Heavy Metal and Coliform Contamination in the Tap Water of Public Schools of Muntinlupa City, Philippines

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Abstract: ***Water in the public schools is essential as it is the primary resource for cleaning, plant maintenance and in some cases, for drinking. If unsafe and unclean water is consumed, it can lead to many diseases that can compromise the health of students and school personnel. Thus, monitoring water resources within the school compound should be of high priority. The study conducted physicochemical, heavy metal and coliform contamination assessment among the tap water of nine public schools of Muntinlupa City. Among the physicochemical parameters, dissolved oxygen across all schools is detected to be not normal. Cadmium content of all tap water among all schools has exceeded the standard limit and has shown concerning level of hazard quotient. Two out nine schools showed bacterial coliform contamination. Schools with this contamination are of great risks not only for students and personnel that utilizes tap water within the school compound.***

Keywords: Water Microbial Contamination, Ecotoxicology, Environmental Health, Public Health Biology, School Health

1. Introduction

Sustainable water resource in the public schools play a vital role in the educational system as it is used to prepare food and to maintain proper sanitation and hygiene inside the campuses, especially in hand washing stations and toiletries. It is also used in home economics, livelihood subjects and laboratory experiments. The school demography is composed mostly of children and it is observed that many students prefer drinking tap water than bottled waters. The unpopularity of the use of bottled water in public schools is due to its high price as compared to free tap water.

Generally, tap water is a safe water since it undergoes conventional treatment that includes coagulation, sedimentation, filtration and disinfection. However, it can also be a source of chemical and microbial contamination [1] [2]. As reported by [3], poor water sanitation among low and medium class countries greatly contributes to about 10% of child mortality and gastrointestinal disease causation. A large portion of this event is caused by fecal - oral pathogens and chemical contaminations that can travel from soil to water and vice versa [4]. Contaminants like coliforms are pathogens that came from the feces of warm - blooded animals and its presence in the water can be caused by some breakage in the water pipes and water sanitation systems, entering the body through ingestion of the contaminated water [5]. On the other hand, heavy metal contents in water may enter the body through dermal route and can be a neurotoxin that can cause child behavioural problems and low physical and mental capacity [6] [7] [8].

It is undeniable that water in the schools is essential and is used in almost every activity of the school campuses, hence, the development and monitoring of programs regarding environmental health services and water sanitation may help promote not only the health stability of the students but also their school performance [9]. This can be possible if monitoring and evaluation of the current bio - physicochemical status of tap water in schools are done.

The monitoring of these contaminants with regard to the physicochemical condition of water can be expensive, time consuming and complex, but this can prevent contamination that can affect water sources [10]. Although it is required for the schools to have treated water, regrettably, not all of the public schools have access to consistent bio-physicochemical monitoring of tap water. Fiscal and human resources are just two of the many factors why monitoring among public school campuses is not as consistent, and so this monitoring activity is done seldom times in a school.

This study generally aims to assess the quality of the tap waters in the public schools in Muntinlupa City, specifically the (1) physicochemical characteristics, (2) heavy metal contents and its hazard quotient (HQ) and the (3) biological (coliform) contamination. Through this assessment, administrators can establish the fundamental plan on improving water safety and reducing the risks of water contamination in the school campuses.

2. Methodology

Research Parameters

The study utilized descriptive – evaluative approach that appraised the status of the physicochemical characteristics, biological and heavy metal contaminations of the tap water in the research sites. It evaluated the biological components which were the *Coliform* and *Escherichia coliform* count, while the physicochemical characteristics included

Dissolved Oxygen, Salinity, Total Dissolved Solids and Water pH. Cadmium, Mercury, Chromium and Lead were the heavy metals measured in the water samples. The correlation of the physicochemical characteristics to the biological and heavy metal contaminations was then analysed.

Water Sample Collection

The location of the hand washing area varies in each school. There are handwashing areas located near the main gate, while others are beside the garden area and another is at the back of the school covered court. Samples were collected from the main hand washing areas of each school as per recommended by the office of the school principal. Only one hand washing area was recommended per school. The faucet was opened for five minutes so the water will keep flowing. One liter of water was collected from each school using new and sterilised bottle. Water samples were stored in a cooler maintaining 2ºC to 4ºC of temperature. All samples were analysed in triplicates.

Physicochemical Analysis of Tap Water

All the water samples collected from the schools were brought to the De La Salle University – Dasmariñas, Biological Science Graduate School Laboratory. The temperature of the water was measured in the collection site, the rest of the parameters, such as the pH, Dissolved Oxygen and Total Dissolved Solids were measured using the monitoring probes in the DLSUD CSCSGS Biological Science Laboratory. The device consists of a sensitive probe and reader to identify the values needed for water characteristics. The reading was done three times per sample to secure validity [11].

Heavy Metal Analysis of Tap Water

The US EPA vigorous digestion method [12] was adopted for water sample acid digestion. From each sampling bottle per school, 50mL of tap water were taken and placed in their respective beakers, where 10 mL of concentrated nitric acid were added. Solutions were then boiled until only 20mL of it remained. After cooling, 5mL of concentrated nitric acid was added and the heating was continued until 20 mL of solution remained in the beaker. The beakers were cooled again and 5mL of concentrated hydrochloric acid was added and rewarmed until 20 mL of the solution remained. As the heating continues, 5mL of 5M of sodium hydroxide was added. The solutions were filtered through a whattman filter paper. Demineralised water was added until the solution reached 50mL. The solution was then subjected to Atomic Absorption Spectrometer (AAS) machine at the De La Salle University – Dasmariñas, Graduate School Chemistry Laboratory to test for the presence of Cadmium, Lead and Chromium. Another 1L of Tap Water Samples were collected for mercury processing and testing to InterTek™ Alabang.

Coliform and Escherichia coliform Count and Identification

The 3M™ Petrifilm High (95%) Sensitivity for *Escherichia coliform* and *Coliform* Count Plates were used for the water coliform count. One milliliter of water sample was inoculated in each of the petrifilms. Five petrifilms per school were prepared for replication. Plates were incubated under room temperature for 48 hrs. [13] [14] [15]. Plates were then checked for coliform count and coliform culture.

Data Gathering and Analysis

Data on the physicochemical characteristics of the water and heavy metal contamination were expressed in mean. Results of the measured temperature, dissolved oxygen, pH and total dissolved solids, as well as the Mercury, Cadmium, Lead and Chromium were considered for water quality assessment. All the values for temperature, dissolved oxygen, pH and total dissolved solids, as well as the measured heavy metals (mercury, cadmium, chromium and lead) were compared to the set standard of DENR Administrative Order no.2016 - 08 [16].

The Hazard Quotient (HQ) (Fig.1) of dissolved oxygen, temperature, pH and heavy metals (mercury, cadmium, chromium and lead) were computed as the ratio between the measured values compared to the Reference Concentration. The farther the computed HQ value from 1.0, the greater the environmental risks [17] [18].

$$HQ = \frac{\text{Exposure or Measured Concentration}}{\text{Reference Concentration}}$$

Figure 1: Hazard Quotient Formula

The biological data were expressed in total number of coliforms forming unit (CFU) per school. Pink coliforms were counted as coliform count while the blue - green coliforms are counted as *Escherichia coli*. Coliform genera were confirmed using biochemical tests.

3. Results and Discussion

Physicochemical Characteristics of Tap Water

The physicochemical parameters of water quality included temperature, dissolved oxygen (DO), pH and total dissolved solids (TDS) (Table 1).

Table 1: Physicochemical characteristics of the tap water from participating schools

School	Temp. (ºC)	DO (mg/L)	TDS (mg/L)	pH	Conductivity (uS)	Salinity (ppt)
Acceptability values set by DENR	26-30	5	<500 mg/mL	6.5-8.5	< 200 uS	< 3.5 ppt
School A	29	9.09	14.6	8.27	17.50	0.01
School B	28	7.62	311.9	7.29	445.10	0.01
School C	30	6.31	1014	7.32	1.18	0.8
School D	31	6.85	263.1	7.46	366.40	0.2
School E	30	6.74	163.1	7.59	1.92	0.1
School F	29	9.59	343.6	7.49	375.30	0.2
School G	31	7.18	317.6	7.14	340.30	0.2
School H	28	8.33	166.2	7.53	356.10	0.1
School I	29	7.93	871.0	7.50	0.95	0.7

The highlighted (blue) values mean it has exceeded the acceptability limits for drinking water.

The temperature of water from schools measured from 28ºC to 31ºC, with School D and School G slightly exceeded the standard limit for temperature. School C and School I exceeded the standard limit for total dissolved solids. The water pH among the schools is within the normal range, but the dissolved oxygen for all the school has exceeded the set limit. The high level of dissolved oxygen in the water is cause by rapid aeration of water due to its strong movement. The high level of dissolved oxygen does not directly affect human health, but it can facilitate the release of heavy metal and other inorganic materials needed in water making it more basic and susceptible to microbial contaminations. The increased TDS in water can be facilitated by its source and how it is treated. Study shows that water treatment process is a high contributor of dissolved solids in the water sources [19] [20] [21]. School I and School Cwater resources may be affected by the contaminants of Laguna de Bay due to their proximity, whereas all the other schools use underground or river water. This could have facilitated the difference of TDS among schools. As reported by the LLDA (2019) [22], the status of water quality in Laguna de Bay is currently classified as class C, which means it is not as safe for contact nor for drinking. Hence, longer treatment process is much needed before it can be used as tap water.

The high concentration of total dissolved solids, as in the case of School D and School I – could lead to kidney and heart diseases of contaminated individuals [23]. In addition, water that may contain high level of dissolved solids may experience constipation and other inconvenient gastrointestinal reactions [24].

Heavy Metal Contamination of Tap Water

Table 2: Presence of heavy metals in the tap water from participating schools

School	Cadmium (ppm) *	Mercury (ppm) *	Chromium (ppm) *	Lead (ppm) *
Acceptability values set by DENR	<0.003	<0.001	<0.01	<0.01
School A	0.3487	< 0.001	< 0.001	< 0.001
School B	0.6150	< 0.001	< 0.001	< 0.001
School C	0.9575	< 0.001	< 0.001	< 0.001
School D	0.1965	< 0.001	< 0.001	< 0.001
School E	1.2619	< 0.001	< 0.001	< 0.001
School F	0.2345	< 0.001	< 0.001	< 0.001
School G	0.9575	< 0.001	< 0.001	< 0.001
School H	0.8814	< 0.001	< 0.001	< 0.001
School I	0.5009	< 0.001	< 0.001	< 0.001

*Highlighted (blue) values exceeded the acceptable limit. *ppm=parts per million.*

Cadmium (Cd) is present in all the water samples across different schools of Muntinlupa City (Table 2). School E has the highest mean cadmium contamination and School F with the lowest. The amount of cadmium contamination in all water samples are beyond the limit set by the DENR for drinking water. The rest of the metals, mercury (Hg), chromium (Cr) and lead (Pb) are below the detectable limit (bdl).

The hazard quotient for the levels of cadmium is greater than one (Table 3). This means that schools are at risks of cadmium contamination, coming from the water.

Table 3: Water quality parameters with significant result in the computation of Hazard Quotient (HQ) in the public schools of Muntinlupa City

School	Cadmium (ppm) *	Cadmium
Ideal Result	**<0.003**	**<1.0**
School A	0.3487	69.74
School B	0.6150	123.00
School C	0.9575	191.50
School D	0.1965	39.30
School E	1.2619	252.38
School F	0.2345	46.90
School G	0.9575	191.50
School H	0.8814	176.28
School I	0.5009	100.18

*Highlighted (blue) values exceeded the set standards. *ppm=parts per million.*

The traces of cadmium could be associated to the result of impurity of zinc in galvanized pipes where tap water runs through, paint pigments, electrical supplies and ceramic products that are found inside and outside the school environment. In addition, all schools have on - going building construction that uses heavy machineries and materials like vehicle batteries, electrical supplies and ceramic tools that could be source of cadmium. There is a positive correlation between water pH and D. O., while negative correlation among the following is observed: D. O. and salinity, D. O. and TDS, D. O. and temperature, salinity and conductivity, TDS and pH, TDS and conductivity, pH and conductivity. It is known that water has less dissolved oxygen when it is warmer; furthermore, the solubility of the oxygen also decreases when the salinity and the total dissolved solids increases. The high level of conductivity with regards to its relationship to salinity, TDS and pH indicates the susceptibility of the water samples from heavy metal contamination. The total dissolved solids in the water samples may be composed mainly of heavy metals because of its observed relationship to water pH. The negative correlation between dissolved oxygen and cadmium is due to the formation of cadmium oxide leading to the increase of water pH. This makes the water basic, pointing out the positive correlation between dissolved oxygen and water pH. The presence of cadmium in the water supply of all these schools is also alarming for the users. As cited by Burke et al. [25], cadmium is toxic even in extremely low levels, it accumulates especially in the kidney and is a potent causeof cancer and cardiovascular diseases; cause cough, headaches, and nausea followed by vomiting in low doseintakes; accumulates in the liver andkidneys in high doses; and replaces calcium in bones which culminates in painful bone disorders, renal failure, and implications in human hypertension.

Cadmium could stay in the environment for months or even years – unless otherwise treated and can also enter the human body by dermal entry due to direct contact [26] [27]. Cadmium is carcinogenic in nature although its teratogenicity has not yet been proven [28]. Chronic cadmium accumulation among children is associated with nephrotoxicity leading to kidney failure and osteoporosis as they age [29]. Long term cadmium exposure could also lead to the disruption of the immune system through the cell degeneration within the thymus. Endocrine system can also be also affected through hypothalamus of the children, making the metabolic process unbalanced for their bodies [30] [31].

Coliform Contamination in Tap Water

The two schools showed beyond the limits for coliform count that the DENR has set, which is 0.0 CFU per 100mL of water sample. The schools are serviced by the national water treatment provider; however, School C principal shared that when the sewage system of their school was built, it was connected to the pipes where untreated waters are flowing, this is making all the treated waters contaminated. This is also one of the schools where some students were observed to drink water from the hand washing area. In the case of School F, not all faucets are connected to the treated water lines, some faucets are connected to the school water district tank that yields ground water and therefore, it is also untreated.

The presence of coliform in water from the hand washing areas of the School C and School F are at risk of infection and diarrheal and other gastrointestinal diseases [32] [33]. Microbial contaminations in waters are prevalent in tap environmental waters and can infect humans via ingestion and dermal entry [34]. The occurrence of diseases such as urinary tract infection, diarrhea and other gastrointestinal tract infections [3] [5] is possible in these two public schools, due to the confirmed contamination in the water sources, especially that some students are observed to be drinking from contaminated the tap. The presence of *E. coli* in their water system is also health threatening for all the water consumers in these schools. Confirmation of *E. coli* in a water system indicates recent fecal contamination, which may pose an immediate health risk to anyone who consumes the water [35]. Gruber et al. (2014) [36] found that studies using *Escherichia coli* (Ec) as an indicator of household drinking water quality reported consistent effect estimates, that when pooled suggested a significant association with increased diarrheal illness. Even low levels of contact with contaminated water in rivers [36] or beaches [37] are significant and can result in outbreak of gastroenteritis.

Utilization of massive drug administration may be used but infection may reoccur; although, utilizing the Wa. S. H. (Water Sanitation and Hygiene in Schools) program of UN, can reduce infection risk from waters [38]. This program is also adapted in the public schools as WinS (WASH in Schools).

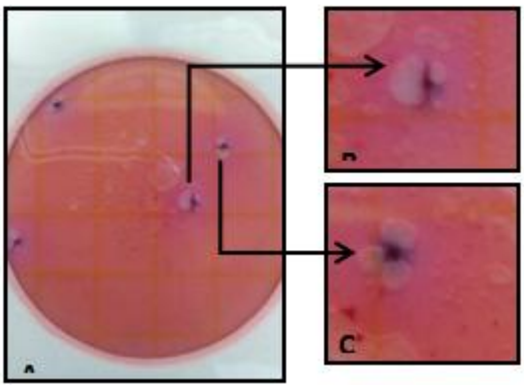

Figure 2: (A) Petrifilm that contains both pink and bluish colonies from School C. (B) Pink colonies confirmed coliform counts C. Bluish colonies are confirmed *E. coli* counts

The coliform contamination in the tap water of the schools was observed through petrifilm (Fig.2). School C and School F are the only two areas that yielded coliform contamination (Table 4).

Table 4: Coliform Count data from the tap water samples

School	*Total Coliform Count*
Acceptability values set by DENR	**0**
School A	0
School B	0
School C	4
School D	0
School E	0
School F	6
School G	0
School H	0
School I	0

Highlighted (blue) values exceeded the acceptablele limit for the drinking water.

4. Conclusion

The total dissolved solids for Muntinlupa Science High School also exceeded the set standard by DENR, while the coliform count of School F is also positive with coliform contamination. School C have the highest health risks among the participating schools because of the presence of cadmium, coliform and high total dissolved solids. These contaminations could also be facilitated due to high dissolved oxygen level of water if proper interventions will not be given. These values coincide with the computed hazard quotient, which means that water poses danger to health and to the environment. Water supply in School C and School G is not safe for drinking or consumption for brushing teeth and washing directly consumed food like fruits. This means that water quality in these schools is not in good condition and was fair enough for consumption for majority of the public schools but became limited due to heavy metal and microbial contamination.

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