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Original Research Article

Health risk assessment of heavy metals and quality of tap water in and around Davao Oriental State University, Philippines

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ABSTRACT

The study assessed the health risk of heavy metals and tap water quality in five stations in and around Davao Oriental State University. The main objectives were to determine the physico-chemical and biological characteristics, which included the pH, temperature, total dissolved solids (TDS), Cadmium (Cd), Lead (Pb) heavy metal, and the presence of coliform. The results for pH and TDS had mean values of 7.34 and 551.6 mg L^{-1}, respectively, while the temperature ranged from 26.4 ºC to 28.3 ºC. Furthermore, Cd and Pb concentrations determined using Atomic Absorption Spectroscopy were below 0.003 mg L^{-1} and 0.01 mg L^{-1}, respectively. As evaluated using a hydrogen sulfide kit, the absence of coliform was also noted. Overall, the quality of tap water for this study was within the allowable limit set by the Philippine National Standards for Drinking Water (PNSDW) except for TDS. Moreover, the values for health risk assessment indices (Chronic Daily Intake, Hazard Quotient, and Hazard Index) for Cd and Pb did not exceed the United States Environmental Protection Agency (US EPA) and World Health Organization (WHO) standards. Hence, both metals showed no potential contamination and health risks. However, the carcinogenic risk for lead (6.47E-04) slightly exceeded the limit. The results of the study were preliminary by nature, and further monitoring and evaluation must be implemented.

Keywords: Tap Water Quality, Heavy metals, Health Risk Assessment

INTRODUCTION

Safe drinking water is accepted nowadays as a fundamental right of human beings. However, approximately 780 million people are deprived of uncontaminated and safe water, and around 2.5 billion unfortunate people do not have appropriate sanitation and proper hygiene (Mebrahtu & Zerabruk, 2011). These result in nearly 6 to 8 million fatalities yearly because of water-related diseases. Therefore, water quality control is a top-priority policy agenda in several world portions and is determined by its taste, odor, color, and concentration of organic and inorganic matters. Existing contaminants affect the water quality and, eventually, human health (Rahmanian et al., 2015).
One of the most determined contaminants in the water is heavy metals. Heavy metals are usually found in the environment and diet. In low concentrations, they are essential for sustaining good health, but to greater extents, they can be toxic and risky (Jaishankar, Tseten, Anbalagan, Mathew, & Beeregowda, 2014). These heavy metals are difficult to eradicate. They can accumulate throughout the food chain, creating possible human health risks and ecological turbulences. The occurrence and accumulation of heavy metals in the environment are caused by direct or indirect human activities, such as fast industrialization, urbanization, and anthropogenic sources, or caused by natural activities such as soil erosion, sediments, etc. (Akpor & Muchie, 2010).

Safety is usually defined as "an acceptable level of risk" (DeSesso & Watson, 2005). However, human health is at the greatest risk because of the rapid pollution and environmental deterioration, which result in enormous water-associated diseases (Myers, Gaf, Golden, Ostfeld, & Redford, 2013). Health risk assessment provides a synopsis of an individual's health status and concrete evidence to prepare the stakeholders for a lifestyle adjustment. It can also support risk managers in assessing the benefits and costs of several alternatives for reducing contact with hazardous chemicals (Health and Safety Executive, 2014).

Approximately 8,000 students are known to be reliant on the tap water of Davao Oriental State University (DOrSU). Therefore, determining the water quality is vital to protect public health and promote the population's right to access safe drinking water. This study provides information, specifically the physico-chemical and biological aspects. Furthermore, the heavy metals (lead and cadmium) concentrations and the risk of these metals to human health were measured.

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MATERIALS AND METHODS

Establishment of Sampling Stations

The criteria for selecting sampling points were based on the water sources that serve most of the population of DOrSU. Two (2) sampling sites were inside the campus, specifically the two canteen areas, and three sampling sites were established outside the DOrSU campus, mainly the nearby cafeterias, which the students preferred more. The following are the descriptions of the different sampling sites and Global Positioning System (GPS) coordinates: station 1 – main food station situated beside the engineering building inside the campus (N 06º55'59.0" E 126º15'14.0"); station 2 - food station located near the Thelma Z. Almario (TZA) building inside the campus (N 06º55'47.1" E 126º15'16.7"); station 3 – 6J's Square near Regional Integrated Center (RIC) building outside the campus (N 06º55'56.1" E 126º15'21.5"); station 4 – Yamyan's LB eatery situated right in front of the DOrSU's third gate (N 06º55'56.4" E 126º15'20.7"); station 5 – Food Ville (N 06º56'00.7" E 126º15'18.2").

Sample Collection, Preparation, and Heavy Metal Analysis

Water sampling was done at the five (5) established sampling sites between 2:00 to 5:00 in the afternoon. Before the water samples were collected, the faucet was heated first using an alcohol lamp, then wiping the faucet with a cotton wet with alcohol. After that, the tap water was free-flowed for 2-5 minutes. Afterward, water samples were taken using a 4-liter container rinsed three times with the tap water sample. The water samples were placed in a styrofoam box with a temperature maintained at 4ºC and transported to the laboratory for physico-chemical analysis for all parameters except the temperature that was determined on-site. Glass Electrode method, gravimetric method, and Atomic Absorption Spectrophotometry (Perkin Elmer PinAACle^{TM} 900F) were used for the determination of pH, total dissolved solids (TDS), and heavy metal cadmium (Cd) and lead (Pb), respectively. Previously labeled primary health care (PHC) bottles were filled with water collected directly from the faucet for the biological characteristics. The samples were incubated for 24 hours at room temperature. A color change (black) is an indication of the presence of coliform bacteria (Tiotangco, 2011).

Data Analysis

Results were expressed in terms of mean and standard deviation. Using the t-Test, the results of the analyses were compared to the available standards, including the Philippine National Standards for Drinking Water (PNSDW) of 2007, the World Health Organization (WHO), and the US Environmental Protection Agency (US EPA). The statistical significance was considered at p values < 0.05. Data were further processed to estimate risk analysis using Risk Quotient (RQ) based on the standards. The risk quotient (RQ) was calculated using the equation of Maigari et al. (2016), while health risk assessment was calculated using the equation of Naveedullah et al. (2014).

RESULTS AND DISCUSSION

Physico-chemical Analyses

The standard value set by PNSDW, WHO, and US for pH levels in water are between 6.5 to 8.5. Figure 1 shows the very nominal difference in pH level in five sampling stations with a mean value of 7.34 and is therefore safe for drinking and cooking purposes. According to Kale (2016), pH is one of the most important water quality parameters, even though it has no direct impact on the consumers. High pH affects water taste, while low pH levels will leach metals and other substances.

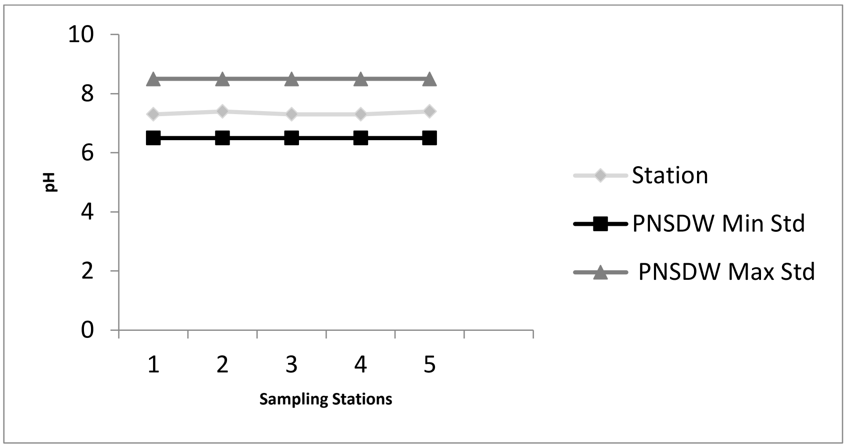

Figure 1. pH levels of the different tap water stations in and around DOrSU

A fluctuation of the temperature readings between 26.4 ºC to 28.3 ºC, as shown in Figure 2, may be due to the change of weather during sampling. There has been no standard value provided for drinking water temperature. However, Rahmanian et al. (2015) stated that cold water passes through the stomach and rehydrates the body faster. According to Whelton et al. (2001), cold tap water is roughly at 7ºC while tap hot water should be at 50ºC. Tap water temperature varies according to local conditions and geographical location.

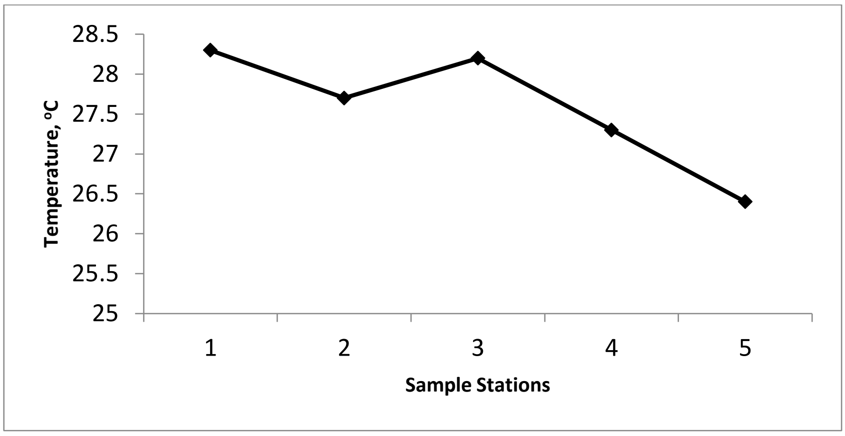

Figure 2. Temperature levels of the different tap water stations in and around DOrSU

Figure 3 shows that the TDS level for all stations was below the PNSDW standard values except for stations 3 and 4. The TDS range for this study is comparable with the result conducted by Tayone (2015) in a nearby barangay. The high TDS concentration may be due to dense residential areas and geographical location. The total dissolved solids concentration of good & palatable drinking water should not be more than 500 mg/L according to WHO and not more than 600 mg/L according to PNSDW. Indicators of high TDS are hardness, scale formation, bitter taste in drinking water caused by calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), and brackish taste resulting from sodium chloride (NaCl) and potassium chloride (KCl) (Shrivastava, 2014). According to Mebrahtu and Zerabruk (2002), a TDS level of less than 500 mg/L is generally considered good. Therefore, higher concentrations might be taken without detrimental physiological effects and might be even more advantageous without a doubt. However, continuous water usage might cause weakness, reduced production, bone deterioration, and risky if consumed constantly (Shrivastava, 2014). Also, high TDS can damage the water supply system.

On the other hand, water with very low concentrations of TDS (less than 100 mg/L) may also be unbeneficial to consumers because of its flat, insipid taste (World Health Organization, 2003). TDS test is an indicator of chemical elements present in water. An elevated level of TDS does not show that the water has health risks. Instead, the chemical element (nitrates, carbonates, potassium chloride) brings health risks. Analysis of each chemical is then required to regulate health effects (Shrivastava, 2014).

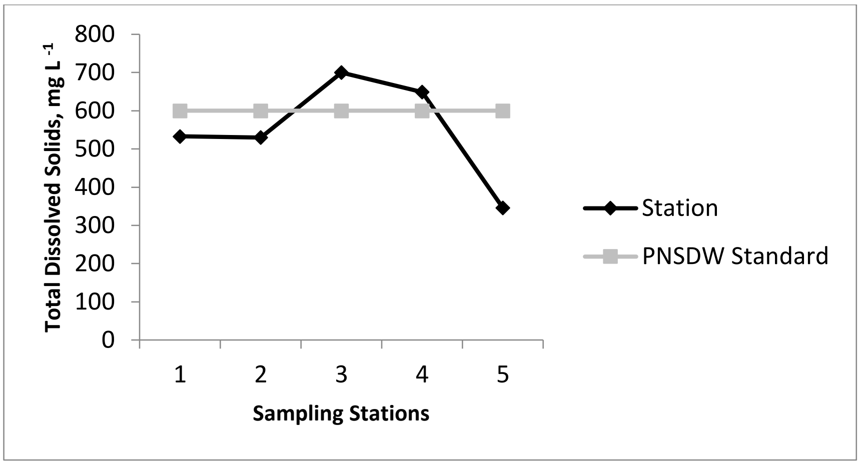

Figure 3. TDS levels of the different tap water stations in and around DOrSU

Heavy Metals

Cd is commonly used in television screens, batteries, paint dyes, cosmetics, and galvanizing steel, as a barrier to nuclear fission. It is usually used with zinc to weld seals in lead water pipes (Eteng et al., 2015). Minimal exposure to Cd can cause cough and headaches, while it can mainly cause cancer, chronic anemia, and cardiovascular illnesses in high exposure (Bernard, 2008). Protein binding into excess essential metals reduces their non-availability to human blood supply (Burke, Hamza, Naseem, Nawaz-ul-huda, Azam & Khan, 2016).

US EPA set the allowable limit for Cd to be 0.005 mg/L, while WHO and PNSDW are 0.003 mg/L in drinking water. Cd is released into the water supply due to the zinc coating of galvanized pipes and metal fittings (Philippine National Standards for Drinking Water, 2007). Figure 4 shows that all sampling sites in selected food stations in and around DOrSU were below the acceptable standards of US EPA, WHO, and within PNSDW's guidelines for Cd. These results indicated that Cd in the study sites was acceptable for drinking and cooking.

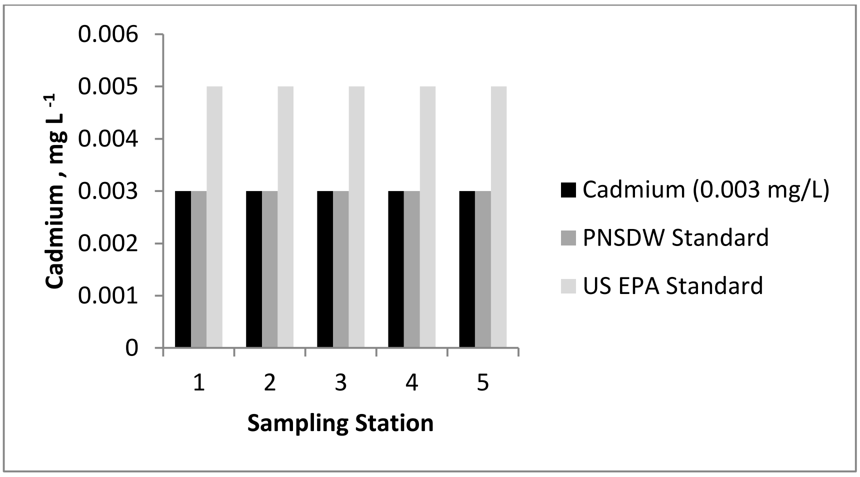

Figure 4. Cd concentration in different sampling stations and standard values

Figure 5 shows the concentration of Pb with values 0.01 mg/L in all sampling sites. Pb is present in tap water due to dissolution from natural sources or household plumbing systems containing Pb in pipes. Also, food can be contaminated with lead from the soil and lead from sources such as atmospheric fallout or water used for cooking (Flora, Gupta, & Tiwari, 2012). Pb's common effects are headache, fatigue, abdominal discomfort, constipation, anemia, peripheral neuropathy, and renal insufficiency in a minimal exposure (Kosnett, 2008). Increased levels of Pb in the body can lead to poisoning (Hou et al., 2013). The results of this study were lower than the levels of Cd and Pb in the study of Mebrahtu and Zerabruk (2011), who consider it a pollution hazard and has implications on people's health.

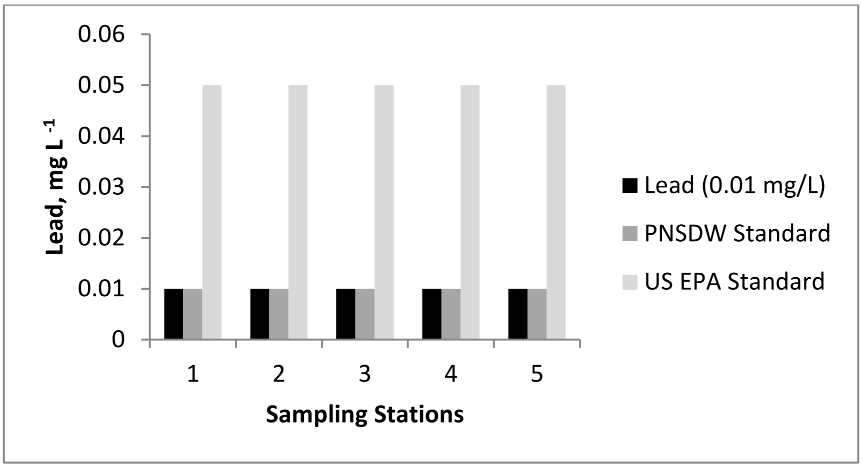

Figure 5. Lead concentrations in different sampling stations and standard values

Biological Characteristics

Primary Health Care (PHC) bottle is also known as H_2S Kit. Its composition includes ferric ammonium citrate, dipotassium hydrogen phosphate, sodium thiosulfate, peptone, teepol, and a folded (1 square) tissue that contains 1 mL of the solution. The principle behind this method is the rapid reaction of H_2S with iron to form black iron sulfide precipitate. If the water sample in the vial turns black after 24 hours, the water is contaminated. Water containing coliform bacteria also consistently contained organisms producing hydrogen sulfide(H_2S) (Tiotangco, 2011). Water samples from all stations showed negative results, indicating the absence of coliform bacteria, as presented in Table 2.

Chemical Reaction :

$$\mathbf{Fe}_{\text{(rich growth medium)}} + \mathbf{H_2S}_{\text{(from microorganisms)}} \longrightarrow \mathbf{FeS}_{\text{(black precipitate)}}$$

Table 2. PHC method for the presence of coliform in water samples.

Sampling Stations	Results (Presence of Coliform)
1	Negative
2	Negative
3	Negative
4	Negative
5	Negative

Three trials were conducted for each station.

Risk Assessment

Selected Physico-chemical analyses

As shown in Table 3, the Risk Quotient was calculated using the formula of Maigari et al. (2016) to estimate the risk based on the standard limit. Risk Quotient >1 may indicate the potential risk of the studied parameter. Since the results of the calculations were less than 1, parameters did not show any risk except for TDS on sampling sites 3 and 4. This is consistent with the result of TDS with values of 700 and 649 mg/L, respectively, which were greater than the standard set by PNSDW (600 mg/L). This may indicate a slight risk when taken constantly.

Table 3. Risk Quotient of the selected physico-chemical analyses.

	Risk Quotients of Selected Physico-chemical parameters			
Sampling Stations	**pH**	**RQ**	**TDS, mg/L**	**RQ**
1	7.3	0.9733	533	0.8883
2	7.4	0.9866	530	0.8833
3	7.3	0.9733	700	1.1666
4	7.3	0.9733	649	1.0816
5	7.4	0.9866	346	0.5766

Note: RQ > 1 may indicate the potential risk of the studied parameter.

Heavy Metal Risk Assessment

The toxicity of Cd and Pb has been characterized to assess the exposure levels from which these widespread pollutants could threaten human health (Mebrahtu & Zerabruk, 20011). The average risk analysis of Cd and Pb through ingestion and dermal is shown in Table 4.

All sampling sites had exposure values of 0.0016 and 0.0055 through ingestion (Exp_{ing}) and 1.26 x 10^{-5} and 0.0001 through dermal absorption (Exp_{derm}) for Cd and Pb, respectively. Exposure values between metals showed that Pb had a higher exposure value than Cd. These calculated exposure values were used to calculate the risks such as Chronic Daily Intake (CDI), Hazard Quotient (HQ), Hazard Index (HI), and Carcinogenic Risk (CR).

Table 4. Average risk analysis for Cd and Pb.

	Average Risk Analysis			
Indices	**Cd**	**US EPA**	**Pb**	**US EPA**
Ave Concn, mg/L	0.003		0.01	
Exp_{ing}	0.0016	-	0.0055	-
Exp_{derm}	1.26 x 10^{-5}	-	0.0001	-
CDI, mg/kg/day	9.42 x 10^{-5}	0.5	0.0003	1.4
HQ_{ing}	0.0033	<1	0.0039	<1
HQ_{derm}	0.0005	<1	0.0004	<1
HI_{ing}	0.0165	<1	0.0196	<1
HI_{derm}	0.0025	<1	0.002	<1
CR	2.70 x 10^{-7}	1.0 x 10^{-6} to 1.0 x 10^{-4}	6.47 x 10^{-4}	1.0 x 10^{-6} to 1.0 x 10^{-4}

Note: HQ< 1 indicates no potential health risk;
HI <1 indicates no potential non-carcinogenic risk

The CDI for Cd in water from the selected food stations in and around DOrSU was 9.42 x 10^{-5} mg/kg/day, while Pb had the value of 0.0003 mg/kg/day. Therefore, CDI indices for Pb were higher than that of Cd. However, all calculated CDI were below the Reference Dose (RfD) of Cd and Pb in water which was 0.5 and 1.4 mg/kg/day, respectively. The US EPA's maximum acceptable oral dose of a toxic substance is the reference dose. This showed that both metals posed no risk for tap water consumers in terms of CDI.

HQ is calculated by comparing the calculated contaminant from each exposure route (ingestion, dermal) with the reference dose (RfD). The reference doses for Cd through ingestion and dermal are 0.5 and 0.025, while Pb is 1.4 and 0.42, respectively. HQ >1 might indicate adverse effects (US Environmental Protection Agency, 2005). HQ_{ing} and HQ_{derm} for Cd were 0.0033 and 0.0005, while Pb had 0.0039 and 0.0004, respectively. $HQ_{ing/derm}$ for both metals was below US EPA standards. The results indicated that these metals do not pose a health threat to tap water consumers in selected food stations in and around DOrSU.

Hazard index (HI) was calculated to estimate the total probability of non-carcinogenic effects posed by more than one pathway, the sum of the HQs (Naveedullah et al., 2014). Non-cancer health effects (such as asthma, nervous system disorders, and congenital disabilities) typically become more severe as exposure to a chemical increases (Ayantobo, Awomeso, Oluwasanya, Bada & Taiwo, 2014.) The mean calculations of HI_{ing} and HI_{derm} for Cd were found to be 0.0165 and 0.0025, respectively. On the other hand, HI_{ing} and HI_{derm} for Pb were 0.0196 and

0.002, respectively. Since both values were less than the acceptable value (<1), there are no potential adverse health effects to the consumers of the tap drinking water via oral ingestion and dermal absorption.

Carcinogenic risk (CR) refers to the increased probability of an individual developing cancer in a lifetime because of exposure to carcinogens (US Environmental Protection, 2005). The range of carcinogenic risk acceptable or tolerable value is between 1.0 x 10^{-6} to 1.0 x 10^{-4}. Exposure values used in this study were obtained from the study of (Naveedullah et al., 2014) in China and were assumed to be constant in this study. The average CR levels through ingestion of Cd and Pb in water samples from selected food stations in and around DOrSU exposure were 2.70 x 10^{-7} and 6.47 x 10^{-4}, respectively. Therefore, the CR_{ing} for Cd did not exceed the acceptable value. This showed no carcinogenic risks. However, the calculated CR_{ing} for Pb using the exposure values of body weight (70 kg), ingestion rate (2,2 L/day), Exposure duration (30 years), exposure time (0.6 h/day), and averaging time of 10,950 days used by Naveedullah et al. (2014) in China, shows that Pb slightly exceeded the target standard value which is 1.0 x 10^{-7} to 1.0 x 10^{-4}. However, body weight (50 kg), ingestion rate (1.6 L/day), exposure time (0.6 h/day), averaging time of 10,950, and exposure duration of 4 years were also calculated for the short-term exposure. Using these values, carcinogenic risks of Cd and Pb for short-term exposure are 1.57 x 10^{-8} and 3.76 x 10^{-5}, respectively. This indicated that short-term exposure did not exceed the standard value for carcinogenic risks.

According to US Environmental Protection Agency (2005), even very low exposure to a cancer-causing chemical may result in cancer if the chemical alters cellular functions that cause cancer to develop. Additionally, human cancer often develops many years after exposure to a chemical. In Titilyano, Olufemi, and Ogbemi (2012) study, Pb has exceeded the allowable limit of carcinogenic risk (3.0 x 10^{-3}) in India. They concluded that Pb in water samples and health risk assessment showed potential cancer and non-cancer total health risks for the water consumers if they continue to use tap water for their domestic purposes.

CONCLUSIONS

The physico-chemical characteristics (pH, T, Cd, and Pb) of the tap water from the selected food stations in and around DOrSU were below the levels set by PNSDW, WHO, and US EPA. The water from all stations was also free from coliform bacteria. On the other hand, TDS for food stations 3 and 4 were high, indicating risks to the consumers as shown on the value of the risk quotient, which was greater than 1. However, there was no potential non-carcinogenic health risk for both metals as revealed by the calculated CDI, $HQ_{ing/derm}$, and $HI_{ing/derm}$ for Cd and Pb. CR_{ing} of Cd also showed no carcinogenic risk. Although Pb for short-term exposure poses no carcinogenic risk, one should take necessary precautions since long-term exposure gave CR_{ing} value slightly greater than the standard. This study was just but preliminary, further monitoring and evaluation are highly recommended.

REFERENCES

Akpor O, Muchie M (2010). Remediation of Heavy Metals in Drinking Water and Wastewater Treatment Systems Processes and Applications. *International Journal of Physical Sciences*, 5: 1807-1817.

Ayantobo O, Awomeso A, Oluwasanya G, Bada B, and Taiwo A (2014). Non-Cancer Human Health Risk Assessment from Exposure to Heavy Metals in Surface and Groundwater in Igun Ijesha, Southwest Nigeri. *American Journal of Environmental Sciences*, 10 (3): 301-311.

Burke F, Hamza S, Naseem S, Nawaz-ul-huda S, Azam M, and Khan I (2016). Impact of Cadmium Polluted Groundwater on Human Health. *SAGE Open*. 1: 1-8.

DeSesso J and Watson R (2006). Should apparently beneficial effects of low dose exposures to agents be integrated into risk assessments performed by the US Environmental Protection Agency. *Human & Experimental Toxicology*, 25: 1-4.

Eteng M, Barena G, Anacletus F, and Bassey S (2015). Effect of Exposure To Lead And Cadmium In Drinking Water Sources From Nigeria's Niger Delta Region On Fecundity In Albino Wister Rats. *Journal of Biotechnology and Biochemistry*, 37–39.

Flora G, Gupta D, and Tiwari A (2012). Toxicity of lead : A Review with Recent Updates. *Interdiscip Toxicol*, 5 (2): 47–58.

Health and Safety Executive. Risk assessment (2014).

Hou S, Yuan L, Jin P, Ding B, Qin N, Liu X, and Wu Z (2013). A Clinical Study of The Effects of Lead Poisoning on The Intelligence and Neurobehavioral Abilities of Children. *Theor Biol Med Model*, 10:1–9.

Jaishankar M, Tseten T, Anbalagan N, Mathew B, and Beeregowda K (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiscip Toxico*, 7(2):60-72.

Kale V (2016). Consequence of Temperature, pH, Turbidity and Dissolved Oxygen Water Quality Parameters. *International Advanced Research Journal in Science, Engineering and Technology,* 3(8):186–190.

Kosnett MIJK (2008). Health Effects of Low Dose Lead Exposure in Adults and Children, And Preventable Risk Posed by the Consumption by Game Meat Harvested with Lead Ammunition. 24–33.

Maigari A, Ekanem E, Garba I, Harami A, and Akan J (2016). Health Risk Assessment for Exposure to Some Selected Heavy Metals via Drinking Water from Dadinkowa Dam and River Gombe Abba in Gombe State, Northeast. *World Journal of Analytical Chemistry,* 4: 1-5.

Mebrahtu G, Zerabruk S (2011). Concentration of Heavy Metals in Drinking Water from Urban Areas of the Tigray. Concentration of Heavy Metals in Drinking Water from Urban Areas of the Tigray Region, Northern Ethiopia. College of Natural and Computational Sciences Mekelle University, 3 (1):105-121.

Myers S, Gaf L, Golden C, Ostfeld R, and Redford K (2013). Human Health Impacts of Ecosystem Alteration. Proceedings of the National Academy of Sciences, 1–8.

Naveedullah H, Yu C, Shen H, Duan D, Shen C, and Chen Y (2014). Concentrations and Human Health Risk Assessment of Selected Heavy Metals in Surface Water of the Siling Reservoir Watershed in Zhejiang Province. *Pol.J. Environ. Stud*, 23 (3): 801–811.

"Philippine National Standards For Drinking Water." DENR Administrative Order NO. 26-A

Series 2007.

Rahmanian N, Hajar S, Ali B, Homayoonfard M, Ali N, Rehan M, and Nizami A (2015). Analysis of Physiochemical Parameters to Evaluate the Drinking Water Quality in the State of Perak, Malaysia. Journal of Chemistry, 1-10.

Shrivastava, S (2014). Water Quality Analysis of Water Bodies of Kantajhar Basti.Thesis.

Tayone JC (2015). Biological and Chemical Characteristics of Groundwater in a Rural Settlement Area of Davao Oriental. *American Scientific Research Journal for Engineering, Technology, and Sciences*, 14 (1): 94-99.

Tiotangco A (2011). Water Quality Surveillance by Using the H2S kit (PHC bottle). 50th PACT National Convention. University of Santo Tomas.

Titilayo E, Olufemi A, and Ogbemi E (2012). Chronic Exposure to Heavy Metals in Public Water Supply and Human Health Risk Assessment. Terrestrial and Aquatic Environmental Toxicology, 6 (2): 106-111.

USEPA. (2005). Guidelines for Carcinogen Risk Assessment. U.S. Environmental Protection Agency Washington, DC.

USEPA. (2004). Risk Assessment Guidance for Superfund. Vol. I: Human Health Evaluation Manual.

World Health Organization. (1999). Guidelines for Drinking Water Quality.

World Health Organization. (2003). Total Dissolved Solids in Drinking-Water Background Document for Development of WHO Guidelines for Drinking Water Quality.