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Seasonal Variations of some Physico-chemical Properties of Drinking Water in Akre District, Kurdistan Region – Iraq

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ABSTRACT: Drinking water considers one of the main concerns in most developing countries. The current study aimed to evaluate the quality of drinking water in Akre district, Kurdistan Region – Iraq in four different seasons, and to compare them with WHO standards. Drinking water samples were collected from seven densely populated quarters of the city. The samples were analyzed for their physico-chemical and heavy metal quality. Physico-chemical parameters were temperature, turbidity, Electrical conductivity "EC", pH, Total Dissolved Solids "TDS", Chlorine "Cl-", Sulphate "SO4-2", Nitrate "NO3", Sodium "Na+", Zinc "Zn", Copper "Cu", total alkalinity, total hardness, Cadmium "Cd" and Plumbum "Pb". These are indications of polluted water and weak treatment practice, which in turn will cause many human health problems. The results from this study showed that almost all the water samples were normal in compare to the WHO guidelines, except for the total alkalinity, total hardness, Cd and Pb, were showed to be higher than WHO standards in some locations. Therefore, the study recommends the city authorities to improve their drinking water treatment or use alternative water supply to have a better drinking water.

Keywords: Drinking water, water pollution, physico-chemical properties, heavy metals, Akre district.

1. Introduction

Water is a compound that considers being the most vital natural resource available in the Globe where life is impossible without it, because it shares in all of the vital processes in human bodies, and the supply of the best quality of drinking water for every human beings and the basis for good human health (Salem et al., 2000). Fresh water comprises less than 3% of Earth's water that is suitable for human consumption, and of this, about 13% is groundwater, which considers as vital source of drinking for many inhabitants globally (Muzvondiwa et al., 2013). It is estimated that more than 2.5 billion people depend rely on groundwater for their drinking water, which is the only source for many rural communities (Grönwall et al., 2020). Water pollution is one of the main global problems, which requires continuous evaluation, recognition and revision of the water policies.

Today, the requirement to the good quality drinking water sources increased with the increase of natural and human activities including atmospheric deposition, geologic weathering, chemicals, pathogens, agricultural activities, land use change, residential and industrial products that have a great capability to degrade the ecological balances through their pollution of air, water and land that eventually will contaminate the drinking water (Chakrabarty et al., 2011). Polluted water does not only affect the aquatic ecosystem, but it can also afterward enter the food chain, and causing problems the human health through initiating various health diseases from the intake of contaminated water through poisoning and accumulating in benthos, aquatic plants, eventually, the upper level of animal hierarchy (Bhaskar et al., 2020). This study aims to evaluate the quality of drinking water through measuring the following criteria:

1. Temperature, turbidity, pH, EC, TDS, total hardness, total alkalinity, Cl-, SO4-2, NO3, and Na+
2. Heavy metals: In this section, we will measure the main heavy metals present in drinking water including Zn, Cu, Cd, and Pb.

2. Methods and Materials

a. The study area

This study has been carried out in Akre district during (Spring – Winter 2017). The place is about 88 km to the north east of Duhok Governorate, Kurdistan region, with latitude of 36°44′29″N and longitude of

43°53′36″E with a total area of about (1134 km2) and about 85,000 inhabitants (Malaika et al., 2020). The area characterized by its wonderful nature and a lot of sources of drinking water and according to the directorate of water at Akre district, the region consists of seven sources of drinking water were mostly depending on wells.

b. Water sampling

A total of 34 drinking water samples have been collected from seven quarters inside Akre district, namely Shahidan, Fawje, Sipa, Khirga, Gulan, Azady and Aleye. Among them, six places Shahidan, Fawje, Sipa, Khirga, Gulan, Azady and Aleye are depending on well water, while one of them, Sipa is depending on spring water. Prior to sampling, all the bottles were rinsed with three times with distilled water, and water allowed to run for about 2 minutes to be stabilized before taking the water sample. Sodium thiosulphate "Na2S2O3" (0.1 mL/ 100 mL of the samples) was added to neutralizes the chlorine in order to prevent further bactericidal effects on organisms in the water during transit or any other chemical reactions. All the samples sorted in a cold box to exclude the bacterial activity and unnecessary chemical reactions until arriving the laboratory and performing the tests. All the samples were taken in duplicates.

c. Measuring and Analyzing Parameters

The measurement of some physicochemical parameters like Temperature, Turbidity, pH, Total Dissolved Solids "TDS" and Electrical Conductivity "EC" of the samples have been measured directly in the locations using conductometer (Hanna Instrument code HI-8633). Chlorine was measured using DPD 4-in-1 Kit. Total alkalinity and total hardness were measure according to APHA 2015 (APHA, 2005). NO3, SO4-2, Na+, Zn, Cu, Cd and Pb were measured using ultraviolet spectrophotometer. The technique measures the concentrations of elements in digested samples, and converted to parts per million (ppm). All the measurements have been carried out in the labs of the Directorate of Environment in Duhok and the scientific center, College of Science, University of Duhok

d. Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 23 was applied in this paper to perform the statistical analysis. Single factor, multiple-factor analysis of variance (ANOVA) and Tukey's multiple comparisons of means were used. The effect the interactions among different factors as well as the independent variable were also determined. The level of significance (P- value) of all coefficients was < 0.05.

3. Results and Discussion

1. Physical properties

a. Temperature

The highest value of the temperature of 25.5 ºC was measured in Khirga Qr. during summer, while the lowest temperature of 11.9 ºC was recorded in Fawje Qr. during winter (Table 1). The overall results of the water temperature were within the seasonal cycle (WHO, 2004).

b. Turbidity

Turbidity is another indicator for the water quality which shows the cloudiness of water. It measures the relative clarity of the water through the existing of organic and mineral suspended particles and color creating substances (Malaika et al., 2020). The results of turbidity values in all locations were measured to be acceptable compared to results of other studies by Toma et al. (2013) and Ameen (2019) and to be within the range given in the WHO recommendations (WHO, 2004), where the permissible limit of turbidity in drinking water is within 1 to 5 NTU as shown in Table (1). However, the highest value of 1.8 NTU was measured in Sipa and Alaye Qrs. during winter, which might be due to the long distance between this quarter and the source that might leads to mixing the drinking water with the neighboring environment, especially when there is breaks and cracks inside the network pipes, as well as the suspended solid particles inserted to the water sources due to fast transport pathway connecting potentially contaminated surface water with the aquifer (Salih and Al-Azzawi, 2011). The statistical analysis showed a significant ($P < 0.05$) difference among the quarters and among the four seasons for turbidity.

c. Electrical Conductivity

Regarding the electrical conductivity, the highest value of 410 µS/cm was measured in Sipa Qr. during the spring season (Table 1). Despite this high value, but it is still within the range given by WHO which is 0 – 800 µS/cm (WHO, 2011). However, this high value might be due to the discharges to the groundwater that may

raise the conductivity of the water, because of the presence of some chemical elements like chloride, phosphate, and nitrate (Rahmanian et al., 2015). While, the lowest value was measured in Fawje Qr. during the autumn season with 200 µS/cm. The statistical analysis showed a significant ($P < 0.05$) difference among the quarters and among the four seasons for electrical conductivity.

Table 1: Average values of seasonal variation of physical properties of drinking water at seven different quarters in Akre district

	Location	Season	Temperature ˚C	Turbidity NTU	Electrical Conductivity (µS/cm)
1	Shahidan Qr.	Spring	18.3	0.3	268
		Summer	20.2	0.4	250
		Autumn	14.6	0.6	310
		Winter	16.2	1.6	305
2	Fawje Qr.	Spring	17.6	0.4	262
		Summer	22.5	0.6	210
		Autumn	16.2	0.6	200
		Winter	11.9	1.4	220
3	Sipa Qr.	Spring	16.1	1.5	410
		Summer	19.6	0.8	261
		Autumn	14.3	1.2	310
		Winter	15.1	1.8	280
4	Khirga Qr.	Spring	22.4	0.4	324
		Summer	25.5	0.8	266
		Autumn	16.5	0.6	224
		Winter	18.8	1.4	234
5	Gulan Qr.	Spring	16.3	0.8	290
		Summer	21.1	0.6	310
		Autumn	18.4	0.8	288
		Winter	13.5	1.6	244
6	Azady Qr.	Spring	16.8	0.8	262
		Summer	14.2	0.8	288
		Autumn	25.3	1	266
		Winter	13.5	1.4	326
7	Alaye Qr.	Spring	18.4	1	298
		Summer	23.4	0.8	280
		Autumn	17.5	1.2	224
		Winter	14.6	1.8	310

2. Chemical properties

a. pH

The highest mean pH value of 8.24 was found in Azady during the winter, while the lowest value of 6.88 was detected in Sipa Qr. during the summer as illustrated in (Table 2). All these values showed almost identical seasonal cycles. Nevertheless, higher levels of the pH might be attributable to the presence of carbonate, bicarbonate, hydroxide and calcium carbonate compounds that dissolve in water, as well as alkaline sewage water system that might raise the pH level (Salih and Al-Azzawi, 2011). The statistical analysis showed no significant ($P > 0.05$) difference among the quarters and among the four seasons for water pH.

b. Total Dissolved Solids "TDS"

Total Dissolved Solids were ranged from a lowest of 121 mg/L in Fawje Qr. in spring to a highest value of 236 mg/L in Khirga Qr. during winter (Table 2). The high dissolved solids might be due to natural weathering of certain sedimentary rocks and certain anthropogenic activities such as high domestic and sewage effluent, irrigation discharges and surface run-off from the residential and commercial areas to the ground water which

might increase the concentration of ions (Rabee et al., 2011). The statistical analysis showed no significant ($P > 0.05$) difference among the quarters and among the four seasons for water TDS.

c. Total Dissolved Solids "TDS"

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d. Total Alkalinity (TA)

Total alkalinity is usually refers to the ability of water to resist changes in pH, where carbonate and bicarbonate alkali substances represent the major forms of alkalinity in natural waters. The results of total alkalinity demonstrated that high total alkalinity of 232 mg/L was measured in Sipa Qr. during the autumn, while the lowest value of 121 mg/L in Fawje during spring as shown in Table (2). The results also shows that some of the concentrations such as in Sipa Qr were exceeded the highest permeable value according to WHO guideline of drinking water (WHO, 1984). Reasons behind the high alkalinity in drinking water might be due to the anthropogenic disturbances such as urbanization-related activities, land uses change, industrial and sewage effluent and the existence of carbonates and bicarbonate in the drinking water source for the quarters of elevated concentrations (Rout and Sharma, 2011). The results from the statistical analysis expressed no significant ($P > 0.05$) difference among the quarters and among the four seasons for water total alkalinity.

e. Total hardness

The total hardness of the water is well known by its lather formation with soap, which means foam made by detergent when stirred in water, and it mostly depends on the quantity of calcium or magnesium salts or both. The total hardness of the analyzed water samples were varied from 134 to 236 mg/L as CaCO3 as shown in Table (2). The high water hardness is mainly contributed to the presence of high levels of chlorides, carbonates and bicarbonates of calcium and magnesium (Rout and Sharma, 2011). According to a classification by Durfor and Becker (1964) (Durfor and Becker, 1964), water can be classified as soft, moderate, hard and very hard as shown in Table (3). According to this classification, no water samples were classified under soft and moderate, 42.9% of the water samples were hard and 57.1% were very hard in nature. The statistical analysis stated no significant ($P > 0.05$) difference among the quarters and among the four seasons for water total hardness.

Table 2: Chemical properties of drinking water of Akre district (spring, 2017)

	Location	Season	pH	TDS (mg/L)	Total Alkalinity ppm	Total Hardness	CL- (mg/L)	SO4-2 (mg/L)	NO3 (mg/L)	Na (mg/L)
1	Shahidan Qr.	Spring	7.95	134	176	152	28.6	10.3	11	4.8
		Summer	7.66	146	188	166	24.5	16.4	14	4.2
		Autumn	7.72	136	146	188	20.7	18.6	12	1.8
		Winter	7.43	215	134	162	26.3	21.3	18	1.3
2	Fawje Qr.	Spring	7.81	121	192	156	22.6	6.2	13	0.5
		Summer	7.62	142	168	172	36.3	12.1	18	1.7
		Autumn	7.88	122	188	134	28.7	8.3	15	1.4
		Winter	7.78	236	168	164	22.2	18.6	21	1.8
3	Sipa Qr.	Spring	7.62	205	226	172	38.5	23.4	16	9.1
		Summer	7.72	210	220	222	24.4	65.5	18	8.9
		Autumn	6.88	186	232	226	30.6	45.6	13	7.8
		Winter	7.82	226	188	210	16.4	67.3	16	2.5
4	Khirga Qr.	Spring	7.71	162	184	212	34.7	30.6	13	5.9
		Summer	7.22	132	174	202	30.1	22.2	11	3.9
		Autumn	7.77	155	189	189	24.5	18.8	12	2.9
		Winter	7.92	238	164	178	28.3	44.6	18	1.9
5	Gulan Qr.	Spring	8.02	145	168	176	38.6	18.2	18	4.8
		Summer	7.71	161	174	212	32.4	12.5	10	4.6
		Autumn	8.04	144	166	228	28.4	12.6	15	3.9
		Winter	8.14	180	166	236	35.7	32.6	19	2.9
6	Azady Qr.	Spring	7.95	131	196	164	26.7	8.7	11	5.9

		Summer	7.81	144	188	188	32.6	14.5	18	4.9
		Autumn	7.02	129	188	210	17.8	16.5	16	2.5
		Winter	8.24	198	188	218	22.9	26.7	11	2.5
7	Alaye Qr.	Spring	7.75	149	184	212	32.9	15.8	20	0.5
		Summer	7.2	131	166	198	24.9	11.8	16	0.3
		Autumn	6.92	146	164	178	28.1	14.5	11	1.9
		Winter	7.92	164	164	220	28.2	20.4	22	1.7

Table 3: Classification of water based on total hardness

	Total Hardness (mg/L)	Nature of water
1	0 – 60	Soft
2	60 – 120	Moderate
3	120 – 180	Hard
4	> 180	Very hard

f. Chloride (CL^-)

Chloride is usually found as an anion in groundwater in changeable amount. It presents in groundwater in variable amount, either naturally, or from diverse environmental sources such as leaching of sedimentary rocks, weathering and infiltration of seawater. In the analyzed water samples, the concentrations of chloride were varied from 16.2 mg/L in Sipa Qr. during winter to 38.5 mg/L in Gulan Qr. in spring. According to WHO guideline of drinking water (WHO,1996), the highest acceptable limit of chloride is 250 mg/L, and compared with this standard, all our samples showed concentrations within the acceptable level. Statistically, there was no significant ($P>0.05$) difference of the chloride concentrations among the four seasons for all the locations.

g. Sulphate (SO_4^{-2})

Sulphur in groundwater is generally present as sulphate, and it may enter the groundwater through both natural and artificial processes. In the present study, the minimum sulphate concentrations of 6.2 mg/L were observed in Fawje Qr. during spring, while the maximum value of 67.3 mg/L was measured in Sipa Qr. in winter (Table 2). It is clear from the results that all the samples were showed to be well within allowable limits based on the WHO guideline of drinking water (WHO,1996). However, the high values of sulphate concentrations during the winter is due to many reasons, among them, an increase of rains that drift with them the chemical fertilizers, the dissolution of gypsum from sedimentary rocks in ground water, agricultural runoff and pesticides that contain sulphate to the groundwater, as well as the domestic discharges and poor sewage system that tended to increase sulphate concentrations (Mahmood 2008 and Al-Zubaidi, 2011). The statistical analysis stated no significant ($P > 0.05$) difference among the quarters and among the four seasons for sulphate in water.

h. Nitrate (NO_3)

The concentrations of nitrate anion in all our samples were varied between 10 mg/L in Gulan Qr. during summer season to 22 mg/L in Aleye Qr. in winter as shown in Table (2). Compared to international standards recommended by WHO (2006), Jawad et al, (2010) and Abdulwahid (2013) and, the values are within permissible limits of 50 mg/L. The high nitrate concentrations in some locations and usually during the winter season might be due to the high rainfall amount in this season that washed away the soil, which contains chemical fertilizers that oxidize to nitrite, manure from livestock and precipitate to the groundwater (WHO, 2006 and Canter, 2019). Another reason behind the high nitrate concentration could be due to the improper locations of the wells that might lead to algal growth, and when they decompose, they release nitrate into the water (Salih and Al-Azzawi, 2011). The high level of nitrate in drinking water can have severe and even deadly impacts on human being, especially infant from birth to three month age (Abdulwahid, 2013). The statistical analysis showed no significant ($P>0.05$) difference among the four seasons regarding the nitrate content in the drinking water.

3. Heavy metals

a. Zinc (Zn)

Zinc is considers as one of the heavy metals that is found naturally at low concentrations in many rocks and soils, and enter to the groundwater though erosion of rocks (Kaplan et al., 2011). The highest and lowest zinc concentrations recorded in our samples were during spring season with maximum value of 1.000 mg/L in Aleye

Qr. and minimum value of 0.267 in Sipa Qr. as shown in Figure (1). Although all zinc concentrations from all the locations were below the WHO maximum permissible limit of 5.0 mg/L (WHO, 2006), and both the minimum and maximum values were measured during spring season, but a high value of 1.0 mg/L in Aleye Qr. might be due to the older galvanized metals pipes of that quarter and well cribbing might be coated with zinc that may dissolved by an acidic water, resulted in leaching of zinc to the water (Swaminathan et al., 2011 and Hasan et al., 2017). The results from the statistical analysis exhibited no significant (P>0.05) difference among the four seasons for all the studied locations.

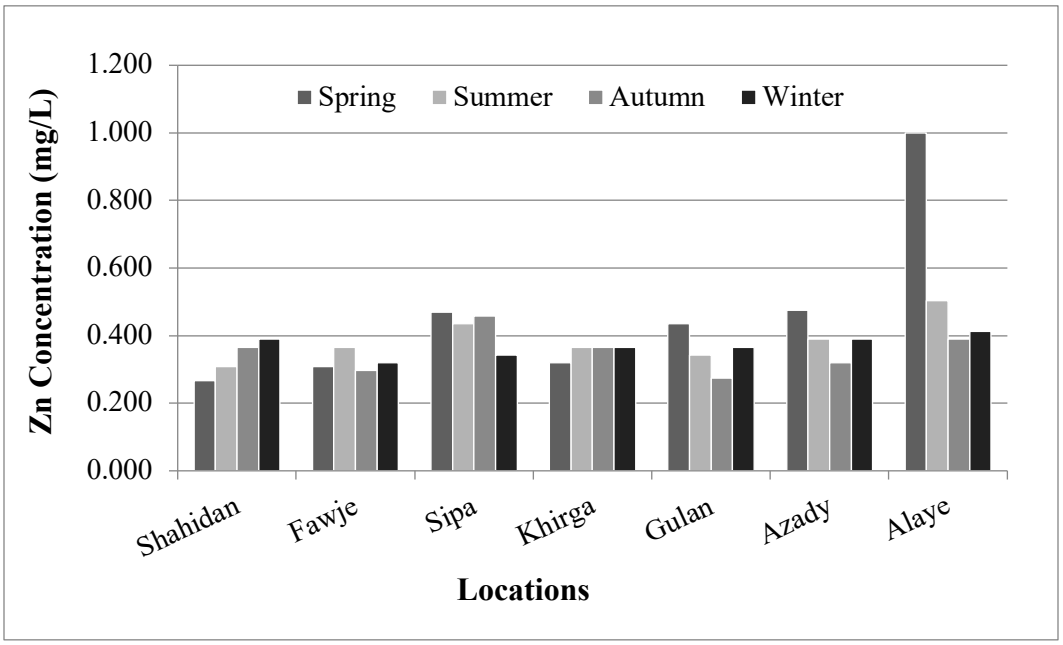

Figure 1: Zn Concentration of Akre district

b. Copper (Cu)

Copper is one of the heavy metals that is found naturally in different aquatic systems like surface water, groundwater, seawater and drinking-water as particulate matter in a concentration range of 0.0005 to 1 mg/L (WHO, 2004). The highest value of 0.121 mg/L was recorded in Gulan Qr. in spring, while the minimum of 0.102 mg/L was measured during summer season in both Sipa and Khirga Qr (Figure 2). All concentrations were considerably below the permissible level of 1.0 mg/L in drinking waters according the WHO standards (WHO, 2004), except in Gulan Qr. during spring. The high value of copper in Gulan Qr. might be due to the corrosion of the quarter's copper pipeline network, especially if the water is acidic (Obiri et al., 2010). Another reason behind the high level of copper could be due to the farming, manufacturing operations and domestic wastewater releases into the groundwater that is directly contaminating well water, which is the main source of drinking water in Akre district (Orosun, 2016). However, the statistical analysis showed no significant (P>0.05) difference in copper concentrations among the different seven quarters and during the four seasons.

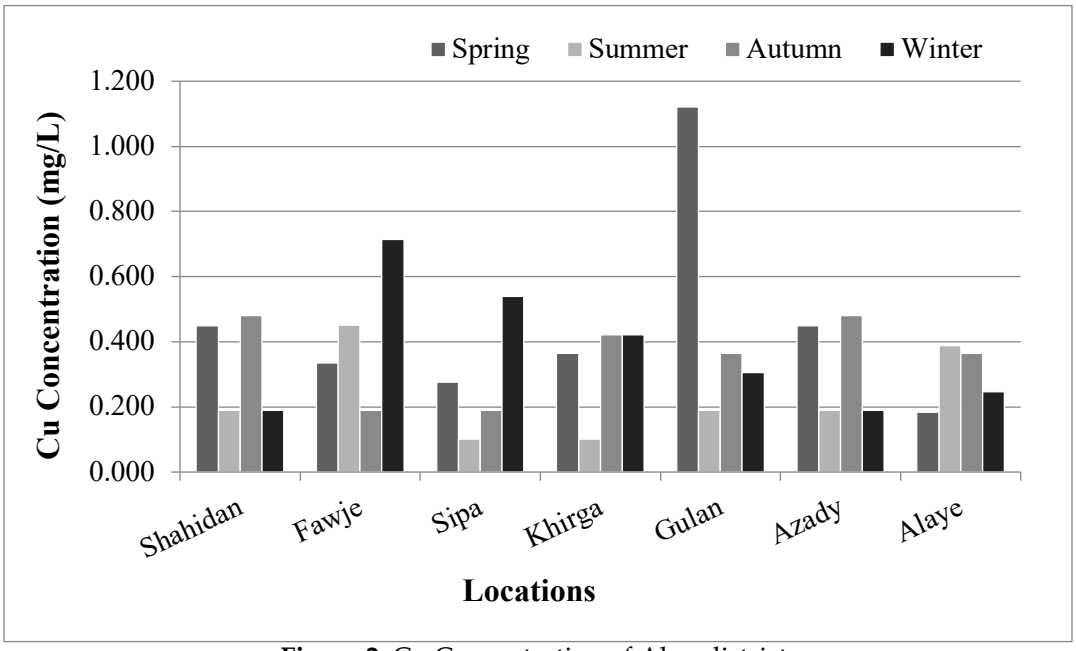

Figure 2: Cu Concentration of Akre district

c. Cadmium (Cd)

Cadmium metal, one of the heavy metals that is occurs naturally with zinc and lead in sulfide ores (WHO, 2004). The results of cadmium in water from figure varied between 0.273 mg/L recorded in Shahidan Qr. in winter, and 0.247 mg/L in Azady Qr. during the summer season. Compared to WHO guideline value for Cd which is set to 3 µg/L (WHO, 2011), all the concentrations were exceeded permissible limit. The reasons behind the high Cd concentrations might be from the natural sources like weathering or bedrocks or from the anthropogenic sources like an intensive agriculture (Balli and Leghouchi, 2018), the impurities in the zinc due to the corrosion of galvanized pipes and some metal fittings (Kaplan et al., 2011), discharges of waste batteries and paints from the domestic uses to the groundwater that eventually infiltrate to the wells (Krishna and Mohan, 2014). The results from the statistical analysis exhibited no significant ($P>0.05$) difference for the CD concentrations among the four different seasons for the seven studied locations.

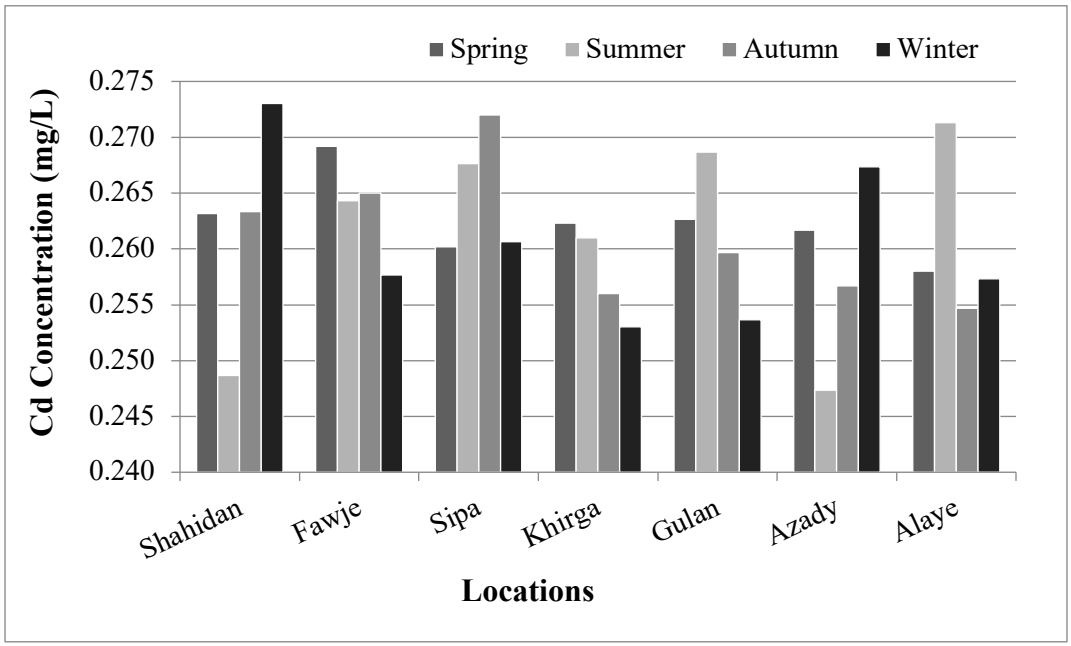

Figure 3: Cd Concentration of Akre district

d. Lead (Pb)

Lead is one of the highly toxicant heavy metals that exists naturally as natural in the earth crust, but its concentration might be increased many times due to the anthropogenic activities (Rajkovic, 2008 and Cobbina, 2015), and it can't be degraded or destroyed easily due to its environmental persistent for a long period of time (Mason, 2012). Sipa Qr. recorded both maximum and minimum values of Pb in drinking water with concentrations of 0.341 mg/L and 0.084 mg/L, respectively (Figure 4). All the samples from Akre district were surpassed the WHO acceptable limit of 0.010 mg/L in drinking water (WHO, 2011). There are many reasons behind the high Pb levels in our samples, including runoff from domestic, agricultural waste, improper disposal of lead batteries and weathering and leaching of lead from waste rocks dump might be the main source of Pb pollution in Akre community (Rajkovic, 2008 and Cobbina, 2015). Household plumbing systems, in which the lead pipes, Polyvinyl chloride (PVC) pipes, solder, and fittings that contain lead compound that might be leached from to the drinking water are another reasons resulted in high lead concentrations in drinking water from all the collected samples (WHO, 2011). The statistical analysis showed no significant ($P>0.05$) difference in lead concentrations among the different seven quarters and during the four seasons.

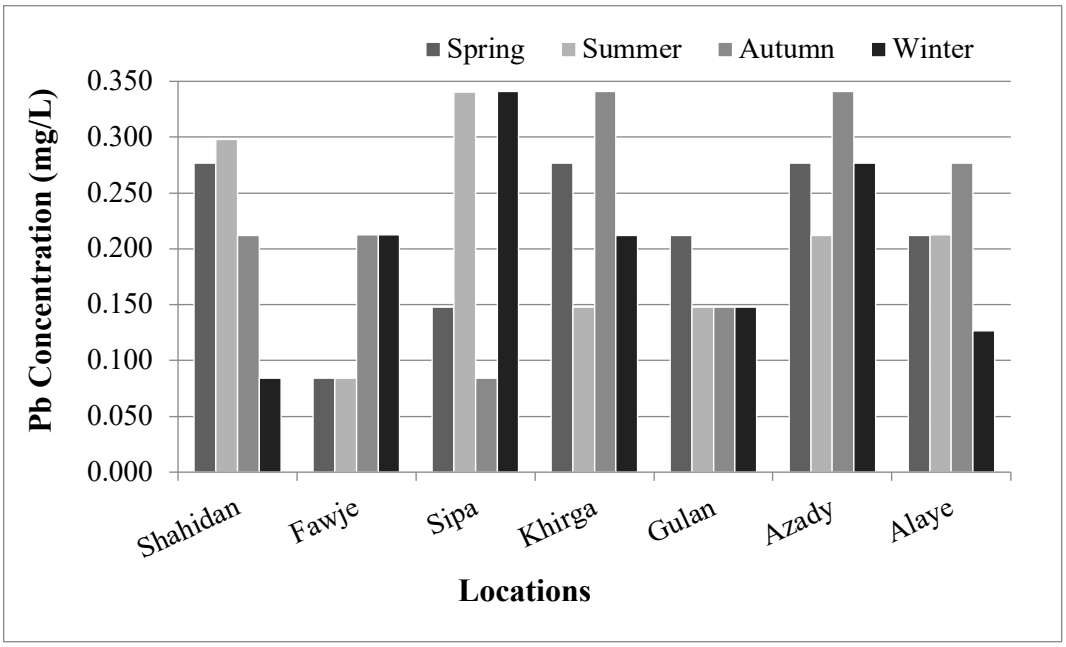

Figure 4: Pb Concentration of Akre district

4. Conclusion:

From the study, it can be concluded that the water in Akre district, except in some places, is safe for drinking purposes from the point of view of levels of turbidity, EC, pH, TDS, Cl^-, $SO4^{-2}$, NO^3, Na^+, Zn, Cu. But the total alkalinity, total hardness, Cd and Pb, were showed to be greater than WHO guideline values.

All Akre inhabitants including the refugees will get benefits from this study as it covers most places of Akre district including refugee camps. The final report with results and recommendations will be reported to the stakeholders or the responsible institutions

5. Recommendations:

The authors recommend the local governmental authorities to soften the tube well water before consumption to avoid future contaminations. Further researches should be carrying out on hydrological studies for the existing water sources to show the hydrogeochemical survey in that area in order to detect the source of contaminations. It is also recommended to do a long term monitoring of the physicochemical and heavy metal variables to evaluate the extent of the impacts on both human health and agriculture.

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