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The Air, Water, and Soil Quality in the Surrounding of Zaatari Refugee Camp

Mohammad Alshirah[1], Mohammad Aljaradin[2], Anwar Jiries and [3] Amjad Shatnawi[4]

[1]*Ministry of Agriculture, Amman, Jordan*
[2]*Water Resources Engineering Department, Lund University, Lund, Sweden*
[3] *Faculty of Science, Mutah University, Karak, Jordan*
[4]*Institute of Earth and Environmental Science, Al-AlBayt University, Mafraq, Jordan*

*Corresponding Author Email: mhmad.alshraa00@gmail.com

ABSTRACT

This study was conducted to assess the water, air, and soil quality in the surroundings of Zaatari refugee camp. Analysis of physical and chemical parameters of the surface runoff water, groundwater, wastewater, soil and air quality were conducted. The electrical conductivity, pH, Ca^{2+}, Mg^{2+}, HCO_3^-, K^+, Na^+, Cl^-, NO_3^-, SO_4^{2-}, and trace of the heavy metals includes Zn, Mn, Cd, Cr, Cu and Pb were analyzed. The sodium adsorption ratio and water salinity were used to assess the feasibility of wastewater effluent for irrigation. The dust settlement system was used to track the air quality within the Zaatari camp for ten months. To better recognize and identify the possible source of pollution, the camp area was divided into three areas (A, B and C). Location was chosen to represent the major activities and population density inside the camp. The result showed the water quality parameters for the groundwater from the three wells inside the camp were found to be within Jordanian drinking water standards' acceptable limits. The soil profile showed high levels of heavy metals, the upper soil had a much higher concentration than the lower soil, suggesting that heavy metals are accumulated on the top of the soil as a result of camp activities, as well as low mobility of these metals in a slightly alkaline soil climate. The results also showed that there was no significant heavy metal contamination in the sewage system. The inlet of the WWTP, on the other hand, had a higher concentration of heavy metals than the other sites, which can be due to wastewater deposition from the three sites examined. There was also no major pollution in the air quality within the camp, indicating that there is no source of heavy metal contamination in the area. Based on sodium adsorption ratio and water salinity analysis, the feasibility of wastewater treatment plant effluent for irrigation purposes indicates that wastewater is unsuitable for sensitive plants but acceptable for certain salt tolerant plants under certain conditions.

Keywords: Zaatari Refugee Camp; Amman-Zarqa Basin; Heavy Metals; Wastewater; Air Quality; Soil.

1. INTRODUCTION

Jordan has experienced several influxes of refugees from surrounding countries during the last century. Several refugee camps were established on the Jordanian land. Due to the recent political conflict in Syria, Jordan hosted more than 1.5 million refugees, constituting more than 10% of the population in Jordan (UNHCR, 2018; UNDP, 2014). Several refugee camps were built across the country to host these waves of refuge. Zaatari refugee camp, the largest camp, is located near the northern border with Syria, east of Mafraq Governorate, in Zaatari city. Around 80,000 people were housed in Zaatari refugee camp. The Zaatari refugee camp is one of the world's largest refugee camps, and it is eventually becoming a permanent settlement. The number of refugees entering Jordan has increased the population significantly. The rapid increase in population due these influxes has increased the stress on available natural resources especially the water. Jordan is considered he fourth most water-stressed country in the world (MWI, 2013). increased population and declining freshwater supply have resulted in a decline in per capita renewable water resources, from 1,857 m^3/ capita/year in 1967 to 145 m^3 /capita/ year in 2013 (Aljaradin et al., 2017 and MWI, 2013).

Jordan depends mostly on groundwater; overexploitation of groundwater has declined aquifer levels and increase water salinity (Schoeffler et al., 2012). The moderate infrastructural for waste and wastewater treatment inside the camp represent another concern for possible groundwater pollution from wastewater leakage and surface runoff. The Zaatari refugee camp is located within the Amman-Zarqa Basin, which is one of the main groundwater aquifer system in country (Al-Taani et al., 2018).

The Amman Zarqa Basin is Jordan's most developed groundwater basin, but it is facing water scarcity and a declining water table as a result of overexploitation to meet water demand. Al-Bakri et al. (2013) predicted that reduction of irrigated areas in Irbed and the Amman-Zarqa basin was observed, from 9.4% to 7.6% at a rate of 125 ha per year, as a result of a decline in irrigation water quality because of over-pumping that used to meet demand including refugee and the increasing salinity of soils. In this article, we intend to investigate the quality of water, air and soil to stand on the environmental and health situation within the camp area.

2. STUDY AREA

The Zaatari refugee camp is situated with an area of about 5.2 km^2, it located 20 Km east of Mafraq city in north Jordan (Figure 1). The camp start to receive and host refugee early in 2012. To meet the increasing in water demands, several wells were drilled within the basin area. In addition, a wastewater treatment plant with a total capacity of 3600 m3 /d was constructed. The climate of the investigated site is characterized by dry and hot summer season with cold and low precipitation during winter season.

The precipitation in the investigated area is low about 100-200 mm/year. Most of the year, more than 90% of the rainfall occur from November to March, temperatures range from 16–33 °C with very low humidity during the summer and 2–12 °C during the winter. The dry climate, the atmospheric dust and low intensity of precipitation affect the quality of precipitation water, generally causing increased salt content (Salameh 1996).

According to Natural Resources Authority (NRA, 2005) the orientation of the drainage system trends NW-SE, most of Mafraq land area is characterized as a desert environment, which attributes to the low precipitation and high evaporation rates (Altz-Stamm, 2012).

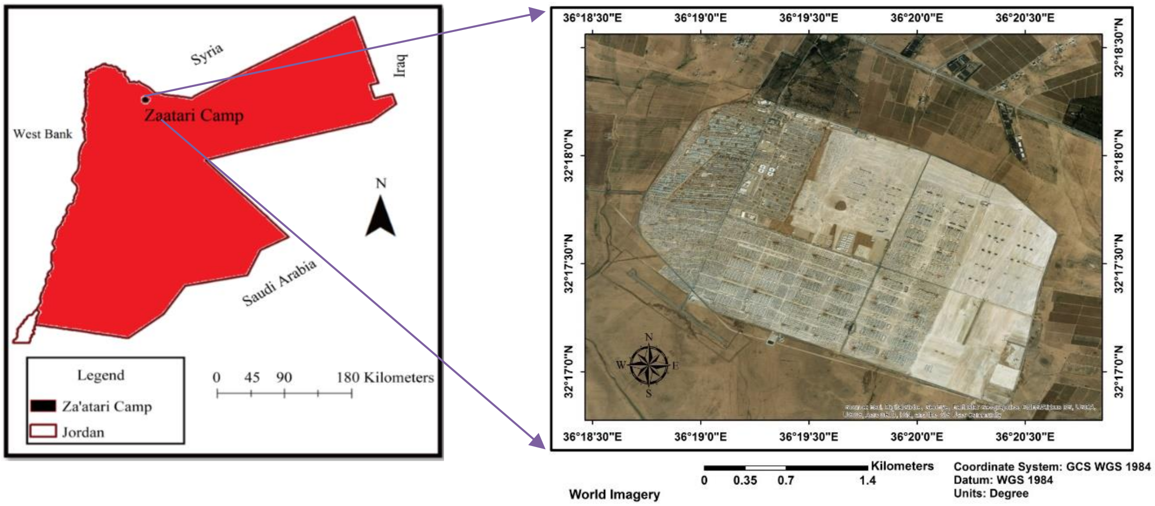

Figure 1: Location of the Zaatari Camp

3. AMMAN ZARQA BASIN

Amman Zarqa Basin lies in the northern part of Jordan, part of the basin is shared with the neighbor country Syria, the basin is about 4,586 km^2 with about 4,074 km^2 in Jordan and 512 km^2 in Syria. The basin serves as a connection between the Jordanian highlands to the west and the desert to the east. Within 400 mm average annual precipitation in the western and 150 mm the average annual precipitation in the eastern part. The basin receive precipitation mainly between the months of November to March.

The main water source in the basin is the Zarqa river within 3,900 km^2 catchment. The Zarqa river watershed has two main branches which are the Amman-Zarqa draining, and the Wadi Dhuliel draining. The average annual stream flow of Zarqa river is estimated at 68 MCM/year. The river receives most of the wastewater treatment discharge influent from the nearby wastewater treatment plant. The Samra treatment plant is the largest with about 95 MCM/year treated wastewater which represent about 90% of the wastewater generated in the basin. Another 8 MCM/year of fresh water originates from around 150 spring. The safe yield of Amman Zarqa Basin aquifer is estimated at 88 MCM/year. Water is abstracted from more than 800 abstraction wells.

The Amman Zarqa Basin has an arid climate in the southeastern, eastern, and northeastern regions and rainy humid conditions in the west. Humidity and precipitation decrease rapidly towards the eastern deserts.

The basin is located over different geological, the limestone formation within (20 m) thickness, and marl chalky limestone and thin marl beds occur below, in the northern, central, and southern parts of basin, and the Basalt plateau in the northeastern part of the basin, B2/A7 is the main groundwater aquifer in the basin and located within this Basalt plateau. With an annual drop rate in groundwater level of 5 m in recent years according to official estimation, the water level is declining to critical and alarming level.

This has increased the salinity level in the major aquifers of the basin (MWI, 2020). The industrial activities in the region, as well as agricultural runoff, have influenced and altered the water quality in the basin (Margane et al., 2015).

4. MATERIALS AND METHODS

The locations of the sampling sites are shown in Figure 2. To better recognize and identify the possible source of pollution, the camp area was divided into three subareas (A, B and C). High population density exists mainly in the area C, which is the first area used for receiving residence. Location was chosen to represent the major activities inside the camp. Geographic information system (GIS) used to map the sampling location and identify the coordination's. Data and samples for runoff, wastewater, groundwater, soil, air, and biofilm was collected from different location considering seasonal change.

Figure 2: Coordination of the divided area (A, B and C) of the Zaatari camp.

4.1 sampling of surface runoff

Three sampling campaigns were done to stand on the effect of runoff on the water quality inside the camp. The first sampling period start at the beginning of rainy season in 2017, then, in the middle and at the end of the rainy season. Sampling location was chosen to represent the major activities of the sub area. The surface runoff samples were collected using one-liter Polyvinyl chloride bottles.

Samples to measure the major ionic composition and heavy metals. Drops of nitric acid (HNO_3) was added to sample that designed to analysis heavy metals on site to eliminate alteration of the heavy metal's concentration through precipitation.

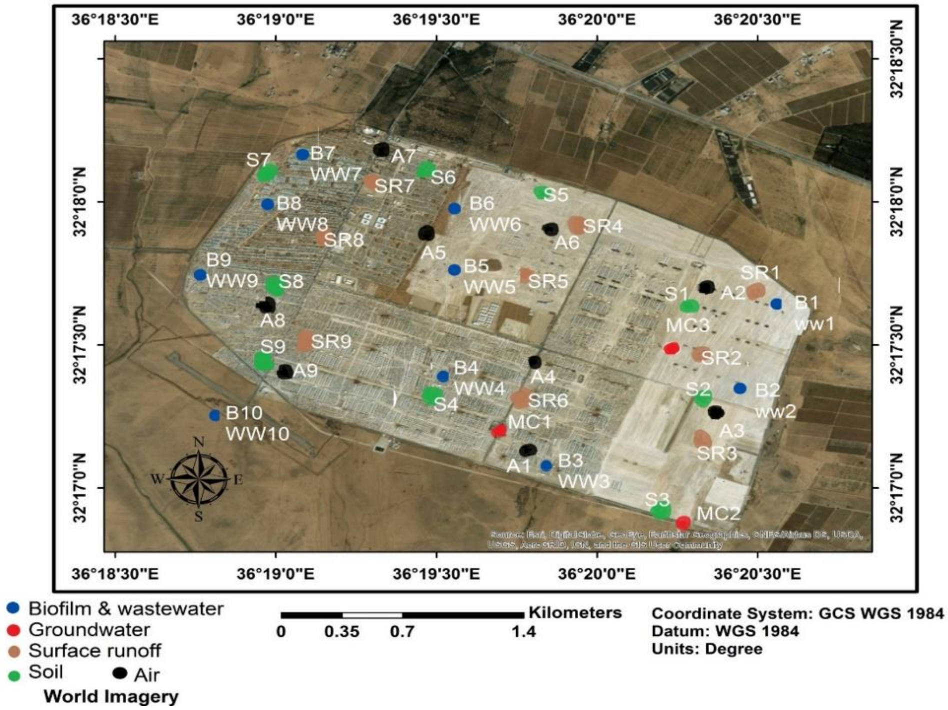

Figure 3: Locations of samples within Zaatari camp

4.2 sampling of wastewater

Ten location were selected along the sewage network of the camp for sampling to analysis the wastewater quality and the biofilm. Direct sampling method as well as using biofilm collector technique (Octopus) used to collect sample to analysis wastewater. Biofilm growth on polyethylene strips of 120 cm long immerged in the sewer wastewater for six weeks to allow enough time for biofilm to grow (ten samples). Every six weeks wastewater samples taken, and the biofilm was gathered easily for three times and transferred to a laboratory using prewashed polyethylene bottles and kept refrigerated at 4C.

4.3 sampling of groundwater

Groundwater sampling was done from three wells located inside the camp which is used to supply the camp with fresh water with a daily capacity of 3,800 m^3, see figure 3. Three samples taken from each well once every month for three months period. pH and EC values were measured direct in the site using portable devices to eliminate alteration of results through transportation.

4.4 analysis of soil

Soil samples were taken from different location at two depths, upper soil (0-15 cm), and lower soil (15-30 cm), see figure 3. The soil samples were collected using polyethylene bags and labeled to be transferred to laboratories for analyses.

4.5 air pollution analysis

Aerosol was analyzed and sampled using traditional methods. Collection traps used to analysis the air quality during the period (Dec-2016 to Aug -2017). The collected dust transferred using polyethylene bags.

The analysis was performed by inductively coupled plasma optical spectrometry (ICP-OES). The analysis also includes the assessment of concentrations of Zn, Mn, Cd, Cr, Cu and Pb. The following wavelength lines of the ICP-OES analysis were used: 202.548, 257.61,226.502,283.563,223.008 and 220.353 respectively. The plasma gas flow rates were 10 l/min, intermediate (auxiliary) argon 0.3 L/min and nebulizer flow 0.5 L/min, with a forward power of 1200 W, viewing height of 7.0 mm, photomultiplier tube (PMT) voltage of 600 V and pump rate 30.0 rpm. The methodology used determine major parameters is listed in table 1.

Table 1: List of methods and devices used to identify different parameters.

Parameter	Method
Electrical conductivity	Conductivity meter (WTW multi-3320)
pH	pH meter (WTW multi-3320)
Ca	Titration was done using 0.02N Ethylene diaminetetra acetic acid EDTA using murexide as an indicator
Total Hardness	Titration with 0.02N Ethylene diaminetetra acetic EDTA with EBT (Eriochrome Black T) indicator
Mg	Difference between total hardness and Ca
Cl	Titration was done using 0.01N Silver nitrate with K_2CrO_4 as an indicator
HCO_3	Titration was done using 0.02N Sulfuric acid (H_2SO_4) and Bromocresol green as an indicator
K and Na	Flame Photometer
SO_4 and NO_3	Spectrophotometer

5. RESULTS AND DISCUSSION

Table 2 shows the average chemical composition of the collected runoff samples from camp area, see figure 3. The salinity in the samples showed increase in different location inside the camp, where it was highest at the area C, which is the highly populated area. This can be attributed to the anthropogenic activities and nature of the soil in the area. High concentration of NO_3 and Cl was noticed. The NO_3 concentration was 36.6, 42.8 and 59.4 ppm respectively and 183.3, 211.4 and 336.4 ppm respectively for Cl in the area A, B and C respectively. This can be attributed to the anthropogenic activities.

The predominant anion was $HCO_{3,}$ and the predominant cations were Ca^{+2} and Mg^{+2} reflecting the predominant lithology of the carbonate rock of the area. As shown in Table 2, the average pH value of surface runoff for all sites showed slightly increase in alkalinity which is due to the buffering effect of calcareous rocks. Another potential source of increasing alkalinity is the use of chemical detergents within the camp. The average value of pH ranged 7.2, 7.4 and 7.5 for site A, B and C respectively, no significant difference in pH values between the sites. The electrical conductivity (EC) showed a variation between sites as it average ranged from 1895 µS/cm, 1308 µS/cm and 1835.1 µS/cm for site A, B and C respectively.

The variation in EC is not due any natural conditions where the three sites are located next to each other. It can be attributed to variation of human habits inside the camp where many people dispose some of the liquid waste outside of their houses which is washed out with surface runoff and effect the effluent of water discharge, see figure 4. The table 2 shows decrease in the concentration for all parameters because of diluting with mixing of the rainfall with the effluent out of the camp area. The nitrates highest concentrations were found in the area C with an average of 59.4 ppm while its concentration at sites B and A were 42.8 ppm and 36.6 ppm respectively. This can be due to the daily anthropogenic activates inside the camp.

The potassium concentration was low, this can be attribute to the absence of agriculture activity inside the camp. The sources of sodium and chloride ions in surface water related to human activities including using of table salt (NaCl). Another factor contributes to enrichment of Na and Cl ion is the atmospheric condition of the camp as it is located in arid climatic conditions where halite rich soils are found.

Table 2: The average ionic concentration of surface runoff water for the start, middle and end of the rainy season for the investigated sites inside Zaatari camp.

	Site											
	A				B				C			
	Start	Middle	End	Av.	Start	Middle	End	Av.	Start	Middle	End	Av.
EC	1788	2039	1858	1895	1293	1326	1306	1308	1807	1966	1729	1835
pH	7.1	7.3	7.2	7.2	7.4	7.5	7.4	7.4	7.4	7.6	7.4	7.5
HCO_3	1049	980.0	901.1	976.5	665.1	551.9	536.1	584.4	885.9	751.5	715.8	784.4
NO_3	41.6	36.5	31.6	36.6	52.3	43.5	32.5	42.8	66.6	60.9	50.6	59.4
Cl	211	173.7	165.4	183.3	260.3	196.3	177.6	211.4	374.8	322.0	312.3	336.4
SO_4	120	44.0	29.0	64.4	65.2	21.8	11.5	32.8	138.5	65.8	28.7	77.7
Ca	338	283.8	241.3	287.8	212.3	167.6	128.3	169.4	273.4	226.0	199.6	233
Mg	136.4	100.1	77.0	104.5	147.2	96.6	56.4	100.1	199.1	142.7	122.1	154.6
Na	15.2	11.3	7.1	11.2	12.6	9.5	6.7	9.6	18.0	10.7	8.1	12.3
K	9.2	4.0	2.3	5.2	11.2	5.7	2.8	6.6	14.3	9.5	5.7	9.8

Concentration are in ppm

The concentration of heavy metals for the three sites (A, B and C) within Zaatari camp is shown in table 3. The concentration of all analyzed metals was low except Pb which can be attributed to absence of source of these metals and the slightly alkaline water enhance its precipitation rather being dissolved in the collected samples. The impact of rainfall on heavy metals concentration was not clear as there was no significant difference between the start and end of the rainy season. No significant variation between the three sites indicating that the possible source of these metals is from the natural with no significant effect of anthropogenic activities inside the camp area.

Table 3: The average concentration of heavy metals of surface runoff from the investigated sites inside Zaatari camp.

	Site											
	A				B				C			
	Start	Mid.	End	Av	Start	Mid.	End	Av	Start	Mid.	End	Av
Zn	9.8	17.9	19.0	6.4	129.7	97.5	111.8	113.0	232.3	185.9	208.7	208.9
Mn	8.1	7.4	8.3	6.2	495.4	416.1	453.4	455.0	1237	883.8	1057	1059
Cd	ND	ND	ND	ND	0.9	ND	ND	0.9	27.8	18.2	23.8	27.8
Cr	73.2	47.0	60.9	24.4	55.3	42.0	51.8	18.4	143.5	73.7	88.9	47.8
Cu	47.5	16.4	28.2	30.7	73.2	74.6	85.1	59.9	102.6	78.4	93.5	91.5
Pb	1948	1257	1348	1518	1455	1267	1351	1359	1902	551.4	668.7	1041

Concentrations are in ppm

The ionic composition of groundwater within Zaatari camp is shown in table 4. All the analyses of groundwater parameters for the three wells falls within the Jordanian standard of drinking water (JSMO,2008).

Table 4: The major ionic concentration for groundwater for the investigated sites inside Zaatari camp.

	Parameters /ppm									
	EC	pH	K^+	NO_3	Na^+	Cl^-	Mg^{+2}	Ca^{+2}	HCO_3^-	SO4^{-2}
Min	784	7.8	1.4	1.0	8.4	160	56.0	102	296	2.6
Max	854	7.9	2.2	1.3	9.3	172	67.5	111	342	5.9
Mean	819	7.7	1.9	1.1	8.8	165	60.7	106	318	4.0

The mean average concentration showed a low concentration of zinc, manganese, chromium, cadmium, and cupper. See figure 4. The concentration of the lead was high in all the wells, the average concentration of surface runoff is 1305 ppb and for groundwater 1325 ppb, this could be attributed the use of unleaded fuel that mange to find its way to leach to the basin aquifers.

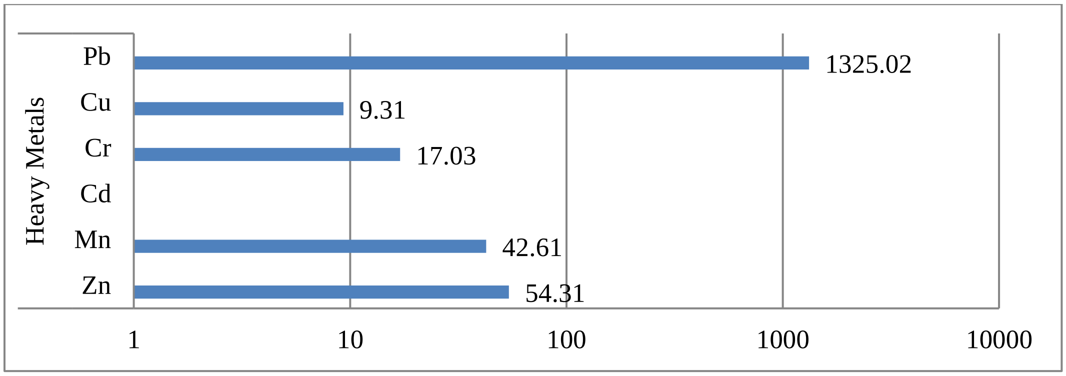

Figure 4: The mean average concentration of heavy metals in ppb of groundwater within Zaatari camp.

The major ionic composition of wastewater from the three investigated sites and wastewater treatment plant are shown in table 5. Owing to the use of detergents in household activities, which causes a rise in alkalinity, the pH values for all sites were similar each other and slightly alkaline. The pH for site A ranged between 7.3- 7.5 with an average value of 7.4, between 6.9-7.4with an average value of 7.2 for site B and between 5.5-6.9 with an average value of 6.1 for site C, for wastewater treatment plant (WWTP) inside the camp pH ranged between 7.3- 7.7 with average value 7.5.

The predominant anion was HCO_{3-} and the predominant cations were Ca_{+2} and Mg_{+2} reflecting the predominant lithology of the carbonate rock of the area. The electrical conductivity was found to be closely related to number of population living in every site, the highest EC as it ranged from 2415-3140 µS/cm with an average value of 2823 µS/cm at site C and the lowest EC was found at site A which is the lowest population density as it ranged from 1866.7-2564.0 µS/cm with an average value of 2178.8 µS/cm. However, for site B the EC ranged from 1833-1999 µS/cm with an average value of 1905 µS/cm.

The wastewater reaching the wastewater treatment plant with EC ranging from 2020.0 -3079.0 µS/cm with an average value 2412 µS/cm, see table 5, the average ionic composition from the collected wastewater samples from site A (WWA), the collected wastewater samples from site B (WWB) and the collected wastewater samples from site C (WWC) and samples from the WWTP.

Table 5: The average ionic composition in ppm of wastewater within Zaatari Camp.

Sampling site		Ions / ppm									
		EC µS/cm	pH	K^+	NO_3^-	Na^+	Cl^-	Ca^{+2}	Mg^{+2}	HCO_3^-	SO_4^{-2}
WWA	Min	1867	7.3	8.5	61.5	18.8	203.6	133.6	144.2	733.7	210.6
	Max	2564	7.5	17.1	80.3	33.0	274.2	192.2	192.2	929.4	246.8
	Mean	2179	7.4	12.2	69.5	25.6	234.8	162.7	162.7	826.7	226.8
WWB	Min	1833	6.9	5.7	40.5	13.1	251.2	210.5	96.6	776.3	181.8
	Max	1999	7.4	13.1	74.8	32.2	284.4	282.3	142.5	829.2	220.2
	Mean	1905	7.2	8.8	55.9	22.9	265.9	248.1	118.5	802.1	198.8
WWC	Min	2415	5.5	9.0	71.5	20.1	345.5	176.5	201.4	972.5	378.0
	Max	3140	6.9	20.4	86.6	46.4	396.6	252.5	256.2	1038.3	440.0
	Mean	2823	6.1	14.1	79.0	31.1	371.4	212.2	227.0	1008.8	408.4
WWTP	Min	2020	7.3	12.9	68.6	22.3	233.0	82.0	160.4	662.9	376.9
	Max	3079	7.7	19.1	84.0	38.2	286.8	119.5	207.0	752.9	417.0
	Mean	2412	7.5	15.1	75.6	31.2	262.3	95.7	184.2	710.4	393.4

Nitrate and potassium are important components of wastewater as its ultimate use is for irrigation. The average nitrate concentration was high at sites C> A> B, and rich to WWTP with average concentration 75.6

ppm, which are due to daily anthropogenic activates of the residence. Potassium was found at low concentration because there is no agricultural activity inside the camp.

The Sodium and chloride were found at slightly high concentration, this can be attributed to anthropogenic activates like using bleaching, detergent and for sterilization when dishwashing. Sulfate is a naturally occurring anion in freshwater as its average concentration was 408.4 ppm for C ,198.8 ppm for B 226.8 ppm for A and rich the WWTP with value 393.4 ppm, see figure 5, Thus, a major source of sulfate in domestic wastewater is from the source water that was processed into tap/drinking water and then became wastewater, another source it's from human waste disposal to sewage system.

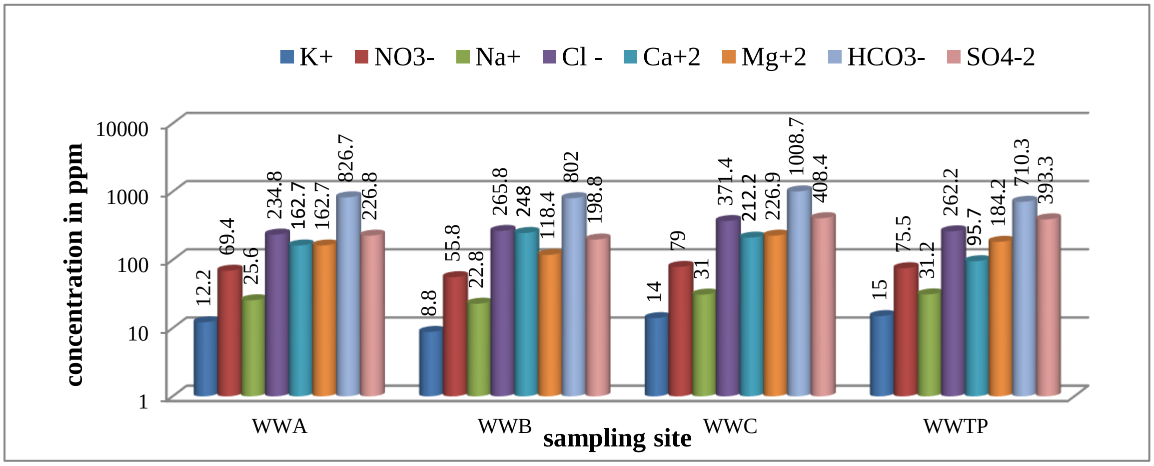

Figure 5: The average major ionic concentration/ppm for wastewater inside the Zaatari camp and the camp WWTP.

The heavy metals content in wastewater for the three examined sites is shown in Figure 6. Except for Pb and Mn, which were present at high concentrations, heavy metals concentrations were low in all sites. Vehicle emissions are the most likely source of these two heavy metals since they were detected in high concentrations in wastewater from the same locations. Heavy metal concentrations in wastewater have increased in Site C, which can be due to the density of population in the area and the co-disposal of waste such as cosmetics, medication, ointment, agricultural products, pesticides, and health supplements.

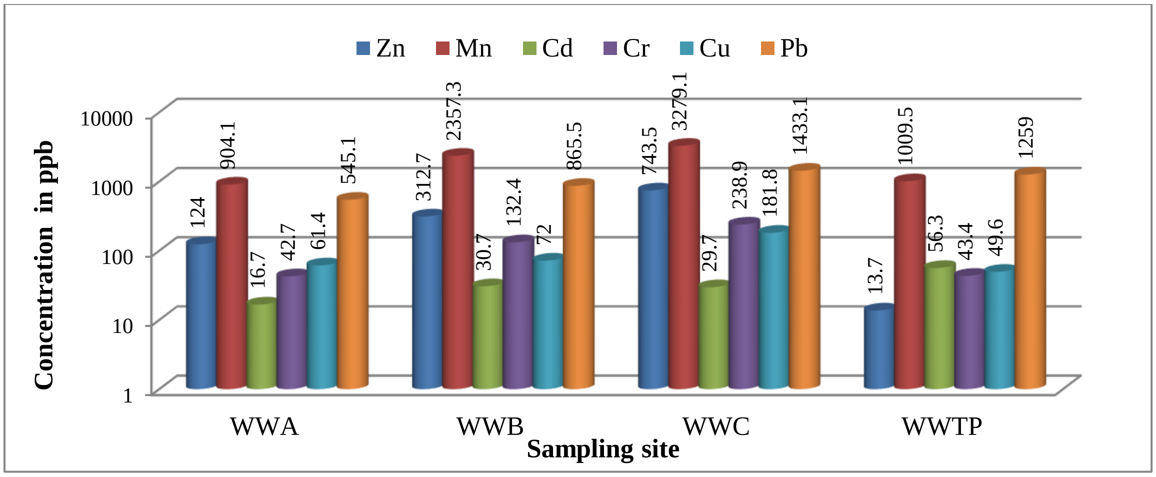

Figure 6: The average heavy metal concentration /ppb for the wastewater inside the Zaatari camp and the camp WWTP.

Using Wilcox diagram to determine the viability of wastewater effluent for irrigation purposes based on sodium adsorption ratio (SAR) and water salinity (Paliwal and Gandhi, 1976).

$$\boldsymbol{SAR} = \frac{\boldsymbol{Na}}{\sqrt{(\boldsymbol{Ca} + \boldsymbol{Mg})/\boldsymbol{2}}}$$

The result showed that SAR values in wastewater effluent were found to be low between 1 and 7 (low sodium hazard) and electrical conductivity between 2000 S/cm to 3200 S/cm (high to very high salinity hazard) making wastewater to be unsuitable for sensitive plants but suitable with specific conditions for some salt tolerant plants.

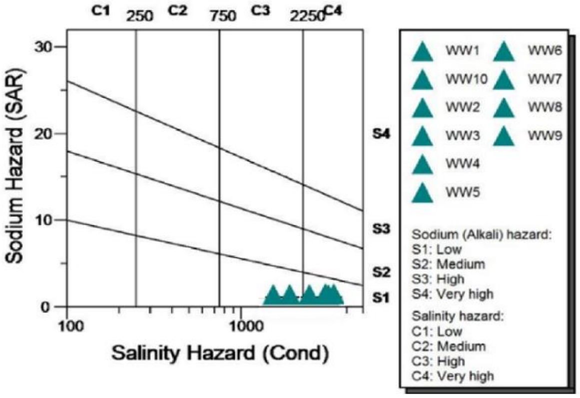

Figure 7: Wilcox diagram for the wastewater produced from the Zaatari Camp.

Biofilm samples were collected directly from site to monitor heavy metals content in wastewater. The monitor extended to six weeks. During the installation process, the biofilm can detect any pollution emissions. The biofilm sample was taken from the same location as the wastewater sample, as shown in Figure 3. Figure 8 The heavy metal concentrations in ppb at three examined sites (A, b and C) and the WWTP.

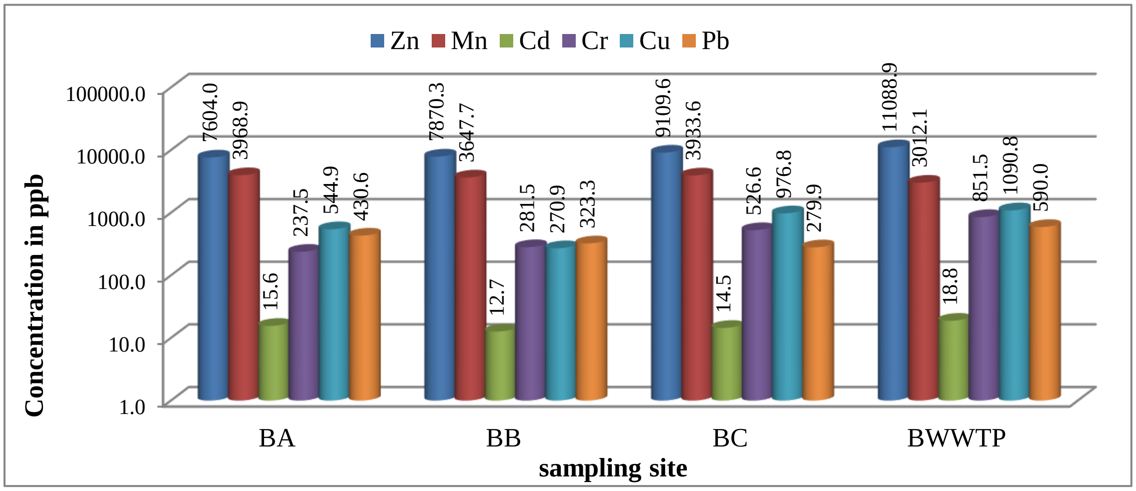

Figure 8: The average heavy metal concentration in ppb for biofilm inside the Zaatari camp and the camp WWTP.

Figure 8 shows that there is no noticeable difference between locations, indicating that there was no abnormal heavy metal input into the sewage system. However, the inlet of the WWTP had a higher concentration of heavy metals than the other sites, which can be attributed to the deposition of wastewater from the three examined sites and precipitation on the polyethylene arms. The slightly alkaline wastewater helped heavy metals to participate on the biofilm collectors. Since the heavy metals on biofilm are derived from the same source as the wastewater samples, biofilm is capable of absorbing ingredients from the wastewater, accumulating them, and retaining them for several weeks, even though the material is no longer present in the wastewater. When the results of biofilm and wastewater indicate a large difference in heavy metal content, the result provides a more precise explanation of contamination in the sewage system than the conventional approach (direct sampling), implying that biofilm collectors (octopus) are a good indicator of heavy metal pollution.

The average concentrations of heavy metals in soil were measured in ten samples taken from two depths: upper soil (0-15 cm depth) and deep soil (15-30 cm depth). The soil profile showed high levels of heavy metals, but the upper soil had a much higher concentration than the lower soil, suggesting that heavy metals are accumulated on the top of the soil as a result of camp activities, as well as low mobility of these metals in a slightly alkaline soil climate. Cr and Mn were the most abundant heavy metals in the upper and lower soil, which could be due to vehicles and transportation inside the camp. Cr is primarily derived from vehicle body wear and tear, while Mn is derived from fuel combustion, as Methylcyclo-pentadienyl manganese tricarbonyl is applied to unleaded gasoline. The average heavy metals concentration in ppb of the upper and lower soil of the three investigated sites as shown in Figure 9.

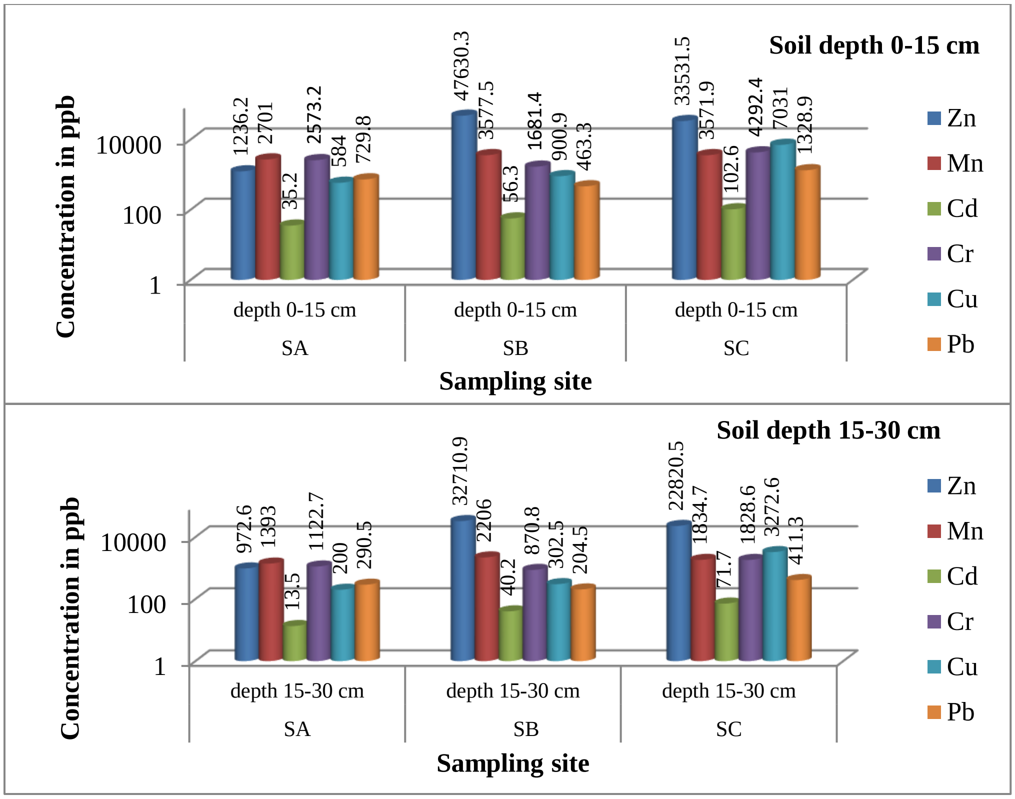

Figure 9: The average heavy metals concentration in ppb of the soil inside the Zaatari camp.

For ten months, the air quality inside the Zaatari camp was monitored using dust settlement method. Figure 10 shows the average heavy metal concentrations in settled dust samples from the three sites.

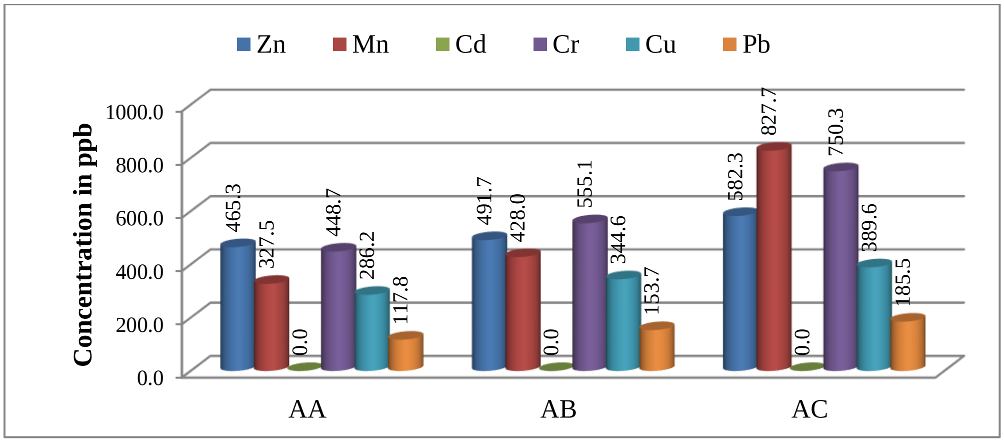

Figure 10: The average concentration of heavy metals in ppb for the settled dust samples inside the Zaatari camp.

Since the camp is situated in a desert area and is relatively far from major cities, the concentration of heavy metals was very low, suggesting that there is no source of heavy metal contamination in the area. The only potential cause is anthropogenic activities within the camp, with the highest concentration of heavy metals at site C, which is the camp's most densely populated location, and the lowest concentration at site A, which is the camp's newest and least densely populated area.

6. CONCLUSIONS

This study was conducted to assess the water, air, and soil quality in the surrounding of Zaatari refugee camp. The water quality parameters for the groundwater from the three wells inside the camp were found to be within Jordanian drinking water standards' acceptable limits. The soil profile showed high levels of heavy metals, the upper soil had a much higher concentration than the lower soil, suggesting that heavy metals are accumulated on the top of the soil as a result of camp activities, as well as low mobility of these metals in a slightly alkaline soil climate. There was also no evidence of heavy metal pollution in the sewage system.

The inlet of the WWTP, on the other hand, had a higher concentration of heavy metals than the other sites, which can be due to wastewater deposition from the three sites examined. There was also no major pollution in the air quality within the camp, indicating that there is no source of heavy metal contamination in the area. The only potential cause is anthropogenic activities within the camp, with the highest concentration of heavy metals at site C, which is the camp's most densely populated location, and the lowest concentration at site A, which is the camp's newest and least densely populated area. However, the current situation and practices inside the camp could pose a threat to future of the groundwater quality in the area if is not handled properly. Weathering of rocks, unregulated and intensive pumping, dissolution of aquifer materials, and the leaching of soluble salts following irregular rainfall events all influence groundwater quality.

The increased demand for water in Jordan, especially in refugee camps, has exacerbated water supply issues and will eventually influence groundwater quality; however, no significant threats of contamination to these groundwater supplies were found in this study. The viability of wastewater treatment plant effluent for irrigation purposes based on sodium adsorption ratio and water salinity analysis that wastewater to be unsuitable for sensitive plants but suitable with specific conditions for some salt tolerant plants. It is important to construct a sustainable collection and sewerage network that is connected to the wastewater treatment plant, as well as an integrated municipal solid waste system that considers recycling and waste-to-energy options. The current water supply, wastewater treatment, and solid waste management systems within Zaatari refugee camp are far from being sustainable.

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