS AND DISCUSSION

Chemical characteristics of wastewater: Twenty four wastewater samples were collected from Petra Wastewater Treatment Plant during the studying period, June 2008 to June 2009. Statistical summary of volume-weighted mean concentrations of physical and chemical parameters are presented in Table 2.

The ratio of total sum of anions to that of cations ((∑anions)/(∑cations)) isoften considered as an indicator for the completeness of measured parameters (Mouli *et al*., 2005). The ratio was 0.91±0.41. Also, for the set of samples considered in this study, linear regression of the relation between cation sum and anion sum gave value $R^2 = 0.95$, indicating that the quality of the data was good.

The mean temperature recorded for the effluent wastewater was 20.5 °C± 3.41 while the water temperature in the treated system was between 10.2 °C and 20.5 °C. This range of temperature was adequate for efficient removal of pathogens and nutrients in the wastewater (Belmont *et al*., 2004). All wastewater samples produced in Petra Wastewater Treatment Plant have pH ranging from 6.52 to 8.14, with a median value of 7.51, which indicates that the treated municipal wastewater is slightly alkaline in nature. The normal pH range for irrigation water is from 6.5-8.5 (WHO, 2004). Irrigation water with a pH outside the normal range may cause unbalance nutritional or may contain toxic metals (Ayers and Westcot, 1985). Irrigation water was the main source of salts addition to soils and their magnitude depends on the total salinity of water, water composition, soil type, drainage conditions and climate (Hussain and Al-Saati, 1999). Electrical conductivity (EC, µs/cm at 25 °C) is the most important parameter in determining the suitability of water for irrigation use and it is considered a good measurement of salinity

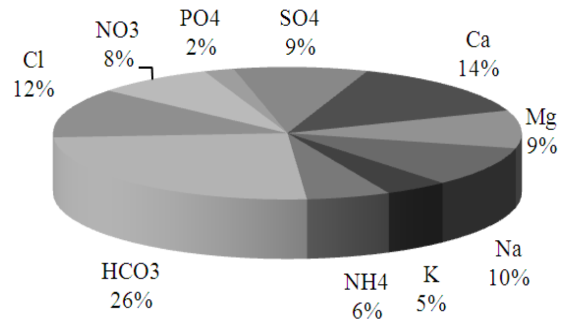

Fig. 3: Contribution of each ion on total ion mass in wastewater samples

hazard to crop as it reflects the TDS in wastewater. The highest value of salinity was measured in this study to be 1120µs/cm during the summer season, while the lowest value of salinity was 899 µs/cm during the rainy season with a median value of 1043±32.12 µs/cm at 25ºC. These results might be explained to high evaporation of ponds during the summer season and dilution of salinity during rainy season. Similar results were observed in Khirbet As-Samra treated effluent (Shatanawi and Fayyad, 1996). TDS values in wastewater varied from 575 to 717 mg/L, with a median value of 668 mg/L. In general, there is an increasing tendency in the TDS values in dry seasons compared with wet seasons except for April where TDS higher amount than in June. Dissolved Oxygen (DO) varied in the range from 3.65 to 4.62 mg/L, with a median value of 4.0 mg/L. The contribution of each ion to total ion mass in treated waste water samples is shown in Fig. 3. The ionic abundance in waste water treatment (meq/l) showed the general trend $HCO_3^- > Ca^{2+} > Cl^- > Na^+ > Mg^{2+} \geq SO_4^{2-} > NO^{3-} > K^+ \ PO_4^{3-}$. The concentrations of Cl^-, Ca^{2+} and HCO_3^- give highest contribution to the total mass of each ion which accounts for 52% of the total ionic species. The high concentration of these ions due to their highest concentration in the drinking water the soil in the investigated area was calcareous and dust in surface runoff during the rainy season. The chloride value was higher in the summer season than in winter season. It ranged from 62 to 120 mg/L with a median value of 99 mg/L. The higher concentration of chloride in the treated wastewater is perhaps due to human excrement and to the evaporation of water in the pond during the summer season not to chlorination of municipal water. The calcium concentration of the wastewater varied from 37.67 mg/L to 140.5 mg/l, with a median value of 120 mg/L. Higher value of calcium in the wet season was due to release of calcium from the sedimentary carbonate rocks and soils in the study area. Sodium values ranged from 55.89 to 94.76 mg/L. The most important sources for sodium are feldspar, albite and

Table 2: Statistical analysis data of ionic composition in (mg/l) of Petra treated waste water

Parameters	Min	Max	Mean	Std. Dev.
T (°C)	10.21	20.5	18.53	3.41
pH	6.52	8.14	7.51	0.50
EC (μs/cm)	899	1120	1043	32.12
DO(mg/L)	3.65	4.62	4.0	0.28
Ca^{2+} (mg/L)	37.67	140.5	120	0.30
Mg^{2+}(mg/L)	20.54	95	80	0.34
Na^{+}(mg/L)	55.89	94.76	85	0.56
K^{+}(mg/L)	18.76	54.36	37.95	0.31
HCO_3^-(mg/L)	175.89	232.14	218.99	0.31
Cl^-(mg/L)	61.68	119.82	105	0.56
NO_3^-(mg/L)	39.06	85.56	70	0.32
SO_4^{2-}(mg/L)	49.92	95.45	80	0.28
PO_4^{3-}(mg/L)	5.65	25.01	18	0.19
Total Solid Suspend (TSS) (mg/L)	20	38	29	5.85
Total Dissolved Solid (TDS) (mg/L)	575	717	592	28.51
Biological Oxygen Demand (BOD_5) mg/L	19	98	63	9.75
Chemical Oxygen Demand (COD) mg/L	85	183	143	17.10

other minerals such as halite. The high concentration of sodium in water samples in the summer season result from the evaporation of wastewater in ponds. On the other hand, the decreasing in sodium concentrations from dry to wet seasons reflects the dilution of spring water by rainwater. Potassium and phosphate concentrations were low in the wastewater samples. Bicarbonate values in water samples ranged from 175.89 to 232.14 mg/L, with a median value of 218.99 (Table 2). The increasing tendency from summer season (dry season) to the winter season wet season was also clearly seen for Na^+, K^+, Cl^-, NO_3^- and PO_4^{3-}. It's related to the concentration of these elements in the drinking water.

Biological Oxygen Demand (BOD_5) is an indicator of the amount of biodegradable organic content of water and used to evaluate the efficiency of wastewater treatment system, industrial waste and any type of pollution in the water. The BOD_5 concentration ranged from 19 to 98 mg/L, with an average value of 63 mg/L. BOD_5 is higher in summer season than in winter season due to the dilution of rainfall during the rainy season. This result agrees with that found by Shatanawi and Fayyad (1996). These values for treated wastewater comply with Jordanian standards (300 mg/L) for irrigation. The Chemical Oxygen Demand (COD) was defined as the amount of oxygen required by organic material in water for its oxidation by strong chemical oxidant. This test was used to measure the pollution values in wastewater, while the COD in the effluent varied from 85 to 183 mg/L, with a median value of 143 mg/L. The COD was higher in summer season than in winter season due to dilution during the winter.

Hydrochemical coefficient: The ratio of Ca^{2+}/Mg^{2+}, Na^+/Cl^-, $Mg^{2+}/Ca^{2+}+Mg^{2+}$, SO_4^{2-}/Cl^- and Ca^{2+}/Na^+ were calculated for wastewater treatment effluents (Table 3). In the wastewater samples, Ca^{2+}/Mg^{2+} equivalent ratios were >1.0, the Ca^{2+}/Mg^{2+} was high in water samples due to higher carbonate concentration in the water. High correlation was found between calcium and magnesium of water (R^2 = 0.89), suggesting that the common source of these ions from carbonate dissolution in the water. While the median Na^+/Cl^- equivalent ratios were>1, the higher ratio of Na^+/Cl^- in water can be due to dissolution of carbonates which include traces of evaporate in the carbonate aquifer. This aquifer is the main aquifer of water in the study area. On the other hand, strong correlation was found between sodium and chloride of water (R^2 = 0.90), suggesting that the common source of these ions from salt dissolution. The possible sources of these ions were anthropogenic sources and natural sources. The median $Mg^{2+}/Ca^{2+}+Mg^{2+}$ ratios were <0.5 indicating weathering of limestone and dolomite, while the median Ca^{2+}/Na^+ equivalent ratios varied between 0.24 to 0.89. The median SO_4^{2-}/Cl^- ratios were <1 in the wastewater samples. Nitrate ion was highly correlation with ammonia (R^2 = 0.84), while they were better correlated with HCO_3^-, $Mg^{2+}$and SO_4^{2-} (R^2= 0.82, 0.85 and 0.81), respectively.

Table 3: Hydrochemical coefficient of wastewater

Ionic ratio	Minimum	Maximum	Median	S.D
Ca/Mg	0.93	1.15	1.07	0.10
Na/Cl	1.11	1.49	1.23	0.11
Mg/Ca+Mg	0.22	0.73	0.46	0.13
SO4/Cl	0.24	0.89	0.61	0.16
Ca/Na	0.43	0.79	0.70	0.10

Suitability of wastewater treatment (effluent) for irrigation: The suitability of treated wastewater for irrigation is dependent on the effects of its mineral constituents on both soil and plant (Todd, 1980). The criteria that were used to evaluate quality of wastewater for use in irrigation are; salinity of irrigation water for salt build up in soil and its adverse effects on plant growth (Hussain and Al-Saati, 1999). On the other hand, Sodium Adsorption Ratio (SAR) for its effect on the physical properties of soil and sodium percent (Na%) for its effects on the final soil water SAR value

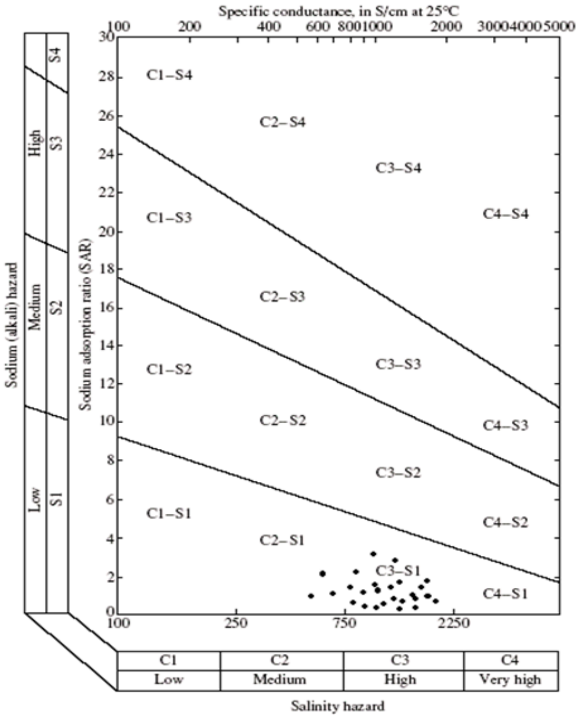

Fig. 4: Classification of wastewater effluent for irrigation purposes

with loss or gain of Ca^{2+} and Mg^{2+} values (Ayers and Westcot, 1985; Hussain and Al-Saati, 1999).

The sodium adsorption ratio (SAR) is defined as:

$$SAR = Na/\{sqrt(Ca + Mg)/2\} \quad (1)$$

where, the concentrations of the constituents are expressed in milliequivalent per liter (meq/L).

The SAR values ranged from 2.21 to 2.68 with a mean value of 2.52. The waste water of Petra Treatment Plant was classified with respect to SAR (Richards, 1954). All analytical data plotted on the US salinity diagram (Richards, 1954) shows that most of water samples classified in the field of C3-S1, indicating high salinity with low sodium water. This type of water is suitable for irrigation on almost all types of soil (Fig. 4). Another parameters can be used for classification of irrigation water is the sodium percentage while, sodium react with soil to reduce its permeability. The sodium percentage (Na%) is calculated using the formula given below:

$$Na\% = \{Na + K/(Ca + Mg + Na + K)\} \times 100 \quad (2)$$

where, all the concentrations are expressed in meq/L.

The sodium percentage indicates that the water is good to permissible for irrigation (Table 4). Most of samples are classified as good water for irrigation and others classified as permissible water for irrigation (Table 4). When the concentration of sodium is high

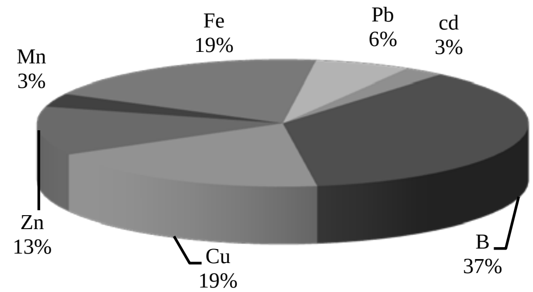

Fig. 5: Contribution of metals in wastewater samples

Table 4: Suitability of wastewater for irrigation based on the %Na

%Na	Water class	No. of samples	Samples %
<20	Excellent	-	-
20-40	Good	16	66.7
40-60	Permissible	8	33.3
60-80	Doubtful	-	
>80	Unsuitable	-	

Table 5: Water quality based on residual sodium carbonate (Na_2CO_3)

RSC(meq/L)	Remark on quality	No of samples	Sample %
<1.25	Good	17	70.8
1.25-2.5	Doubtful	7	29.1
>2.5	Unsuitable	-	-

value in irrigation water, sodium ions tends to be adsorbed by clay minerals, displacing Mg^{2+} and Ca^{2+}ions. This exchange process of sodium in water calcium and magnesium in soil reduced the permeability and eventually results in soil with weak internal drainage (Subramani *et al*., 2005; Saleh *et al*., 1999).

In addition to the Sodium Adsorption Ratio (SAR) and sodium percentage (%Na), the Residual Sodium Carbonate (RSC) represents the excess sum of carbonate and bicarbonate over the sum of calcium and magnesium also influences the suitability of water resources for irrigation. The Residual Sodium Carbonate (RSC) is calculated by the following equation:

$$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \quad (3)$$

where, the concentration of ions are expressed in meq/L.

The classification of irrigation water in Petra Wastewater Treatment Plant according to the Residue Sodium Carbonate (RSC) values is shows in Table 5. The first category has (RSC) <1.25 epm (good quality). The second category has ranged from 1.25 to 2.5 epm (doubtful), while the third category has more than 2.5 epm (unsuitable). It is clear from this table that the water was mostly of good quality. This type of water is suitable for irrigation for most types of soils in the study area.

Trace metals: The concentration of the trace metals; B, Fe, Pb, Cd, Zn, Cu, Mn and Cr are given in Table 6.

Table 6: Summary of descriptive statistics of trace metals in wastewater treatment samples (µg/L)

Parameters	Minimum	Maximum	Median	S.D
B (µg/L)	255	630	320	35.21
Fe (µg/L)	33	196	170	24.23
Pb (µg/L)	25	97	78	4.82
Cd (µg/L)	3	36	23	1.32
Zn (µg/L)	75	125	109	10.18
Cu (µg/L)	98	220	146	24.15
Cr (µg/L)	2	5	3.2	0.91
Mn (µg/L)	6	37	30	9.58

The average values for B, Fe, Pb, Cd, Zn, Cu, Mn and Cr are 320, 170, 78, 23, 109,146, 30 and 3.2 ppb, respectively, while the relative abundance of the trace metals in wastewater observed were B> Fe> Cu> Zn> Pb>Mn> Cd >Cr depending upon their evaporation rate relative concentration of metals and solubility of metals (Fig. 5). The mean concentration of trace metals of effluent wastewater was low (Table 6) which can be due to enhancing precipitation of metals under high pH value (Karvelas *et al*., 2003; Wang *et al*., 2005). Similar findings were reported in Cairo/Egypt (El-Nennah and El-Kobbia, 1983) in Greece (Karvelas *et al*., 2003), in Kuwait (Al-Enezi *et al*., 2004) and in Mexico city (Mireles *et al*., 2004) and in China (Wang *et al*., 2005).
Boron, a constituent of synthetic detergents, is toxic to plants, especially citrus crops and should be mentioned when wastewater is used for irrigation (WHO, 1989). The concentration of boron in the treated wastewater ranges from 255 to 630 µg/L, with mean value of 320µg/L. The boron value in this study is below the American standards of 0.75 to 2 mg/l (EPA, 1994). Boron is an essential plant nutrient, but at high levels it can be toxic to plants and crops. When the boron value is on the range of 0.3-1 ppm, it can be suitable for sensitive plants such as; apple and orange trees. While the concentration range of 1-2 ppm is suitable for medium tolerance plant as potato and olive tree. The range of 2-4 ppm of boron concentration is suitable for high tolerance trees as palm carrot (Al-Shammiri *et al*., 2005).

The concentrations of all trace metals are found to be low and within guidelines for irrigation water due to the low level of industrial activities in the investigation area. However, a possible long-term problem with wastewater irrigation is that toxic materials or salinity may accumulate in the soil. As the unsaturated zone removes chemical pollutants, particularly trace metals, their concentration in the soil will increase with time and, after many years of irrigation, it is possible that levels will reach toxic level to human.

CONCLUSION

The study of chemical composition of wastewater treatment was carried out at the Petra Wastewater Treatment Plant in the southern region of Jordan during the time period between (June 2008 to June 2009). This study represents the first contribution in the area to the knowledge of treated wastewater chemistry in the study area. The chemistry of water in the wastewater treatment plant is similar to that of the other plants in the country. Even though concentrations of Na^+, Ca^{2+} and HCO_3^- are high, suggesting that the effluent treated wastewater is typically neutral to alkaline, while the observed pH values of treated water ranges from 6.52 to 8.14, with a mean value of 7.51±0.50. Based on the classification of the US Department of agriculture for wastewater quality for irrigation, the combination of SAR and salinity of sewage effluent of Petra city suggest category C3-S1, i.e., water of high salinity and low sodium content and considered marginal for human consumption. However, the concentrations of trace metals determined in treated wastewater are relatively low and within safe limit, due to the low level of industrial activities in Petra city. Accordingly, it can be concluded that the wastewater treatment effluent from Petra city is suitable for irrigation purposes. The effluent could be considered as one of the possible sources for irrigation. Also, further work is needed not only to assess the distribution of chemical elements in wastewater but also to examine variations on different times. More intensive sampling and studies to measure any change or increase of chemical elements in water, soil and plant around the wastewater treatment plant are needed. Also, in future further work is needed to study organic and toxic constituents in the sewage effluent of Petra plant.

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