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Non-Carcinogenic Health Risk of Trace Metals in Artesian Well Waters

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ABSTRACT

Levels of lead, copper, zinc, nickel and cadium were assessed in artesian well waters of Agua dulce, Linao, Cogon and Punta in Ormoc City, Leyte, Philippines. Samples of water in three replicates each from the four study sites were brought to the Visayas State University Analytical laboratory to determine the presence of dissolved trace metals using atomic absorption spectrophotometer. Non-carcinogenic health risk of the trace metals for children and adults was also determined using the chronic daily intake of trace metals and hazard quotient index. Results revealed that lead and cadmium were found to be beyond the WHO permissible limits in all areas studied. Hazard quotient greater than 1 in all study sites was found in lead for both children and adults and in cadmium in children. Total hazard quotient of trace metals in the four study sites was found higher than 1 in both children and adults. These results indicate a non-carcinogenic health risk to the people which call for immediate attention and concern by the local authorities.

Keywords: Non-carcinogenic risk, Health risk assessment, Trace metals, Artesian well waters

INTRODUCTION

Quality drinking water is a basic right and essential to the well-being of all humans and aquatic organisms. However, the quality of drinking water is increasingly vulnerable for the past decade[1–3]. With population growth, rapid urbanization and industrialization has increased the contamination of ground and surface water reserves[4,5]. Day by day, wastes from toxic chemicals from industries, agricultural runoffs and from domestic sources are funneled into bodies of water. These effluents are in the form of raw sewage, detergents, fertilizer, heavy metals, chemical products, and even solid wastes[5–7]. Contamination from these pollutants such as trace metals is detrimental to the health of people as these accumulate into the tissues and organs of living organisms which bring disastrous effects to health[5,8].

Risk associated with trace metals is now an issue of health concern around the globe[9–11]. Although some of them such as Cu, Mn and Zn are beneficial to health[5], beyond allowable limits, these trace metals including other metals (lead (Pb), Cadmium (Cd), Arsenic (Ar), Aluminum (Al), Chromium (Cr), Iron (Fe), Mercury (Hg), and Nickel (Ni)) are toxic to humans and aquatic organisms. They are non-biodegradable and non thermo-degradable hence can magnify at toxic levels in the human body[12]. Depending on the specific kind of metal, these can cause various diseases such as cancer, malfunctioning of internal organs, neurological and cardiac problems, skin diseases and can even cause impairment of growth and reproduction[4,6,8,13,14].

The need to determine the presence of trace metals in drinking water is therefore essential to people. In Ormoc City, Leyte, Philippines it is quite interesting to note that several artesian wells are still existing and located at the hub of the City and are still useful for domestic purposes including drinking. People use them in spite of their close proximity to industrial establishments and residential houses and chances are these waters could possibly be exposed to waste contamination. Referring Calderon (2000), the artesian wells were constructed for decades thus plumbing systems may have been corroded contributing to the source of trace metals. No published report has been done on the presence of trace metals on these waters. The purpose of the study then is to determine whether the artesian well waters contain trace metals and determine the possible non-carcinogenic risk associated with drinking water with trace metals.

METHODS

Study Site

The study was conducted in Ormoc City which is located in the northwestern part of Leyte, Philippines, with coordinates at Lat. 11° 00' 26.59" N, Long. 124° 36' 28.46" E. Ormoc City is supplied with water for drinking and other domestic purposes by the Ormoc Water system of Ormoc City. In spite of the presence of this water system, artesian wells are still present in the City and most people are still using them for domestic purposes including drinking as they are accessible to people without any payment.

Figure 1. Labeled locations of study sites
(Source: Google Map)

Sample Collection of Water

Samples of water were collected in commonly used artesian wells in Ormoc City such as that in Agua Dulce, Cogon, Punta and Linao. Five hundred (500 ml) of water in three replicates each were collected from the study sites last October 2017 and were placed in separate clean, emptied distilled water bottles and stored in cooled containers to prevent evaporation. After the collection, these waters were brought right away to the Visayas State University, Leyte Philippines analytical laboratory for the presence of dissolved trace metals namely cadmium, lead, copper, nickel and zinc. Determination of trace metals was done using atomic absorption spectrophotometer. After the results were obtained, the data were processed, tabulated and analyzed for the levels of trace metals.

Non-carcinogenic Health Risk Assessment Associated with the Trace Metals

Health risk assessment is done through hazard identification, exposure assessment, dose response (toxicity) and risk characterization[15]. This is a function of hazard and exposure and the process of calculating the probability of occurrence of an event and the impact of its health effects to humans exposed to environmental hazards over a period of time[6,14]. Health risk to a potentially toxic metal is expressed in terms of its non-carcinogenic effect by calculating the chronic daily intake of a potentially toxic trace metal and hazard quotient index[5,7] where;

Chronic Daily Intake (CDI)

$$CDI = \frac{CxDI}{BW} \qquad (1)$$

CDI = is expressed in (mg/kg/Day)
C = is the concentration of trace metals in mg/L
DI = average amount of drinking water in a day (2L/day for adult and 1 L/day for child)[15]
BW = body weight (kg) (15 kg for child and 70 kg for adult)[15]

Hazard quotient (HQ) was calculated for non-carcinogenic health risk with the given formula:

$$HQ = \frac{CDI}{RfD} \qquad (2)$$

RfD is the reference dose. This calculation was determined whether the trace metals studied pose health risks and HQ ≥ 1 indicates non-carcinogenic health risk.

The overall potential for non-carcinogenic risks for all possible toxic substances is determined by summing up the hazard index (THQ) as applied US EPA (1989)[15] to be

$$THQ = HQ1 + HQ2 + ..HQn \quad (3)$$

Table 1 shows the reference dose index for each metal[6].

Table 1. Reference dose index

Trace Metal		Reference dose
1.	Pb	3.5×10^{-3}
2.	Cu	4.0×10^{-2}
3.	Zn	0.3
4.	Ni	2.0×10^{-2}
5.	Cd	5.0×10^{-4}

RESULTS

Trace Metals Concentration

Table 2 shows the concentrations of trace metals in the study sites conducted.

Table 2. Concentrations of trace metals (mg/L) in artesian well waters in Ormoc City

Artesian Well Source	Pb	Cu	Zn	Ni	Cd
Agua Dulce	0.15	0.003	0.0257	0.021	0.012
Linao	0.21	0.003	0.0291	0.01	0.016
Cogon	0.22	0.003	0.0239	0.02	0.013
Punta	0.29	0.003	0.0257	0.02	0.013
Minimum	0.15	0.003	0.0239	0.01	0.012
Maximum	0.29	0.003	0.091	0.021	0.016

WHO (2008) permissible limits: [a] Pb - 0.01 ; [b] Cu - 2 ; [c] Zn - 3; [d] Ni - 0.07; [e] Cd - 0.003

Chronic Daily Intake of Trace Metals

Table 3. Chronic daily intake of trace metals in artesian well waters

Artesian Well Source	Lead (Pb)		Copper (Cu)		Zinc (Zn)		Nickel (Ni)		Cadmium (Cd)	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Agua Dulce	0.01	0.004	0.0002	8.57E-05	0.0017	0.0007	0.0014	0.0003	0.0008	0.00034
Linao	0.014	0.006	0.0002	8.57E-05	0.0019	0.0008	0.0007	0.0001	0.0011	0.00046
Cogon	0.015	0.004	0.0002	8.57E-05	0.0016	0.0007	0.0013	0.000286	0.0009	0.00037
Punta	0.019	0.004	0.0002	8.57E-05	0.0017	0.0007	0.0013	0.000286	0.0009	0.00037
Ave.	0.014	0.0045	0.0002	8.57E-05	0.0017	0.0007	0.0012	0.00024	0.0009	0.0004

Hazard Quotient/THQ of Trace Metals

Table 4 Hazard quotient and THQ of trace metals in artesian well waters

Source	Lead (Pb)		Copper (Cu)		Zinc (Zn)		Nickel (Ni)		Cadmium		THQ	THQ
	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Agua Dulce	2.857	1.224	0.005	0.002	0.006	0.002	0.07	0.03	1.6	0.686	4.538	1.944
Linao	4.00	1.714	0.005	0.002	0.006	0.003	0.033	0.014	2.133	0.914	6.177	2.647
Cogon	4.19	1.796	0.005	0.002	0.006	0.002	0.067	0.029	1.733	0.743	6.001	2.574
Punta	5.524	2.367	0.005	0.002	0.006	0.002	0.067	0.029	1.733	0.743	7.335	3.136

DISCUSSION

Trace Metals Concentration

Trace metals (Pb, Cu, Zn, Ni and Cd) were detected in all sampling areas studied. Lead concentrations were beyond WHO permissible limit of 0.01mg/L in all areas studied. Punta artesian well exhibited highest concentration of Pb (0.29 mg/L) while Agua dulce had the lowest concentration of Pb (0.15mg/L). The presence of this trace metal in these artesian waters could be attributed to the plumbing pipes which have corroded already releasing Pb into the waters. Cadmium was also detected in significant amounts (0.012 - 0.016mg/L) in all sampling sites beyond the permissible limit of WHO (0.003). Copper (Cu), Zinc (Zn) and Nickel (Ni) concentrations were below the permissible limits of WHO; Cu – 2; Zn – 3; and Ni – 0.07 respectively hence not a health threat.

Chronic Daily Intake of Trace Metals

Chronic daily intake (CDI) observed in table 3 shows that of the trace metals involved in the study, CDI of Pb in children was highest in Punta (0.19 mg/kg/D) and lowest in Agua dulce (0.01 mg/kg/D); while in adults, CDI (0.004 mg/kg/D) was found the same and highest in three study sites (Agua Dulce, Cogon and Punta). CDI of Cu was the same in all study sites in children (0.0002 mg/kg/D) and in adults (8.57143 E-05 mg/kg/D). CDI of Zn found in highest concentration was in Linao for both children (0.0019 mg/kg/D) and adults (0.0017mg/kg/D) and lowest in children in Cogon (0.0016mg/L/D) while in adults, CDI was found the same for the three study sites (Agua dulce, Cogon and Punta). CDI of Ni was found highest in children in Agua dulce (0.0014 mg/kg/D) and for adults in Cogon and Punta (0.0002 mg/kg/D) while CDI for Ni was lowest both in children (0.0007 mg/kg/D) and adults (0.0001 mg/kg/D) respectively. CDI for Cd was found highest in Linao for both children (0.0011 mg/kg/D) and adults (0.00046mg/kg/D) respectively and lowest CDI was found in Agua dulce for both children and adults.

Chronic daily intake of all trace metals was found generally to be higher in children than in adults. As shown in table 3, average CDI of Pb in children was 0.014 mg/kg/D than in adults (0.0045 mg/kg/D). The rest of the CDI of trace metals (Cu, Zn, Ni, and Cd) likewise have values higher in children than the adults. This confirmed the results obtained in the studies of[11,14] where CDI of metals in children was generally higher in adults. This could be attributed to the lesser in take of water against body weight in children thus have higher CDI values of trace metals than in adults.

Hazard Quotient/THQ of Trace Metals

Hazard quotient (HQ) of trace metals was shown in table 4 where HQ of Pb is higher than 1 in the following descending order in the 4 study sites Punta > Cogon > Linao > Agua dulce for both children and adults. The data indicates that presence of Pb in water will have a significant non-carcinogenic effect to health of people both in children and in adults. This was also noted in Cd in children where the hazard quotient was greater than 1 with Cogon and Punta having the same HQ values of 1.73 while HQ in children is 2.133 (Linao) and 1.600 (Agua dulce) respectively. The rest of the trace metals has hazard quotient values of less than 1 which will not have a significant effect to health. However, the total hazard quotient (THQ) of all trace metals in each study site is higher than 1 both in children and adults. These results indicate that the combined presence of these trace metals would have non-carcinogenic effects to the health of the people whether children or adults. It is also observed that hazard quotient of the trace metals is higher in children than in adults implying that children are more at health risk than the adults. The result confirms the findings of the study of Miagari et al, 2017 where children are more at risks than the adults since the HQ for these metals was higher in children than the adults.

CONCLUSION

The artesian well waters in Ormoc City contain trace metals which are found to pose non-carcinogenic health effects both in children and adults. The total hazard quotient for the combined trace metals is greater than 1 with major contribution of lead and cadmium. Lead (Pb) contributes most to the health risks since the hazard quotient is greater than 1 in all areas studied. Cadmium has hazard quotient values greater than 1 only in children in all the areas studied. Children are found to be more at risks compared to the adults since the hazard quotient of the metals is higher in children than in adults. The results indicate attention and concern for the government of Ormoc City to look into the matter and ascertain further the findings of the study. They may set up investigation to identify where the sources of contamination are coming from and may develop policy to manage the entry of trace metals into the water sources.

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