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Evaluating the Water Quality of Key Freshwater Sources in Gingoog City, Philippines

Ronnie L. Besagas*, Romeo M. Del Rosario, Girlie D. Leopoldo, Myrna S. Ceniza, Noel T. Dael, Antonio Y. Asoy

University of Science and Technology of Southern Philippines, Cagayan de Oro City, 9000 Philippines

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Abstract

This study investigates the water quality of major freshwater sources in Gingoog City, Philippines, focusing on physico-chemical, heavy metal, and microbial characteristics. Water samples were collected from five deep wells and three springs, and analyzed for parameters including pH, temperature, turbidity, conductivity, total dissolved solids (TDS), salinity, chlorides, total hardness, and total organic carbon (TOC). Heavy metals such as arsenic, cadmium, copper, mercury, lead, aluminum, zinc, iron, and antimony were also measured. The results indicate that the water quality generally meets both Philippine and international standards, with low levels of dissolved solids and ions. However, the presence of antimony (Sb) remains a concern, as its levels (<0.01 mg/L) may exceed the stricter standards set by the USA and EU. Microbiological analysis revealed high water quality, with no detectable *E. coli* and minimal total coliform counts. The findings provide valuable insights for the management and conservation of freshwater resources in Gingoog City, emphasizing the need for continuous monitoring and adherence to stringent water quality standards to ensure the sustainability and safety of these vital water sources for the community.

* **Corresponding Author:** Ronnie L. Besagas ✉ rlbesagas@ustp.edu.ph

Introduction

Water is an indispensable resource for all forms of life on Earth. It is crucial for the survival of living organisms, as life would not be possible without it. Approximately 71% of the Earth's surface is covered by water, amounting to about 1,386,000,000 cubic kilometers. However, 97% of this water is found in oceans, seas, and bays, making it too salty for drinking, irrigation, or industrial use (except as a coolant). Around 2% of the water is locked in glaciers and polar ice caps, leaving less than 1% available for human use through lakes, rivers, reservoirs, and aquifers (USGS, 2014; Soh *et al*., 2007; Wetzel, 2001; Miller, 2000). This highlights the scarcity of freshwater as a resource.

Freshwater plays a vital role in the natural environment and is essential for human activities such as drinking, washing, bathing, agriculture, and industry. The quality of water is a significant concern because it must be free from harmful substances or contaminants that can cause illness. Ensuring water quality involves more than just microbial safety, such as meeting standards for indicator organisms like total coliform and E. coli. It also requires reducing exposure to chemical and physical hazards that can be ingested through contaminated drinking water.

In many parts of the world, freshwater is a limited resource. According to the World Health Organization (WHO), 1.1 billion people lack access to safe drinking water, and 2.4 billion people lack basic sanitation services (WHO, 2000). The increasing demand for freshwater due to population growth, rapid industrialization, and economic development exacerbates this problem. These factors contribute to the production of large amounts of anthropogenic and industrial waste, which can degrade water systems. Additionally, climate change and ozone depletion pose further threats to the quality, quantity, and treatability of freshwater (Soh *et al*., 2007).

Given these challenges, it is imperative to study the levels of selected physico-chemical, heavy metal, and microbial characteristics of major freshwater sources in Gingoog City, Philippines. The city has undergone numerous changes, both man-made and natural, that could have impacted the quality of its freshwater sources. The results of this study can provide valuable insights for managing water resources for human consumption.

Materials and methods

Sampling

Water samples were collected in clean, acid-washed polyethylene bottles rinsed with distilled water. Separate sterile bottles were used for microbial testing, following aseptic techniques. Samples were placed in an ice-filled polystyrene foam box and kept there during transit to the laboratory.

Physico-chemical Analyses

The parameters analyzed were pH, temperature, turbidity, conductivity, TDS, salinity, chlorides, total hardness, and TOC. Conductivity, TDS, and salinity were measured with a HACH sension5 Conductivity Meter. Chloride content was calculated from salinity using the formula:

$$Chloride\ \left(\frac{mg}{L}\right) = \frac{Salinity\ (in\ ppt)}{1.80655} \times 1000$$

The turbidity was measured onsite using the HACH 2100Q turbidimeter. The total hardness was determined through the standard EDTA titration method (PCARRD, 1991).

The total organic carbon (TOC) was quantified employing the spectrophotometric method of Hach—Method 10129 (Direct Method). This method, suitable for measuring TOCs in the range of 0.3 to 20.0 mg/L, is based on the indicator color change affected by the pH variation due to CO_2 production from the oxidation of organic carbon by persulfate in a specialized reagent-containing vial. The absorbance was recorded at wavelengths of 598 nm and 430 nm using the HACH DR 5000 UV-Vis spectrophotometer.

Analysis of Heavy Metals and Other Metals

Nine metals were analyzed in this research: arsenic, cadmium, copper, mercury, lead, aluminum, zinc,

iron, and antimony. Zinc, copper, iron, lead, and cadmium were measured using flame atomic absorption spectroscopy; mercury was analyzed with cold vapor spectrometry. Antimony was assessed via inductively coupled plasma–optical emission spectroscopy. Arsenic was tested using silver diethyldithiocarbamate, and aluminum with eriochrome cyanine R. Water samples not analyzed within 24 hours were preserved by adjusting the pH to 2.0 with concentrated nitric acid.

Microbiological Test (Total Coliform and Escherichia Coli)

Microbial testing of samples was performed using membrane filtration. Total coliform colonies were counted, and E. coli presence was determined by colony appearance.

Results and discussion

Basic Information of Major Sources

Gingoog City is a second-income class component city encompassing a total land area of 56,844 hectares and a population of 136,698 as recorded in the 2020 census. The city comprises 79 barangays.

The water supply is sourced from five deep wells and three springs. The Gingoog City Water District (GCWD), a government-owned and controlled corporation under the Local Water Utilities Administration (LWUA), manages the water system. The GCWD has an average monthly production of 109,548 cubic meters with over 5,000 residential and 300 commercial service connections.

Geographically, Gingoog City is situated at 8.82° North Latitude and 125.10° East Longitude, with an elevation of 6.496 meters above sea level. It is located on the northeastern coast of Misamis Oriental province, 122 kilometers east of Cagayan de Oro City and 74 kilometers west of Butuan City.

The city is bounded to the east by the Municipality of Magsaysay and Agusan del Norte province; to the south by Bukidnon Province; to the west by the Municipalities of Claveria and Medina, and to the north by Gingoog Bay.

Table 1. Quality of Freshwater – Gingoog (Brgy. 25): Physico-Chemical.

Sampling	Parameter									
	Conductivity (µS/cm)	pH	TOC (mg/L C)	Appearance	Turbidity (NTU)	Temp (°C)	TDS (mg/L)	Salinity (ppt)	Chlorides (mg/L)	Total Hardness (mg/L $CaCO_3$)
1st	259.7	7.23	3.42	color-less	0.12	24.9	124.3	0.1	55.3	124.0
2nd	246.0	7.18	1.88	color-less	0.08	24.6	118.2	0.1	55.3	108.1
3rd	244.0	7.37	7.75	color-less	0.10	25.0	118.0	0.1	55.3	114.9
PNSDW Std[1]	***	6.5-8.5	***	***	5	***	500	***	250	300
USA Std[2]	***	6.5-8.5	***	***	5	***	500	***	250	***
EU Std[3]	2,500	6.5-9.5	No abnormal change	Acceptable, no abnormal change	Acceptable, no abnormal change	***	***	***	250	***
WHO Std[4]	***	***	***	***	***	***	***	***	***	***

[1]Philippine National Standards for Drinking Water (2007)

[2]Drinking Water Standards and Health Advisories – USEPA (2012)

[3]Drinking Water Directive – European Union (1998)

[4]Guidelines for Drinking Water Quality – WHO (2011)

***No Available Data.

The livelihood of the inhabitants of Gingoog City is primarily derived from agriculture, fishery, industry, and commerce. The city boasts abundant supplies of fruits such as lanzones, durian, mango, rambutan, and marang, as well as vegetables including tomatoes and sweet peas. Other significant agricultural products include rice, corn, coconut, banana, coffee, spices, and root crops.

Table 2. Quality of Freshwater – Gingoog (Brgy. 25): Heavy Metals and Other Metals.

Sampling	Parameter								
	Pb (mg/L)	Cd (mg/L)	Al (mg/L)	As (mg/L)	Hg (mg/L)	Sb (mg/L)	Zn (mg/L)	Cu (mg/L)	Fe (mg/L)
1st	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	<0.002*	<0.002*	0.036
2nd	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	0.086	<0.002*	0.191
3rd	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	<0.002*	<0.002*	<0.005*
PNSDW Std[1]	0.01	0.003	0.02	0.05	0.001	0.02	5.0	1.0	1.0
USA Std[2]	0.015 (at tap)	0.005	0.05-0.2	0.010	0.002	0.006	5.0	1.3 (at tap)	0.3
EU Std[3]	0.010	0.005	0.200	0.010	0.0010	0.005	***	2.0	0.200
WHO Std[4]	0.01	0.003	***	0.01	0.006	0.02	***	2.0	

*Method Detection Limit
**Reporting Unit
***No Available Data
[1]Philippine National Standards for Drinking Water (2007)
[2]Drinking Water Standards and Health Advisories – USEPA (2012)
[3]Drinking Water Directive – European Union (1998)
[4]Guidelines for Drinking Water Quality – WHO (2011).

Table 3. Quality of Freshwater – Gingoog (Brgy. 25): Microbiological.

Samling	Parameter	
	Total Coliform (colonies/100 mL)	*E. coli*
First	6.5	Absent
Second	1.0	Absent
Third	0.0	Absent
PNSDW Std[1]	<1; not more than 5% of samples positive in a month	Absent
USA Std[2]	Not more than 5% of samples positive in a month	Absent
EU Std[3]	0	Absent
WHO Std[4]	***	Absent

[1]Philippine National Standards for Drinking Water (2007)
[2]Drinking Water Standards and Health Advisories – USEPA (2012)
[3]Drinking Water Directive – European Union (1998)
[4]Guidelines for Drinking Water Quality – WHO (2011)
***No Available Data

Additionally, there is considerable potential for large-scale livestock and poultry production.

Quality of water from major sources

The subsequent tables present the results from water testing at Pumping Station No. 7 in Barangay 25. Table 1 displays the physico-chemical characteristics of the water, Table 2 compiles the findings on heavy metals and other metals present in the water, and Table 3 provides the microbiological test results. Regarding the physico-chemical characteristics, the water quality is highly satisfactory. It meets Philippine standards as well as international standards, featuring very low levels of dissolved solids, particularly ions.

Against various standards, the water demonstrates excellent performance regarding heavy metals and other metallic elements. However, the presence of antimony (Sb) remains uncertain. While it is within the Philippine and WHO standards for metals, its levels may exceed those set by the USA and EU due to the detection limit of the analysis method being 0.01 mg/L, which is higher than the maximum allowable levels of the USA (0.006 mg/L) and the EU (0.0005 mg/L).

Table 4. Quality of Freshwater – Gingoog (Brgy. 22A): Physico-Chemical.

Sampling	Parameter									
	Conductivity (µS/cm)	pH	TOC (mg/L C)	Appearance	Turbidity (NTU)	Temp (°C)	TDS (mg/L)	Salinity (ppt)	Chlorides (mg/L)	Total Hardness (mg/L $CaCO_3$)
1st	187.7	7.77	2.65	color-less	0.13	24.0	89.80	0.1	55.3	76.63
2nd	178.1	7.77	4.28	color-less	0.20	24.2	85.00	0.1	55.3	78.41
3rd	179.0	7.80	4.80	color-less	0.11	23.5	85.60	0.1	55.3	78.34
PNSDW Std[1]	***	6.5-8.5	***	***	5	***	500	***	250	300
USA Std[2]	***	6.5-8.5	***	***	5	***	500	***	250	***
EU Std[3]	2,500	6.5-9.5	No abnormal change	Acceptable, no abnormal change	Acceptable, no abnormal change	***	***	***	250	***
WHO Std[4]	***	***	***	***	***	***	***	***	***	***

[1]Philippine National Standards for Drinking Water (2007)
[2]Drinking Water Standards and Health Advisories – USEPA (2012)
[3]Drinking Water Directive – European Union (1998)
[4]Guidelines for Drinking Water Quality – WHO (2011)
***No Available Data.

The water exhibits extraordinary microbiological cleanliness, with no detectable E. coli and a minimal total coliform count, making it one of the lowest in the province. The GCWD's disinfection protocol ensures that the water is safe for consumer use. The subsequent group of three tables presents the results of the water testing from the deepwell at Pumping Station No. 4 in Barangay 22A. Table 4 provides data on the physico-chemical parameters of the deepwell's water, Table 5 details the levels of heavy metals and other metals found, and Table 6 outlines the results of microbiological testing.

Table 5. Quality of Freshwater – Gingoog (Brgy. 22A): Heavy Metals and Other Metals.

Sampling	Parameter								
	Pb (mg/L)	Cd (mg/L)	Al (mg/L)	As (mg/L)	Hg (mg/L)	Sb (mg/L)	Zn (mg/L)	Cu (mg/L)	Fe (mg/L)
1st	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	0.018	<0.002*	0.165
2nd	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	0.038	<0.002*	<0.005*
3rd	<0.003**	<0.002**	<0.02*	<0.005*	<0.001*	<0.01*	<0.002*	<0.002*	<0.005*
PNSDW Std[1]	0.01	0.003	0.02	0.05	0.001	0.02	5.0	1.0	1.0
USA Std[2]	0.015 (at tap)	0.005	0.05-0.2	0.010	0.002	0.006	5.0	1.3 (at tap)	0.3
EU Std[3]	0.010	0.005	0.200	0.010	0.0010	0.005	***	2.0	0.200
WHO Std[4]	0.01	0.003	***	0.01	0.006	0.02	***	2.0	

*Method Detection Limit
**Reporting Unit
***No Available Data
[1]Philippine National Standards for Drinking Water (2007)
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[3]Drinking Water Directive – European Union (1998)
[4]Guidelines for Drinking Water Quality – WHO (2011).

The deepwell water in Barangay 22A surpasses that of Barangay 25 in terms of dissolved solids or ions, meeting all standards without issue. Regarding heavy metals and other metals, this water source also complies with established standards. Nevertheless, there is still concern over the antimony (Sb) levels, as they fall below the Philippine standard but remain unverified against the stricter standards of the USA

(0.006 mg/L) and the EU (0.0005 mg/L). Microbiologically, the water maintains high quality with an absence of E. coli and a minimal total coliform count, comparable to the first deepwell. With an effective chlorination schedule, the water is rendered safe for human consumption.

Table 6. Quality of Freshwater – Gingoog (Brgy. 22A): Microbiological.

Samling	Parameter	
	Total Coliform (colonies/100 mL)	*E. coli*
First	4.5	Absent
Second	0.5	Absent
Third	10.0	Absent
PNSDW Std[1]	<1; not more than 5% of samples positive in a month	Absent
USA Std[2]	Not more than 5% of samples positive in a month	Absent
EU Std[3]	0	Absent
WHO Std[4]	***	Absent

[1]Philippine National Standards for Drinking Water (2007)
[2]Drinking Water Standards and Health Advisories – USEPA (2012)
[3]Drinking Water Directive – European Union (1998)
[4]Guidelines for Drinking Water Quality – WHO (2011).
***No Available Data.

Conclusion

The comprehensive analysis of the major freshwater sources in Gingoog City reveals that the water quality is generally satisfactory and meets both Philippine and international standards. The physico-chemical characteristics of the water, including pH, temperature, turbidity, conductivity, TDS, salinity, chlorides, and total hardness, are within acceptable limits, indicating a low level of dissolved solids and ions. The heavy metal analysis shows that the water is free from harmful levels of metals such as lead, cadmium, aluminum, arsenic, mercury, and zinc. However, the presence of antimony (Sb) remains a concern, as its levels may exceed the stricter standards set by the USA and EU.

Microbiologically, the water sources exhibit high quality, with no detectable E. coli and minimal total coliform counts, ensuring the safety of the water for consumer use. The effective disinfection protocols implemented by the Gingoog City Water District (GCWD) play a crucial role in maintaining this high level of water quality.

Overall, the findings of this study provide valuable insights for the management and conservation of freshwater resources in Gingoog City. Continuous monitoring and adherence to stringent water quality standards are essential to ensure the sustainability and safety of these vital water sources for the community.

Recommendations

Based on the comprehensive analysis of the major freshwater sources in Gingoog City, it is recommended to enhance the monitoring of antimony (Sb) levels to ensure they remain within safe limits, particularly in light of stricter standards from the USA and EU. Strengthening the current disinfection protocols is crucial to maintain microbiological quality, and continuous public education and awareness campaigns should be conducted to promote water conservation and highlight potential risks of antimony contamination.

Collaboration with environmental agencies will help implement and enforce stringent water quality standards, while investments in research and development can lead to innovative methods for detecting and removing contaminants. Additionally, advocating for stricter local regulations aligned with international standards is essential, as is providing regular public reports on water quality to ensure transparency and build public trust. By following these recommendations, Gingoog City can continue to safeguard its freshwater resources and ensure their sustainability and safety for the community.

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