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Drinking water quality and water risk assessment in the university of science and technology of southern Philippines

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ABSTRACT

The study evaluated the quality of drinking water sources in the University of Science and Technology of Southern Philippines (USTP). The main objective was to determine drinking water quality of different water sources in the university. Six sampling stations were identified which included faucets and water fountains in the different departments of the university, namely engineering, science center, education, and information technology. Physicochemical analyses included pH, temperature, dissolved oxygen (DO), total dissolved solids (TDS), alkalinity, lead (Pb), and cadmium (Cd). Sampling periods commenced on July to September 2014. Overall the university's drinking water sources were within allowable limits set by the Philippine National Standard for Drinking Water (PNSDW). However, Pb and Cd concentrations were beyond the permissible limits. Risk assessments for both metals showed potential contamination. The results of the study is preliminary by nature and further monitoring be implemented.

1. Introduction

The safety and accessibility of drinking-water are major concerns throughout the world. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards. The drinking water contaminants with chronic effects may include chemicals, radionuclides, and minerals (EHSO, 2014). Other threats to human health are also associated from exposure to heavy metals (lead (Pb) and cadmium (Cd)) through water, food, air, and land contaminations. Recent data indicate that adverse health effects of cadmium exposure may occur at lower exposure levels than previously anticipated, primarily in the form of kidney damage but possibly also bone effects and fractures (Jarup, 2003). Lead similarly can bring ill effects such as the delay development for children (US EPA, 2014), stillbirths, deformities, and brain damages (Hernberg, 2000). Thus, any sources of water contamination must be monitored to mitigate the risk.

Several cases of water contamination in the Philippines were identified mainly associated to coliform and heavy metals. Studies revealed contamination of groundwater resources in landfills (Galarpe and Parilla, 2014; Su, 2008), coliform in river water (Bensig et al., 2014) and coastal waters (Lago, 2013). Consequently, a need to monitor drinking water resources is timely to secure public health.

The study was conducted to determine the quality of the drinking water in the University of Science and Technology of Southern Philippines (USTP). Samples from different sources were evaluated in terms of its physicochemical properties and the possible Pb and Cd contamination. It was aimed to evaluate the quality of drinking water sources in the university by comparing it to available water quality standards and extrapolating potential

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risk estimates through available risk assessment methodologies.

2. Materials and methods

2.1. Study area

Six water samples were obtained from different locations and time in USTP. Samples were collected in the morning and afternoon from the different faucets and water fountains in Engineering, Science Center, Education and Information Technology departments. The samples collected were stored in a clean 100-mL glass bottles and transported to the laboratory. All analyses were carried in triplicates.

2.2. Physico-chemical analysis

Each parameter were measured using the different meters; pH (Model CD-221, Lutron Enterprises Inc., Taipei, Taiwan), DO meter (Model DO-5519, Lutron Enterpises Inc., Taipei, Taiwan), Electric Conductivity (Model CD-4322, Lutron Enterpises Inc., Taipei, Taiwan), Turbidity (Model TU-2016, Lutron Enterpises Inc., Taipei, Taiwan), Hand-held Refractometer (Model Master S-28M, Atago Co., LTD, Japan). Alkalinity was carried out by a titrimetric method (APHA, 1998).

2.3. Heavy metals analysis

Determination of the concentrations of lead and cadmium in each water sample was done using Analytik jena novAA 300, Flame - Atomic Absorption Spectroscopy (AAS), from the Environmental Management Bureau Laboratory of DENR Region X. Sampling was done for two months, from August to September 2014 in a composite sampling. Samples were digested using START D Microwave Digestion System.

2.4. Data analysis

All results were expressed in terms of mean and standard deviation. Results were compared to available reference standards which include Philippine National Standard for Drinking Water of 2007, US Environmental Protection Agency of 2012 (PNSDW, 2007; US EPA, 2012), and the World Health Organization (WHO) drinking water quality guidelines. Data were further processed to roughly estimate risk analysis based on available standards. The Risk Quotient (RQ) was calculated as the ratio between the determined concentration and the available standard for pH and TDS. The calculated RQ of >1 may indicate potential environmental risk of the studied parameter (Galarpe and Parilla, 2014; WHO, 2008). Risk analysis for Pb and Cd were carried using the following equations (GEF/UNDP/IMO, 2004; Naveedullah et al., 2014):

$$Exp_{derm} = C\,water \times IR \times EF \times ED / BW \times AT$$

$$Exp_{derm} = C\,water \times SA \times Kp \times ET \times EF \times ED \times CF / BW \times AT$$

$$CDI = C\,water \times DI \times BW$$

$$CR\,ing = Exp\,ing / SF\,ing$$

where Exp $_{ing}$ is the exposure dose through ingestion of water; Exp $_{derm}$ is the exposure dose through dermal absorption; CDI is the chronic daily intake; and CR $_{ing}$ is the carcinogenic risk via ingestion route. Other variables are given in Table 1 (GEF/UNDP/IMO, 2004; Naveedullah et al., 2014).

Table 1: Parameters for estimating environmental risk assessment in this study

Exposure factors	Unit	Value
Concentration of Pb and Cd in the water sample (C water)	μg/L	---
Water ingestion rate (IR)	L/day	2.2
Exposure frequency(EF)	days/year	360
Exposure duration (ED)	Year	30
Average body weight (BW)	Kg	70
Averaging time (AT)	Days	10,950
Exposed skin area (SA)	cm^2	28,000
Exposure time (ET)	h/day	0.6
Unit conversion factor (CF)	L/cm^3	0.001
Dermal permeability coefficient (Kp) for Cd	cm/h	0.001
Dermal permeability coefficient (Kp) for Pb	cm/h	0.004
Average daily intake rate (DI)	L/day	2.2
Carcinogenic slope factor via ingestion (SF ing) for Cd	$\mu g/g/d^{-1}$	6.1 x 10 ^{3}
Carcinogenic slope factor via ingestion (SF ing) for Pb	$\mu g/g/d^{-1}$	8.5

3. Results and discussion

3.1. Physico-chemical analyses

The physical properties evaluated for drinking water sources in USTP included temperature, pH and TDS. The chemical properties assessed were DO, alkalinity, salinity, and turbidity. Overall, temperature for all studied stations ranged from 26˚C to 34˚C (Fig. 1). The lowest temperature was detected in SC drinking water fountain while the highest temperature obtained was from IT faucet. On the other hand four of the studied stations showed slightly alkaline pH (ranged from 7.7 to 7.9) whereas the two other stations were more alkaline (pH ranged from 8.1 to 8.5) (Fig. 2). Water source from the engineering faucet had the highest pH measured. Overall, all studied stations had alkaline pH typical in communal drinking water sources (Koki et al., 2015). Similarly results of TDS analysis in all stations were within the maximum acceptable level is 500mg/L in drinking water (Fig. 3). Determined alkalinity ranged from 259 to 292 mg L^{-1} (Fig. 4). The engineering faucet water source exhibited high alkalinity (325 mg L^{-1}) on August, 2014. The DO levels for the first five studied stations (faucets) ranged from 6.4 to 7.7 mg L^{-1}(Fig. 5). The drinking fountain in the science center had the highest DO level (7.9 -8.6 mg L^{-1}). All stations were within the permissible limit for TDS 300 mg L^{-1} except for station 4 (Fig. 5). There was no turbidity for the water samples in USTP. No colloidal particles were also seen. All the water samples had no salinity.

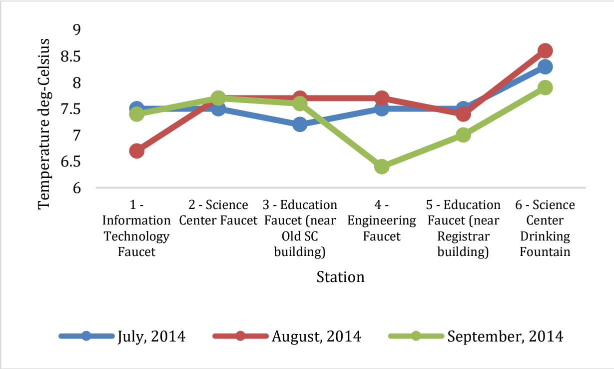

Fig. 1: Temperature levels of the different drinking water sources in USTP

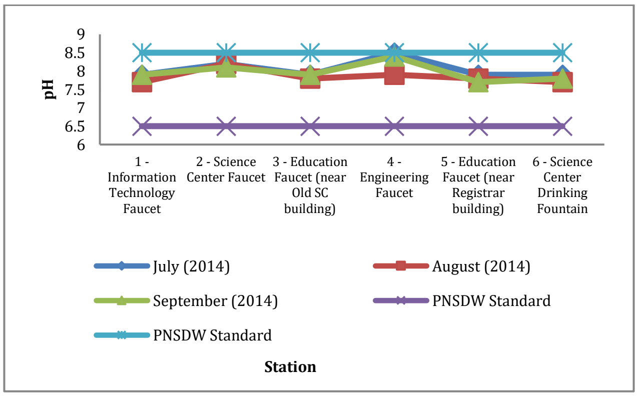

Fig. 2: pH levels of the different drinking water sources in USTP

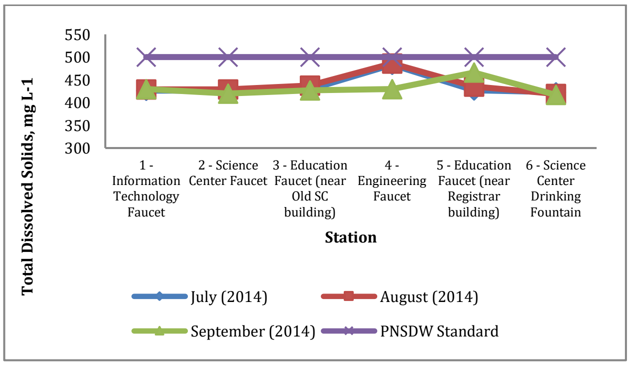

Fig. 3: TDS levels of the different drinking water sources in USTP

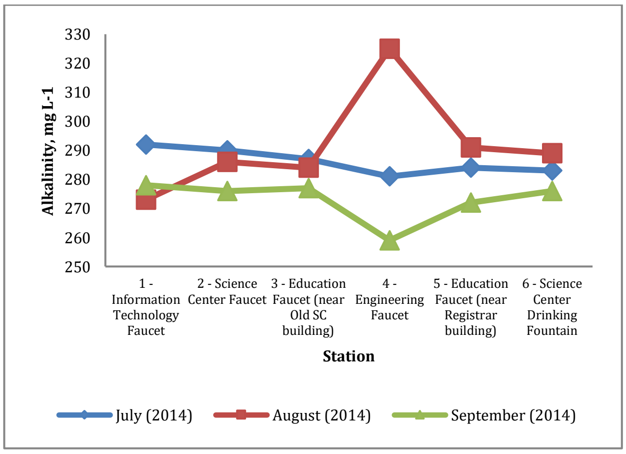

Fig. 4: Alkalinity levels of the different drinking water sources in USTP

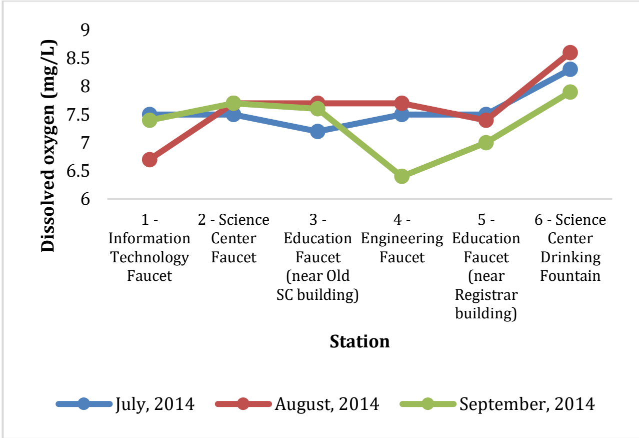

Fig. 5: Dissolved Oxygen levels of the different drinking water sources in USTP

3.2. Heavy metals

Fig. 6 presents the summary of results for total Pb. The sample from the sceicne center faucet had the highest Pb concentration (0.2865 ppm) whereas the lowest concentration (0.1864 ppm) was from SC drinking fountain. Overall, regardless of studied stations (ranged from 0.1710-0.2930 ppm) all exceeded the limits set by PNSDW and USEPA. The Cd concentrations were also tested for all studied stations (Fig. 7). The determined Cd levels ranged from 0.1052 to 0.1806 ppm. Highest Cd concentration (0.1560 ppm) was recorded in the science center faucet whereas the sample from the IT faucet had the lowest Cd concentration (0.1254 ppm). The high levels of Pb and Cb can be associated to impurity or leaching of zinc galvanized pipes, lead fitting-solder pipes, cadmium-containing solders in fittings, water heaters, water coolers, and taps (Tonog and Poblete, 2015).

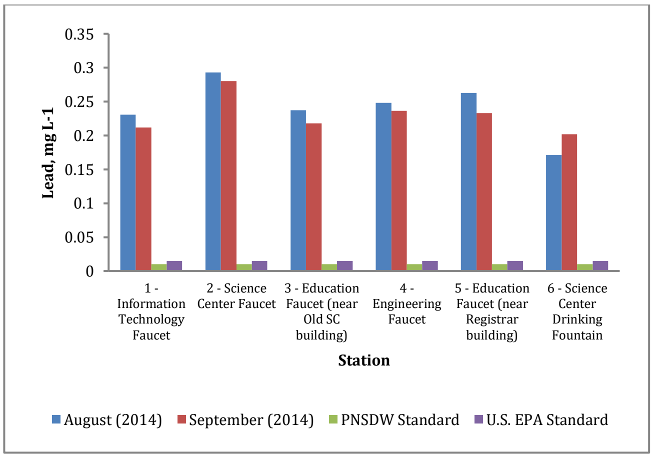

Fig. 6: Levels of Lead in different drinking water sources in USTP

3.3. Risk assessment

The RQ analysis for pH and TDS were based from the study of Galarpe and Parilla (2014). Two standards were used PNSDW and WHO. The RQ for both pH and TDS were approximately 1 (Table 2) indicating less to absence of risk in the water quality parameter. On the other hand, risk analysis of Pb and Cd were calculated based from the study of (GEF/UNDP/IMO, 2004; Naveedullah et al., 2014). Overall, Exp $_{ing}$ was found greater than Exp $_{derm}$ with Pb being higher than Cd. The CDI for both metals were sparingly greater (mean values Pb 7.4329 and Cd 4.422). Notably, the CR $_{ing}$ of both metals were beyond the tolerable or acceptable range which was 1.0 x10 $^{-6}$ to 1.0 x 10 $^{-4}$ (GEF/UNDP/IMO, 2004). Thus, their is higher risk of developing cancer owing to exposure of a potential carcinogen in the water sample evidenced by elevated CR $_{ing}$ (Table 3).

4. Conclusion

All the results for the physico-chemical analyses of the different drinking water sources in USTP conforms to PNSDW, WHO, and US EPA water quality standards for pH and TDS. Other analyses do not show potential risk or contamination. However, results for Pb and Cd indicated contamination of the water sources also evidenced by high risk assessments of Exp $_{ing}$, Exp $_{derm}$, CR $_{ing}$, and CDI. Both Cd and Pb failed to meet the water quality standards. Overall, the results of the study were inconclusive owing to limited analyses considered in this study. Further monitoring is recommended.

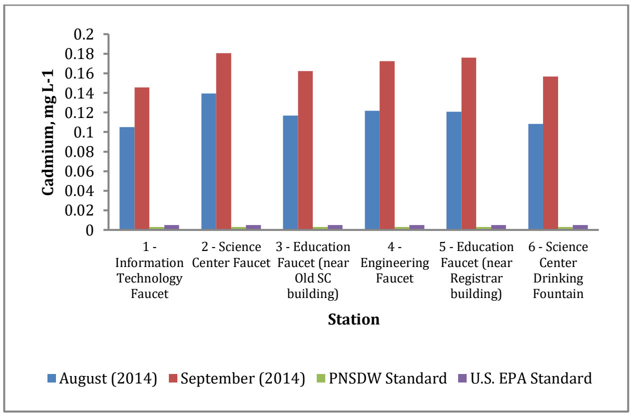

Fig. 7: Levels of Cadmium in different drinking water sources in USTP

Table 2: Risk quotient of selected physicochemical analyses

Parameters	This study	Risk Analysis			
		PNSDW	RQ	WHO	RQ
pH	7.7-8.5	6.5-8.5	1.1-1	7.0-8.5	1.1-1
TDS (mg/L)	420-485	500	0.84-0.97	500	0.84-0.97

Table 3: Risk analysis of the determined metals

Observation	Metal concentration (μg/L)	Risk Analysis			
	Pb	Exp $_{ing}$	Exp $_{derm}$	CDI	CR $_{ing}$
Max.	286.5	8.8809	0.2713	9.0043	0.0015
Min.	186.5	5.7811	0.1766	5.8614	0.0009
Mean	236.5	7.331	0.2239	7.4329	0.0012
SD	70.7107	2.1919	0.067	2.2223	0.0004
	Cd				
Max.	156	4.8357	0.0369	4.9029	0.5689
Min.	125.4	3.8872	0.0297	3.9411	0.4573
Mean	140.7	4.3614	0.0333	4.422	0.5131
SD	21.6375	0.6707	0.0051	0.68	0.0789

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