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RESEARCH ARTICLE

EFFECTIVENESS OF CHLORINE TREATMENT ON PHYSICO-CHEMICAL CHARACTERISTICS OF WATER SUPPLIES FOR ZAKHO CITY/KURDISTAN OF IRAQ

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ABSTRACT

The present work was undertaken to investigate the drinking water quality of Zakho city after adding chlorine (as an efficient disinfectant), and assess the water quality of Little Khabur River (before adding chlorine). Also a systematic study has been carried out to assess the water quality of Zakho city after distribution (at the consumer tap). Water was analyzed during rainy season for 2014 and during all seasons of 2015 to determine its quality using standard methods. The aim was to find how the addition of chlorine could affect the physical and chemical properties of water for Zakho city. Quantification of chlorine residual, pH, turbidity, etc. was performed. Each physico-chemical parameters (pH, dissolved oxygen, COD, BOD, total alkalinity, hardness, turbidity, etc.) was compared with the standard desirable limit of that parameter in river water (or drinking water) as prescribed by WHO. pH generally ranged from 7.02 to 7.30; conductivity fluctuated from 359 to 374 µS/cm; turbidity varied from 0.34 to 2.79 NTU; and TDS values were found to be ranging between 180 and 187 mg/l. Chlorine normally added to public water supplies to kill disease-causing bacteria that the water or its transport pipes might contain. The value of total chlorine was found to be 0.86 to1.7 mg/l.

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INTRODUCTION

In the recent years, numerous studies have been conducted worldwide to understand the associations between water pollution and human health in order to protect public health. Access to safe drinking water is an important issue for human need (Karikari and Ampofo, 2013), i.e. Freshwater is essential to human health, natural ecosystems, industry, agriculture, etc. Water quality analysis is essential to safeguard the consumer from the water-borne diseases. Safe drinking water, as defined by the World Health Organization (WHO) guidelines (WHO, 2008) is water that does not represent any significant risk to health over a lifetime of consumption. Hence, Drinking water should be clear and free from objectionable tastes and odors and from harmful chemicals and microorganisms. Unsafe water and poor sanitation and hygiene have been reported to rank third among the 20 leading risk factors for health burden in developing countries (Abdelrahman, 2011). Contamination of water is becoming a serious problem at global level as fresh water resources are getting deteriorated at an alarming rate (Mahananda, 2010, Andrew, 2012). Therefore, all water supplies should be disinfected.

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This is aimed both at inactivating remaining bacteria before distribution and providing a residual disinfectant to inactivate bacteria introduced by any subsequent increase of contaminated water during storage or distribution (WHO, 2003) and regular testing of water is essential. The principal disinfectant used worldwide is chlorine, although alternatives are being increasingly investigated and process such as ozonation and using UV are becoming more common. Chlorine is a choice as disinfectant in many countries including Iraq, due to low cost and high effectiveness (AWWA, 2000). Chlorine residual decreases from water treatment plant to the consumer's tap. This may be related to the following reasons (Sivakumar *et al*., 2014): a-bulk decay of chlorine, b-wall decay, c-coliform regrowth, d-potential for bio-film formation within the system. In Kurdistan region of Iraq (KROI), there has been a tremendous increase in the demand for freshwater due to rapid growth of population as well as the accelerated pace of petroleum extraction. In the previous work (Ayoub and Yousif, 2015), we investigated water quality Index (WQI) of Little Khabur (LKH) river near Zakho city (ZC), Iraq. Drinking water released into the distribution system in ZC may be change in its physico-chemical characteristics during its passage through pipes, open reservoirs, standpipes and storage tanks. Also bacteria may enter the distribution system through failure to disinfect water or maintenance of adequate disinfection residual, low pipeline water pressure, intermittent service, excessive network leakages, corrosion of parts, and inadequate sewage disposal (Karikari and Ampofo, 2013; Lee & Schwab. 2005. Keeping residual chlorine at a certain level in tap water is effective not only in improving sanitary conditions but also in minimizing the re-growth of micro-organisms and preventing the formation of bio films on the internal surface of distribution pipelines (Munavalli & Kumar. 2003). Occurrence of water-borne diseases in Iraq is mainly due to pollution or contamination of water with municipal sewage, agriculture and industrial waste at different points of the water distribution system (DS), as well as lack of water disinfection practices and water quality monitoring at Water Treatment Plant (WTP). Clark *et al*., (1995), reported that chlorine residuals can vary throughout the day at different locations in a DS depending on the flow path as well as residence time of the water reaching a tap. In Iraq, chlorination is practiced at most of the WTP as means of water disinfectant, and it is supplied to the public via a DS. Water DS play a pivotal role in preserving and providing quality water to the public. Toma (2013) applied the WQI tool to evaluate the changes in the water quality of Greater Zab River within Erbil city, Iraq during the period 2009- 2012. Little is known about the physical and chemical properties of water for Zakho city (ZC), or disinfectants within the water DS. The present work was undertaken to study the drinking water quality of ZC, as well as quality of Little Khabur (LKH) river.

A systematic study has been carried out to assess the water quality. Water were analyzed during rainy season for 2014 and during all seasons of 2015 to determine its quality using standard methods. Aim of this study was to find how the addition of chlorine could affect the physicochemical parameters of water for Zakho city. Quantification of chlorine residual, pH, turbidity, etc. was performed. Each physico-chemical parameters (pH, dissolved oxygen- DO, COD, Electrical Conductivity (EC), hardness, turbidity, etc.) was compared with the standard limit of that parameter.

MATERIAL AND METHODS

Description of Study area

Water samples from different locations at Zakho city were randomly collected, at varying interval in thoroughly washed and sterilized bottle. Samples were collected from each of the followings different locations: (Fig. 1). Site S1, located about 200 m before Delal bridge, (before adding chlorine). Site S2, located at Project of Water Treatment Plant in Zakho (PWTPZ) (after adding chlorine). Site S3, (at the consumer tap) (includes Center ZC, South ZC and Zakho University). This study took place from the beginning of October 2014 to the end of Dec 2015. Potable water supply to ZC originates from Little Khabur (LKH) River, and treat by PWTPZ located near bridge of Delal in ZC. Zakho is a large city in Northwest of Kurdistan region of Iraq (KROI). It had an estimated population of 360 000, and located at the intersection point of longitude (42° 42' 13") and latitude (37° 8' 53" N). The city center is around 440 m above the sea level. When the LKH River goes through ZC is crossed by the ancient possibly Roman bridge of Delal. After crossing ZC the LKH river is the natural border at Ibrahim Khalil between Turkey and Iraq.

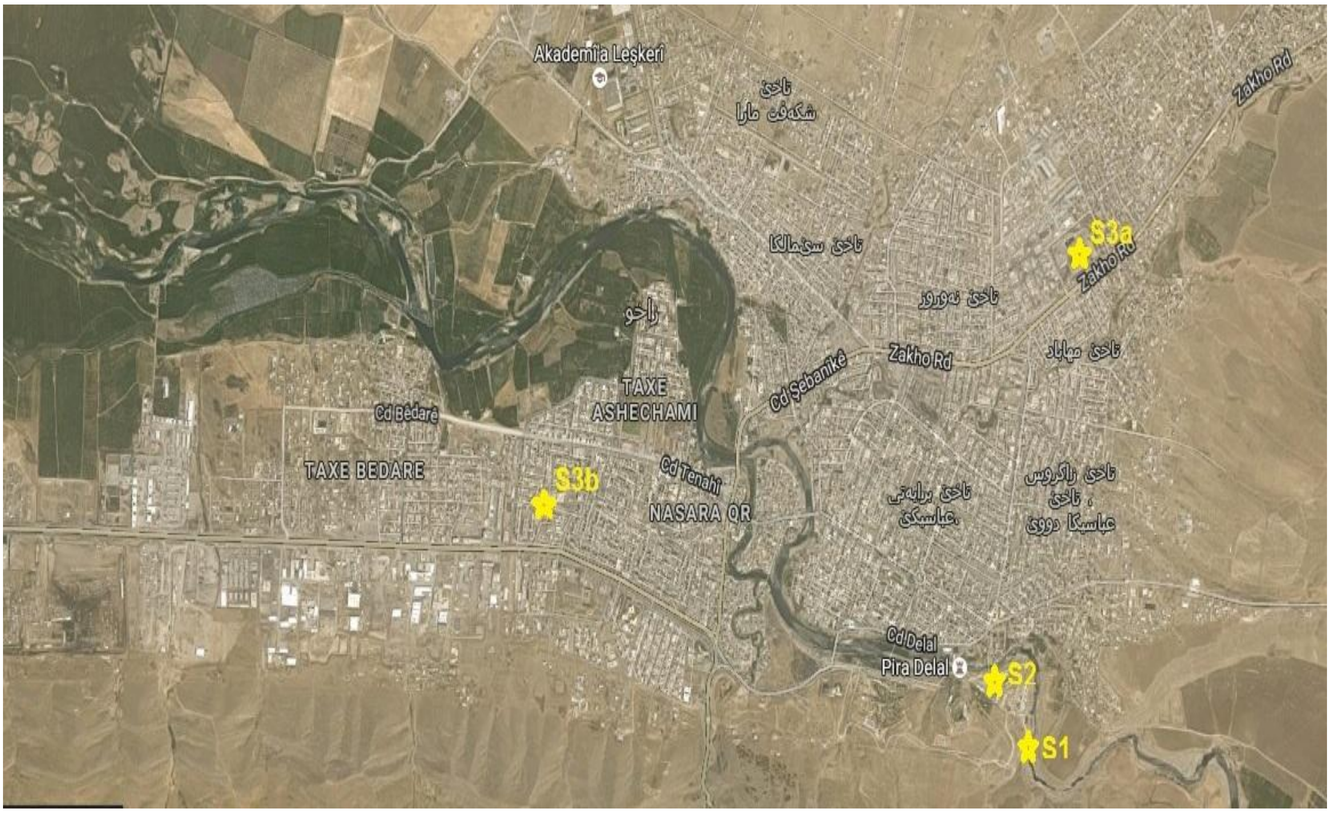

Fig. 1. Satellite view of LKH river showing sampling locations at Zakho city

It empties into the River Tigris at the tri-point between Iraq, Syria and Turkey (Ayoub & Yousif, 2015).

Tests and Analysis of Physico-chemical Parameters

Water Samples for the analysis of water parameters (i.e. temperature, pH, EC dissolved oxygen (DO), total hardness, chemical oxygen demand (COD), total alkalinity, biological oxygen demand (BOD), total dissolved solid, etc.) were preserved and transported to research laboratory. For the preservation and the analysis of water samples, the standard methods (Maiti, 2001, APHA, 2005) were followed. The water temperature (T) was recorded at the sample stations. T and EC of the sample were measured using ADWA AD 32, Mauritius (0.02 Accuracy). The pH of water samples of the water was measured with the help of instrument pH Meter (Elico LI-120) with a glass electrode. Turbidity was measured using a Luton turbid-meter. The COD of the sample was measured by Open Reflux Method. The other physico-chemical water parameters like total hardness (TH), (SO4), Alkalinity, DO and BOD were analysed in the laboratory following the standard procedures (Maiti, 2001, APHA, 2005).

RESULTS AND DISCUSSION

Temperatures are the most important fundamental physical parameter which influences almost all the physical, and chemical properties of water, as well as biological nature of water (Sharma, and Walia 2015). In the present study the Mean temperature of water was 7.1 ± 2.4 (Standard deviation), 7.6 ± 1.5, and 9.5± 1.1 ^{0}C at locations S1, S2 and S3 respectively (in winter season). The Mean temperature was 23.8± 1.4, 30.1 ± 1.2, and 30.7 ± 1.1 ^{0}C at locations S1, S2 and S3 respectively (in summer season). The Mean temperature was 15.5 ± 1.3, 18.5± 1.5, and 20.2 ± 1.6^{0}C at locations S1, S2 and S3 respectively (in Spring and Autumn seasons). The river temperature generally depends on the season, geographic location, sampling time and effluents entering the stream. These deviations are due to sampling in different months of the year, as well as the geographic location, effluents entering the stream, and sampling time. Figures 2, and 3, show some of the average values of physico-chemical parameters of water at locations S1, S2 and S3. The result indicated maximum dissolved oxygen (DO) values of 8.6±0.15 (Standard deviation), mg/L, 8.5 ±0.13 mg/L, 8.5 ±0.12 mg/L, at locations S1, S2 and S3 respectively. This was recorded during spring season. During this season, intense sunlight accelerates photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. DO content of any water body depends on the mixing and aeration of water, water temperature, duration of sunlight received and altitude of the area (Avvannavar and Shrihari, 2008). Oxygen can enter water either from contact with the atmosphere or is produced by plants during photosynthesis. Almost care was taken, so that no bubbling should observe during sampling, which avoids influence of the DO. The minimum values of dissolved oxygen were 6.2 ±0.3 mg/l, 6.3 ±0.1 mg/l and 7.6 ±0.1 mg/l, at locations S1, S2 and S3 respectively. This was recorded during summer season. In summer season, DO decreases due to increase in temperature and also due to increased microbial activity (Moss, 1972, Morrissette and Mavinic, 1978; Kataria *et al*., 1996). The pH is the determination of hydrogen ions [H+]. Also the pH value influences the generation of OH• radical. pH value measures alkalinity or acidic nature of water (Covington *et al*., 1985). During the present investigation, the pH of LKH river water (locations S1) fluctuated from 6.2 ±0.5 (in Winter season), to 8.8 ±0.3 (in summer season) in 2015. The pH of water at locations S2 and S3 was 6.3 ± 0.3 and 7.8 ± 0.4 respectively (in Winter season).

The pH of water at locations S2 and S3 was 8.1± 0.3, and 8.6 ± 0.3 respectively (in summer season). The pH values were found to be almost with in recommended values i.e. 6.5 to 8.5 during all seasons. Highly acidic nature of water at S1, during winter season could be mainly due to significant amount of acid received from the air pollution from vehicles. The water during winter was found more acidic than in other seasons, due to high volume of rainfall. Raising the pH of treated water may assist in controlling the corrosion but will increase the formation of tri-halo-methane (THM) (by products of chlorine disinfectant). Since the THM are carcinogenic, this is not desirable (Sivakumar *et al*., 2014). The intensity of cloudiness/murkiness of water determines its turbidity level, i.e., water having variety of suspended materials in it will exhibit elevated level of turbidity and vice versa. Seasonal variations of turbidity were observed at different sampling sites and maximum level of turbidity was recorded at S2 throughout the study period. In the present study the Mean Turbidity of water was 3.4 ±1.3, 6.1±1.5, and 4.4±1.1 NTU at locations S1, S2 and S3 respectively. In both years, pre seasons were found to exhibit turbidity with values less than the prescribed limit of Standard (i.e. 5 NTU). However, the Mean turbidity level in S2 was higher due to Chlorine residual, and mean turbidity level in S3 was less.

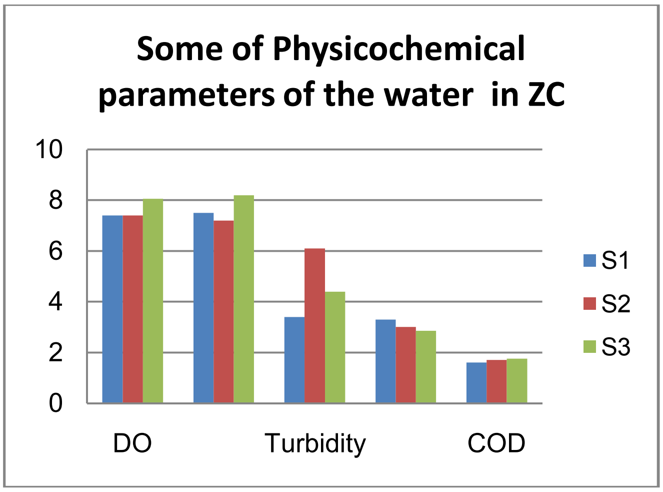

Fig. 2. Comparison of some Physico-Chemical parameters variation in three sampling stations (S1, S2 and S3) at ZC. Units of DO, Turbidity, BOD, and COD are (mg/l), (NTU), (mg/l), and (mg/l) respectively

This may be related to dilution of water by its mixing during passing through distribution system. Biochemical Oxygen Demand $(BOD)_5$ test help to measure the amount of biodegradable organic material of water sample. In present study the BOD_5 of water sample was varied between 1.2 ±0.23 and 5.4± 0.22 mg/l at S1. In the present study the Mean $(BOD)_5$ of water was 3.3 ± 0.24, 3 ± 0.22, and 2.85 ± 0.21 (mg/L at locations S1, S2 and S3 respectively. BOD_5 test help to measure the amount of biodegradable organic material of water sample. Chemical Oxygen Demand (COD) is amount of oxygen required for the oxidation of oxidizable organic matter. The COD values indicate the amount of toxicity in water (Patil and Patil 2011). COD of LKH river water (locations S1) during winter season was found varies from 1.1 ± 0.07 to 2.1± 0.07 mg/l. In the present study the Mean COD of water was 1.6 ± 0.05, 1.7 ± 0.06, & 1.75 ± 0.07 mg/l at S1, S2 & S3 respectively. The results show that the values are below the maximum permissible limit. Mean Values of Electrical Conductivity (EC) monitored during present study was found varying as S1 (424± 40 µS/cm) >S2 (382± 30 µS/cm) >S3 (344 ± 42 µS/cm). High or low EC in water is due to an elevated or reduced level of dissolved ions. As we know, water distribution systems (DS) frequently draw water from different sources, such as a different kinds of pipes. Also, mixing of water from different sources take place within the DS, and is a function of complex system hydraulics. For these reasons the water quality parameters (including EC) of delivered water to the consumer may vary spatially and temporally within the distribution system (Lamare and Singh., 2016). Significantly higher EC values were observed in S1 throughout the study period indicating presence of elevated levels of dissolved ions in the LKH river water. The results show that these values are below the maximum permissible limit. Total dissolved solid (TDS) is the sum of the cations and anions concentrations. Mean Values of TDS monitored during present study was found varying as S1 (272 ± 26mg/l)>S2 (245 ± 22 mg/l)>S3 (219.5 ± 21mg/l). The results show that these values are below the maximum permissible limit. The TDS ranged between (213 ± 20 & 226 ± 24) mg/l. Site (3) recorded the lowest TDS values along the study period, while S1 recorded the maximum TDS values. However, the TDS values in this site is Lower than the upper limit for drinking water (WHO, 2003). The analytical results of the LKH river water samples revealed small amount of sulphate (SO4 2-). Mean Values of (SO4 2-) monitored during present study was found varying as S1 (35 ±1.6 mg/l) >S2 (34.5 ±1.5 mg/l) >S3 (32 ±1.3 mg/l). Sulphate concentration (CON) at all sampling stations and seasons was found less than the prescribed limit.

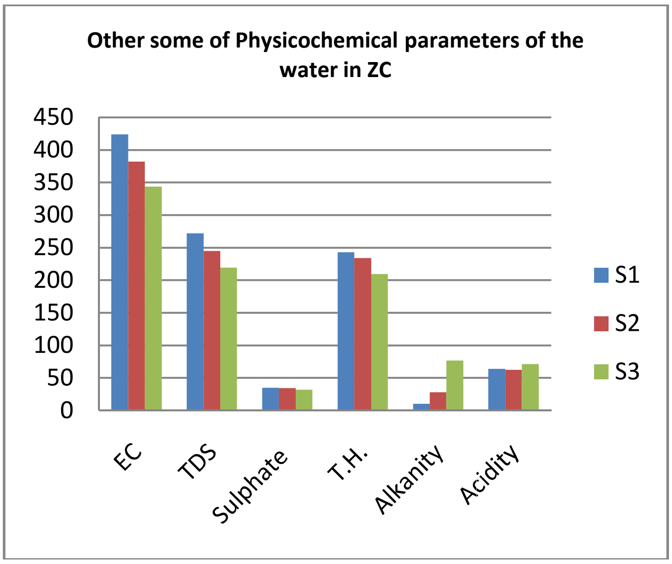

Fig. 3. Comparison of other Physico-Chemical parameters variation in three sampling stations (S1, S2 and S3) at ZC. EC (Conductivity- µs.cm-1), TDS (mg/l), Sulphate (mg/l, T.H. (Total hardness) (mg/l), and Acidity (mg/l)

Hardness value of water gives us a general idea of how easy water can form suds with soap, scale formation in water pipes or boilers. In the present investigation, TH level during winter 2014 and winter of 2015 ranged between 188 ±17.34 mg/l to 231± 18.84 mg/l. The TH (CaCO3) values in S1 ranged between 181 ±16 mg/l to 305 ±19 mg/l; in S2 it varied between 183 ±15 mg/l to 285 ±17 mg/l, and in S3 varied between 188 ±16 mg/l to 231 ±17.7 mg/l. Permissible limit for TH for water is less than 500 mg/l. Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Sverdrup *et al*. 1942). In present study total alkalinity (H_2SO_4) of water samples varied from 9.4mg/l at S1 to a maximum of 91 mg/l at S3. The results show that these values are below the maximum permissible limit. Mean Values of alkalinity monitored during present study was found varying as S3 (76.5 ± 3.4 mg/l) >S2 (28 ±1.7.mg/l) > S1 (10.4 ±1.1 mg/l). Fig.3, shows comparison of Mean Values of Acidity (Na_2CO_3) monitored during present study. It was found varying as S3 (71.5 ±4.98mg/l) >S1 (64 ±4.82 mg/l)>S2 (62.5 ±4. 2 mg/l). Fig.4, shows comparison between the CON of chlorine in water at S2 between October up to December of years 2014 and 2015. It can be seen that more chlorine was added during October and November, may be relate to starting period of raining season in ZC where water is more polluted. The capacity of project of water treatment is about 3500L/h. The addition of chlorine per one hour into water is about (11.410g). It means that the capacity of project of water treatment daily is about (84000 Liter). The solution of chlorine in water contains chlorine (Cl2) hydrochloric acid and hypochlorous acid (HClO))

$$Cl_2 + H_2O \rightarrow HCl + HClO.$$

This conversion is called disproportionation, because the ingredient chlorine both increases and decreases in formal oxidation state, the solubility of chlorine in water is increased if water contains dissolved alkali hydroxide. Figure 5 shows average variation in chlorine during year 2015.

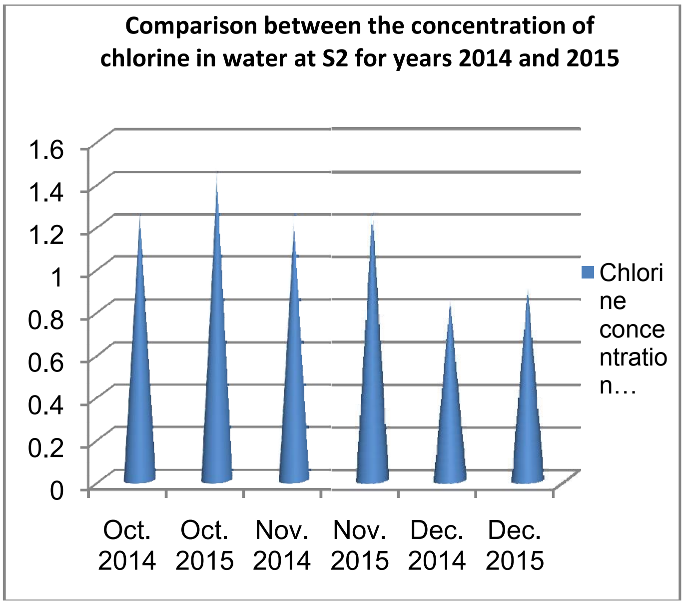

Fig. 4. Comparison between the concentration of chlorine in water at S2 between October up to December of years 2014 and 2015

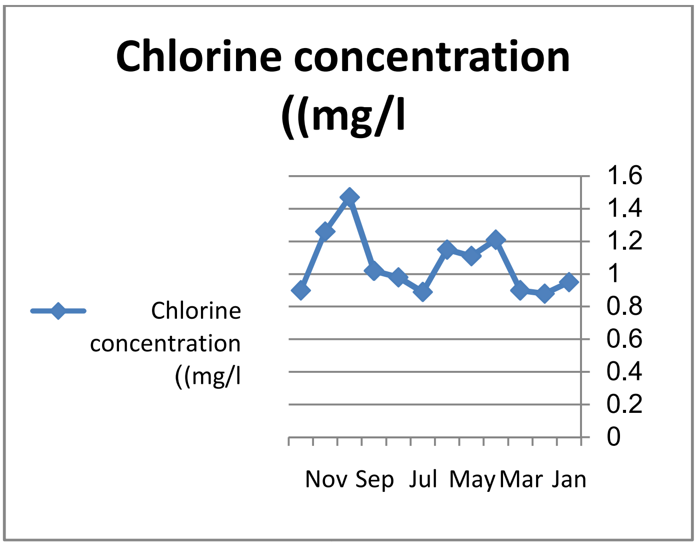

Figure 5. Average variations in chlorine during year 2015

It was observed that there is more chlorine was added during April and May and this is due to the floods and rising rainfall. The use of chlorine is important for ensuring that water is bacteriologically safe to drink unless other reliable means of disinfection e.g. boiling can be used (Karikari and Ampofo, 2013). The mean chlorine residuals (CR) value for this study varied from the lowest value of 0.1 to 0.6mg/l, when the treatment plants apply a chlorine dosage of between 0.9 to 1.45 mg/l for disinfection. The recommended CR for water that is centrally treated at the point of delivery should be within 0.2–0.5 mg/l (WHO 2011). In the present study, CR was obtained at the sampling sites, with most of them below the set target (0.5 mg/l). This could be related to inadequate disinfection residual (i.e. chlorine), or accidental point source contamination by broken pipes (Karikari and Ampofo, 2013). Therefore maintenance of CR is needed in distribution pipelines system to prevent microbial growth. Sharp *et al*. (2010). Suggested that the unlined cast iron pipe has higher chlorine consumption than polyvinyl chloride pipe (PVC) and that of the larger diameter cast iron pipe has lower consumption than the smaller diameter pipe.

Conclusion

This research has provided many information about the water quality status in the distribution system (DS) of Zakho city-ZC/Kurdistan region of Iraq. The investigation indicates that physicochemical parameters such as EC, pH, turbidity, COD, DO, and BOD are within the limits given by WHO guidelines for drinking water quality. Therefore, we can conclude that ZC water is acceptable for drinking purposes according to the parameters evaluated. Also water quality evaluation and continuous observing for ZC water are of highest importance. To prevent the delivery of unsafe water, the following are recommended: Frequent assessment of water quality should be carried out at different points in the DS of ZC by an independent company, or agency. To reduce water pollution or introduction of contaminants in the DS, connections of water into consumer's tap or to distribution lines should not be tampered by unprofessional or unskilled persons.

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