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The Heavy Metals and Microbiological Profiles of the Major Drinking Water Supply System of Cagayan de Oro City, Philippines

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Abstract

This study characterized Cagayan de Oro's major water supply system. Copper, chromium, lead, cobalt, manganese, nickel, and cadmium concentrations were measured in both raw and treated water along with two microbiological parameters (total coliform and *Escherichia coli*). The samples were composed of raw water from the Bubunawan River in Baungon, Bukidnon and processed water from selected households in Carmen, Cagayan de Oro City. The atomic absorption spectroscopy (AAS) found that most selected metals were present in raw and processed water at varying concentrations. The raw water was found to contain Cu, Cr, Pb, Mn, and Cd, while the processed water contained Cu, Cr, Pb, and Cd, with no Mn detected. The concentrations of these metals were within the PNSDW, USEPA, and WHO maximum allowable limits, indicating that the public is safe from the effects of these heavy metals. Too numerous to count total coliform bacteria indicated that the raw water sample was significantly polluted with coliform bacteria. This signifies that pathogen are present in the water supply, rendering it unsafe for human consumption unless regularly disinfected. On the other hand, the disinfected raw water or processed water had less than 1 total coliform count and no *E. coli*. The treated water met the PNSDW and USEPA microbiological criteria. In conclusion, the treatment process applied to Cagayan de Oro City's major water supply system is effective in producing drinking water free of harmful heavy metals and microorganisms.

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Introduction

Natural events—flood, earthquake, ozone depletion, and climate change—affect the water quality in terms of physico-chemical parameters, as do anthropogenic activities—population explosion and rapid economic growth. Ozone depletion and climate change are two of the world's most pressing environmental issues today. These issues have the potential to exacerbate the already-scarce availability of freshwater. Ozone depletion and climate change are related phenomena, and their interaction accentuates their impact (Soh *et al.*, 2008). Precipitation, surface runoff, solar UV radiation, temperatures, and evaporation are all projected to alter as a result of ozone depletion and climate change (Shindell *et al.*, 1998; Voss *et al.*, 2002). They have an effect on the biogeochemical cycles and aquatic ecosystems of lakes and rivers, alter the character of naturally occurring organic matter and hence have the potential to adversely affect the quality, quantity, and treatability of water resources (Soh *et al.*, 2008).

As with natural events, anthropogenic activities represent a serious threat to water resources. Urbanization is cited as a major source of contamination in Asian countries' surface water bodies (Liyanage *et al.*, 2017). A study of the spatial correlation between urbanization and water quality parameters from a regional perspective revealed a positive correlation between human activities and river water quality degradation (Zhao *et al.*, 2013). Furthermore, it has been demonstrated that the population growth rate within a watershed area is positively correlated with the biochemical oxygen demand (BOD), dissolved oxygen (DO), and total coliform in the river (Liyanage *et al.*, 2017). It is a major concern for any country right now to make sure that its economic growth does not hurt the environment or the well-being of its people.

The Cagayan de Oro Water District (COWD), a government-owned and controlled corporation (GOCC), manages and operates the Cagayan de Oro City's public water system. The water district supervises and controls 28 producing wells that supply potable drinking water to its consumers, although the water district receives the bulk of its water from a private supplier. The private supplier draws raw water from the Bubunawan River at Pualas, Baungon, Bukidnon. The company provides 150,000 m^3 of potable water per day to the COWD. Water treatment involves the use of coagulants, flocculants, and chlorine. Coagulation-flocculation is a chemical water treatment approach that is frequently employed prior to sedimentation and filtration in order to enhance the effectiveness of a treatment process to remove particles. Coagulation pertains to a chemical reaction that neutralizes charges and produces a gelatinous mass capable of trapping particles producing even bigger particles. Flocculation, on the other hand, involves gentle stirring or agitation of generated particles to encourage them to aggregate into large enough masses. The two-process allows for the rapid settling or filtration of impurities. Finally, chlorination is used to disinfect water of pathogenic microorganisms.

Water that is safe and easily available is critical for public health, regardless of whether it is utilized for drinking, domestic uses, food production, or recreation. The provision of safe drinking water does not end with the elimination of waterborne pathogens; it also includes minimizing individuals' exposure to chemical and physical hazards that can be consumed through contaminated drinking water.

Thus, officials at the national and municipal levels, as well as administrators of public water systems, must adhere to stringent laws and undertake continuous monitoring of water supply systems to safeguard public health. There are numerous water quality parameters, but some of the most significant are pH, alkalinity, salinity, conductivity, total dissolved solids (TDS), total suspended solids (TSS), turbidity, and total organic carbon (TOC). Another area of concern is the presence and concentrations of hazardous heavy metals. Thus, this research examined the quality of the raw and processed waters from a major drinking water supply system of the Cagayan de Oro Water District (COWD). Water samples were examined for selected heavy metals and microbiological characteristics

Materials and methods

Determination of heavy metals

There were seven metals included in this research: copper, chromium, lead, cobalt, manganese, nickel, and cadmium. To analyze these metals, flame atomic absorption spectroscopy (AAS) was employed using Perkin Elmer AAnalyst 200. Taking all precautions to prevent contamination, an amount of 300 ml of the water sample was concentrated by heating and allowing the water to evaporate until the sample volume dropped to approximately 5 to 10 ml. This was then followed by a series of digestion procedures. First was the digestion with 20 ml of concentrated sulfuric acid for 90 to 120 minutes. The second step was the addition of 2 ml of hydrogen peroxide, and the digestion was completed after 30 minutes. The solution was cooled down to room temperature, filtered, and diluted to 100 ml. The solution was run in the atomic absorption spectrophotometer using the appropriate hollow cathode lamp to determine the metal concentration. The concentration of each metal in the sample was based on the standard calibration curve obtained by running three standard solutions of known metal concentrations in the AAS.

Microbiological analyses (Total coliform and E. coli)

The membrane filtration method was used to determine the total coliform and the presence of *E. coli* in the samples. In this method, samples were vacuum filtered through a membrane filter inside a microbiologically sterile room. Using a pair of sterile forceps, the membrane filter was transferred to an EMB agar media in a Petri dish.

Then the petri dish in inverted position was incubated at 35±5˚C for 24 hours. After the incubation period, the membrane filter was examined for colony growth.

Results and discussion

Concentrations of selected heavy metals

Table 1 summarizes the results for the 7 metals selected. Among the seven metals, cobalt and nickel were not detected in either the raw water or processed drinking water samples, while manganese was not detected in the processed water. In other words, the raw water contains Cu, Cr, Pb, Mn, and Cd, while the processed water contains Cu, Cr, Pb, and Cd.

Table 1. Heavy metal content of the raw water and the processed drinking water.

Heavy Metal	Water Source [mean, mg/L (std deviation)]		Standard Limits (mg/L)		
	Raw	Processed	PNSDW[1]	USEPA[2]	WHO[3]
Cu	0.006 (0.004)	0.005 (0.003)	1.0	1.0	2.0
Cr	0.002 (0.004)	0.001 (0.002)	0.05	0.1	0.05
Pb	0.008 (0.013)	0.020 (0.035)	0.01	0.015	0.01
Co	not detected	not detected			
Mn	0.020 (0.011)	not detected	0.4		Not of health concern at levels causing acceptability problems in drinking-water
Ni	not detected	not detected	0.07		
Cd	0.002 (0.003)	0.002 (0.002)	0.003	0.005	0.003

[1]Philippine National Standards for Drinking Water (2017)

[2]United States Environmental Protection Agency – Water Standards and Health Advisories (2012)

[3]World Health Organization – Guidelines for Drinking Water Quality (2011).

As a water pollutant, heavy metals pose a major threat to human health. This is because their concentrations are linked to a variety of different diseases. For example, excessive copper exposure has been linked to liver and kidney damage, anemia, immunotoxicity, and developmental toxicity (Alberta Environmental Protection, 2006). Exposure to chromium, particularly Cr(VI), may have a deleterious effect on the respiratory tract, as well as damage to the liver, kidney, gastrointestinal, and immune systems, as well as the blood (USEPA, 2000). By inhalation exposure, the USEPA classifies chromium (VI) as a Group A recognized human carcinogen. Lead poisoning can cause severe damage to the brain and kidneys and eventually death. Lead exposure at high levels during pregnancy may result in miscarriage. In men, prolonged exposure can wreak havoc on the organs responsible for sperm production (Martin *et al.*, 2009). Acute inhalation exposure to high concentrations of cadmium in humans may cause lung irritation, including bronchial and pulmonary inflammation (USEPA, 2000; Martin *et al.*, 2009). In the case of manganese, detrimental health effects might occur as a result of insufficient intake (considering manganese is an important mineral) or excessive exposure (WHO, 2011). Exposure to extremely high levels of manganese dust or fumes results in irreversible adverse neurological effects such as weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless "mask-like" facial expression, and slow, clumsy movement of the limbs (Canavan *et al.*, 1934; Cook *et al.*, 1974; Roels *et al.*, 1999; ATSDR, 2000).

Table 2. Independent sample t-test results: raw water versus processed water in terms of the heavy metal content.

Heavy Metal	t	p
Copper, Cu	0.635	0.534
Chromium, Cr	1.119	0.283
Lead, Pb	-1.019	0.336
Cadmium, Cd	0.381	0.709

With the exception of Mn, both raw and processed water showed no significant difference in terms of heavy metal content, as revealed by the t-test results shown in Table 2. Furthermore, the data revealed remarkably interesting findings: the concentrations of the heavy metals in the two water sources were within the maximum allowable limits of PNSDW, USEPA, and WHO (Table 3 and Table 4). This is indicative that the river water, especially, has not been contaminated due to earth-moving activities like mining or dumping of wastes with heavy metal content. Thus, its choice as the raw water source has been a good one on this basis.

What happened to Mn after the water treatment—why its concentration went down below the detection limit of the analysis method—is something that needs further scrutiny. But there is the possibility that the metal could have been significantly eliminated during the coagulation and flocculation stage.

Table 3. One-sample t-test results: heavy metal content of the raw water against the standard values.

Heavy Metal	Standards	t	P
Copper, Cu	PNSDW[1]	-818.727	1.000
	USEPA[2]	-818.727	1.000
	WHO[3]	-1642.028	1.000
Chromium, Cr	PNSDW[1]	-37.430	1.000
	USEPA[2]	-76.785	1.000
	WHO[3]	-37.430	1.000
Lead, Pb	PNSDW[1]	-0.455	0.669
	USEPA[2]	-1.591	0.925
	WHO[3]	-0.455	0.669
Cadmium	PNSDW[1]	-1.155	0.859
	USEPA[2]	-3.464	0.996
	WHO[3]	-1.155	0.859

[1]Philippine National Standards for Drinking Water (2017)

[2]United States Environmental Protection Agency – Water Standards and Health Advisories (2012)

[3]World Health Organization – Guidelines for Drinking Water Quality (2011)

Overall, the results imply that, as far as the adverse health effects from heavy metals are concerned, the waters are safe as a source of drinking water. In light of these findings, it is of utmost importance that the city government and all stakeholders initiate actions to sustain the quality of the freshwater supply and to protect this vital resource from the deleterious effects of human activities.

Table 4. One-sample t-test results: heavy metal content of the processed water against the standard values.

Heavy Metal	Standards	t	P
Copper, Cu	PNSDW[1]	-993.912	1.000
	USEPA[2]	-993.912	1.000
	WHO[3]	-1992.372	1.000
Chromium, Cr	PNSDW[1]	-63.286	1.000
	USEPA[2]	-127.571	1.000
	WHO[3]	-63.286	1.000
Lead, Pb	PNSDW[1]	0.907	0.195
	USEPA[2]	0.473	0.324
	WHO[3]	0.907	0.195
Cadmium	PNSDW[1]	-1.843	0.949
	USEPA[2]	-4.305	0.999
	WHO[3]	-1.843	0.949

[1]Philippine National Standards for Drinking Water (2017)

[2]United States Environmental Protection Agency – Water Standards and Health Advisories (2012)

[3]World Health Organization – Guidelines for Drinking Water Quality (2011).

Microbiological quality

Table 5 shows the total coliform count and the presence or absence of *E. coli* in the raw and processed waters. The raw water sample failed the total coliform test as manifested by the high total coliform count. Since the total coliform count is an indicator species for pathogens, this very high result for total coliform is an indication of microbial contamination from the environment and the likelihood of the presence of disease-causing microorganisms in the water system. While *E. coli* is absent, which is a good thing by itself, with the too numerous to count (TNTC) total coliform, the raw water from the Bubunawan river is considered unfit for human consumption unless regular treatment for disinfection is applied. Failing to disinfect the water is a serious threat to human health, considering that this water is a primary source of drinking in Cagayan de Oro City. A water system with microbial contamination can be treated with chlorine, chlorine dioxide, ultraviolet light, ozone, or distillation (Besagas *et al.*, 2015).

Table 5. Microbiological characteristics of the raw water and the processed drinking water.

Parameter	Water Source [mean (std deviation)]		Standard Limits		
	Raw	Processed	PNSDW[1]	USEPA[2]	WHO[3]
Total Coliform (cfu/100 ml)	TNTC[a]	<1 cfu	< 1 total coliform colonies per 100 ml	5% (No more than 5.0% samples total coliform positive in a month. Every sample that has total coliforms must be analyze for fecal coliforms no fecal coliforms are allowed.)	
E. coli	Absent	Absent			

[1]Philippine National Standards for Drinking Water (2017)

[2]United States Environmental Protection Agency – Water Standards and Health Advisories (2012)

[3]World Health Organization – Guidelines for Drinking Water Quality (2011)

[a]TNTC – Too Numerous to Count

True enough, the disinfection of the Bubunawan river has been shown to be effective, as manifested by the total coliform count that dropped to <1 and the absence of *E. coli* in the processed water. The microbial characteristics of processed water relatively passed the standards of PNSDW and the USEPA. This particular drinking water of the COWD is safe to drink as far as the microbial characteristics are concerned.

Conclusions

The surface raw water source has been well chosen as far as being safe from some dangerous heavy metals. While there is initially high total coliform, the disinfection process is implemented on this major drinking water supply is effective in producing tap water that is practically free from bacteria. In effect, the public in the concerned areas in Cagayan de Oro City is assured that they are receiving tap water that passes the applicable local and international standards as far as the potability measured in terms of microbial characteristics and selected heavy metals of concern.

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