Mindanao Journal of Science and Technology Vol.13 (2015) 1-11

Upland and Coastal Freshwater Sources in Misamis Oriental, Philippines: A Comparison of Water Quality

Ronnie L. Besagas, Antonio Y. Asoy, Myrna S. Ceniza,
Girlie D. Leopoldo, Noel T. Dael and Romeo M. Del Rosario*
College of Arts and Sciences
Mindanao University of Science and Technology
Cagayan de Oro City, 9000 Philippines
* *rmdelr@yahoo.com*

Date received: May 28, 2014
Revision accepted: October 9, 2014

Abstract

This paper compared upland and coastal spring freshwaters in Misamis Oriental in terms of their physico-chemical properties, heavy metal contents, and microbiological characteristics. The physico-chemical properties included the following: turbidity, temperature, pH, conductivity, total dissolve solids (TDS), salinity, chlorides, total hardness and total organic carbon (TOC). The heavy metals determined were lead (Pb), cadmium (Cd), aluminum (Al), arsenic (As), mercury (Hg), antimony (Sb), zinc (Zn), copper (Cu), and iron (Fe). For the microbiological assessment, total coliform count and E. coli detection was tested.

The results of physico-chemical analyses have shown that both coastal and upland freshwaters from spring sources passed the standard requirements of the Philippines, USA, EU and WHO. The upland freshwaters, however, are better than the coastal freshwaters since the former are significantly lower in conductivity, TDS, salinity, chlorides, and TOC. Favorable findings have been seen also for the heavy metals which pass the different standards except for antimony, which is somewhat doubtful when assessed against the stricter USA and EU standards. The microbiological test results revealed substantial contaminations with fecal bacteria for both upland and coastal freshwater sources. Being indicator species, the heavy load of total coliform and the presence of E. coli in both kinds of freshwaters indicate the high possibility of the presence of pathogenic microorganisms in the waters. Hence, there is an eminent health risk in drinking these waters prior to their disinfection. These results call for appropriate and effective action since these spring sources are some of the major drinking water sources of Misamis Oriental.

Keywords*:* freshwater, drinking water, physico-chemical characteristics, heavy metals, total coliform, E. coli

1. Introduction

Water is a resource vital to all life on earth. It is a fundamental component of the existence of life, for without water life on this planet would never be possible. Water covers 70% of the Earth's surface, but less than 1% of this amount is available for human use through lakes, rivers, reservoirs, and aquifers (Soh *et al.*, 2007). The vast quantity of water, about 97%, is in the ocean, which is too salty for drinking, irrigation, or industry (except as coolant) and the remaining 2% is frozen in glaciers and polar ice caps (Wetzel, 2001; Miller, 2000).

Freshwater is an essential and dynamic component of the natural environment. Humans rely heavily in it for drinking, washing, bathing, and for other areas of human endeavor such as agriculture and industry. Drinking water comes from two different sources: surface water which is usually from lakes, rivers, and streams and groundwater which includes water from springs and aquifers. The surface waters are perceived as relatively dirty sources and need more treatment to be potable than the ground water which requires less treatment or, maybe, even no treatment at all. Surface waters are in the open, hence more prone to contamination from domestic waste, agricultural runoff, surface runoff and industrial discharges. Although groundwater is less vulnerable to contamination, it can still be contaminated from a number of sources including underground storage tanks, landfills, abandoned hazardous waste dumps, deep wells used to dispose of liquid hazardous waste and industrial waste, and livestock waste storage lagoons located above or near aquifer (Miller, 2000). Pollution of groundwater is a serious problem particularly in areas where aquifers provide a large part of water supply. Groundwater pollution is far more difficult and expensive to treat than surface water pollution.

Freshwater is a limited resource in many parts of the world. According to the WHO (2000), 1.1 billion people lack basic access to safe drinking water supplies, and 2.4 billion people lack basic sanitation services. With increasing demand for freshwater due to population growth, rapid industrialization and economic development, this problem will, in no doubt, be intensified if not addressed. These growth and development only end up producing massive amounts of anthropogenic and industrial wastes which can degrade our water systems. In addition, the two major environmental problems facing mankind today, climate change and ozone depletion, further threaten the quality, quantity and treatability of this vital resource (Soh *et al.*, 2007).

The world's rivers originate in the highlands and freshwater accumulates in the mountains which supply more than half of humanity. But it is now under stress due to human activities in the mountains which directly affect the resources in the densely populated lowlands (Liniger and Weingartner, 1998). The impact is manifested in the recharging of rivers and groundwater aquifers as well as in the quality of water.

The Province of Misamis Oriental, a coastal province in Northern Mindanao, Philippines, is composed of 23 towns (municipalities) and 3 cities. It is the center of industry, trade and commerce in the region with over 37 major industrial and manufacturing firms. In spite of the growing economy of the province, its drinking water systems have not yet advanced. Water quality is not closely monitored by most municipalities and treatment is limited only to disinfection by chlorination. Chlorination only kills the microorganisms in the water and does not remove the other contaminants such as organic matter, dissolved and suspended particulates, heavy metals, and various forms of inorganic substances. These organic and inorganic contaminants also pose adverse effects to human health. Furthermore, chlorinating water with high organic matter content may form disinfection by-products such as trihalomethanes and haloacetic acids that are believed to be carcinogenic and genotoxic (CBCL Limited, 2011; Texas Commission on Environmental Quality, 2002).

The provision of safe drinking water is not restricted only to eliminating waterborne pathogens but also in reducing the exposure of individuals to chemical and physical hazards that can be ingested through contaminated drinking water. Thus, this paper has made comparison of some upland and coastal waters in Misamis Oriental in terms of certain quality characteristics, namely, (1) physico-chemical, (2) heavy metals and other metals, and (3) microbiological. It also compares the results to the standards indicated in the Philippine National Standards for Drinking water 2007 (PNSDW) and those of other regulatory and guideline-giving agencies in the world.

The upland freshwater sources are springs located at high elevation above sea level while the coastal freshwater sources are, likewise, springs but located at near sea level at distances not exceeding 100 meters from the coastline. There were 3 towns selected for upland freshwater sources and 3 towns for coastal freshwater sources. The upland freshwater sources are in Villanueva, Claveria, and Jasaan whereas the coastal freshwater sources are located in Salay, Kinoguitan, and Balingoan.

2. Methodology

2.1 Sampling

The water samples for heavy metals and physico-chemical tests were stored in clean acid-washed plastic containers while the water samples for microbiological testing were stored in sterile plastic containers. Aseptic technique was observed in collecting samples for microbiological testing. All samples were immediately placed in a polystyrene foam box with ice and kept therein while in transit to the laboratory.

2.2 Physico-chemical Analyses

The following parameters were analyzed: pH, temperature, turbidity, conductivity, total dissolved solids, salinity, chlorides, total hardness, and total organic carbon (TOC). Apart from total hardness and TOC which were analyzed in the laboratory, all other physico-chemical parameters were analyzed *in situ*.

The pH and temperature were determined using a pH meter (HachsensION+ portable pH meter) and a portable digital thermometer (calibrated in parallel with a Hg thermometer). On the other hand, a multi-meter, specifically Hach sensION5 meter was used to determine the conductivity, total dissolved solids and salinity. The chloride content of the sample was calculated from salinity. For the turbidity of the sample, it was analyzed using a turbidimeter (Hach 2100Q portable turbidimeter).The total hardness was determined by the standard EDTA titration method (PCARRD, 1991).

The TOC was analyzed using the method developed by Hach Company. In this method the TOC is determined by first sparging the sample under slightly acidic conditions to remove inorganic carbon. In the outside vial, organic carbon in the sample is digested by persulfate and acid to form carbon dioxide. During digestion, the carbon dioxide diffuses into a pH indicator reagent in the inner ampule. The absorption of carbon dioxide into the indicator forms carbonic acid. Carbonic acid changes the pH of the indicator solution which, in turn, changes the color. The amount of color change is related to the original amount of carbon present in the sample. Test results are measured at 598 and 430 nm (Hach Company, 2013).

2.3 Determination of Heavy Metals and Other Metal

There were nine metals included in this research: arsenic, cadmium, copper, mercury, lead, aluminum, zinc, iron and antimony. Flame atomic absorption spectroscopy was employed to analyze the zinc, copper, iron, lead and cadmium contents of the samples, while cold vapor spectrometry was used to analyze the mercury. Inductively coupled plasma–optical emission spectroscopy was employed in the analysis of antimony. The arsenic was analyzed using silver diethyldithiocarbamate while the aluminum was analyzed using eriochrome cyanine R. Water samples that could not be analyzed within 24 hours from the time of sampling were preserved by adjusting the pH to 2.0 using concentrated nitric acid.

2.4 Microbiological Tests (Total Coliform and Escherichia coli)

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. 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.

3. Results and Discussion

3.1 Physico-chemical Characteristics

The results of physico-chemical analyses of the upland and coastal freshwaters are summarized in Table 1. The data show that both the upland and coastal freshwaters are of good quality as far as their physico-chemical characteristics are concerned. All the test results do not exceed the limits set by the Philippine government via the Philippine National Standards for Drinking Water 2007 and by the other international agencies and organizations. This is an indication that natural events and anthropogenic activities may not have caused any serious impacts on the very sources of these freshwaters, the water tables and aquifers.

Table 1. Physico-chemical characteristics of the upland and coastal freshwaters

Parameter	Freshwater Source [mean (sd/n)]		Standard Limits			
	Upland	Costal	PNSDW[1]	USA[2]	EU[3]	WHO[4]
Appearance	Colorless-clear	Colorless-clear			Acceptable; no abnormal change	
Turbidity (NTU)	0.53 (0.42/9)	1.57 (1.6/10)	5	5	Acceptable; no abnormal change	
Temperature (˚C)	24.2 (3.2/9)	25.3 (0.9/10)				
pH	7.3 (0.5/9)	6.7 (0.2/10)	6.5-8.5	6.5-8.5	6.5-9.5	
Conductivity (µS/cm)	148.1 (74.6/9)	407.9 (199.5/10)			2,500	
TDS	69.7 (35.3/9)	203.3 (106.3/10)	500	500		
Salinity (ppt)	0.1 (0/9)	0.2 (0.1/10)				
Chlorides (mg/L)	55.3 (0/9)	110.7 (58.3/10)	250	250	250	
TOC (mg/LC)	2.4 (1.6/9)	5.0 (1.8/10)			No abnormal change	
Total Hardness (mg/L $CaCO_3$)	58.7 (25.6/9)	81.2 (14.1/10)	300			

[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)

On the basis of the data, there is no indication for the need to treat both kinds of water on the physico-chemical aspect. Both water sources are drinkable by their crystal clear appearances alone. The turbidities of both upland and coastal freshwaters were very low indicating insignificant suspended solid contamination. Furthermore, there were also low levels of dissolved organic and inorganic particulates in both waters as implied by the test results for TOC, TDS, conductivity and total hardness.

Although the physical and chemical characteristics of the two kinds of water sources are within acceptable levels, they have significant differences in water quality with respect to some parameters. By means of the independent two-sample t-test (unequal variance), it is shown in Table 2 that the two sources differ significantly in pH, conductivity, TDS, salinity, chlorides, and TOC at the 0.05 significance level.

Table 2. t-Test Results: Upland freshwater versus coastal freshwater

Parameter	P-Value
Turbidity	0.0759
Temperature	0.2907
pH	0.0029*
Conductivity	0.0019*
TDS	0.0023*
Salinity	0.0114*
Chlorides	0.0112*
TOC	0.0051*
Total Hardness	0.9506

*Statistically significant at $\alpha = 0.05$

The coastal freshwater is significantly higher in conductivity, TDS, salinity, chlorides, and TOC than the upland freshwater indicating that the upland freshwater is of better quality than the coastal freshwater. The significant difference in conductivity can be attributed to the geology of underground water system such as the type of rocks and minerals through which water flows. For example, limestone leads to higher conductivity because of the dissolution of carbonate minerals. Contact time between water and rock, the flow rate, and the flow path could also affect conductivity. The same factors might influence the observed statistical difference in pH, total dissolve solids, salinity, chlorides, and total organic matter. Another reason, in the case of coastal freshwater sources, is the intrusion of salt water considering that the springs are only a few meters away from the sea. However, this phenomenon is not evident based on the test results for salinity. Nevertheless, it should be monitored because if this will happen, the treatment of saline water is costly and requires a major investment (Guillermo, 2002).

3.2 Heavy Metals and Other Metals

Table 3 summarizes the results of the metal analyses of the upland and coastal freshwaters. The data revealed a very interesting finding – both upland and coastal freshwater sources are practically safe and free from the heavy metals and other metals included in the testing.

Table 3. Heavy metal concentrations

Heavy Metals	Freshwater Source [mean (sd/n)]		Standard Limits			
	Upland	Costal	PNSDW[1]	USA[2]	EU[3]	WHO[4]
Pb	<0.003**	<0.003**	0.01	0.015 (at tap)	0.01	0.010
Cd	<0.002**	<0.002**	0.003	0.005	0.005	0.003
Al	<0.02*	0.02	0.2	0.05-0.02	0.2	
As	<0.005*	<0.005*	0.05	0.010	0.010	0.01
Hg	<0.001**	<0.001**	0.001	0.002	0.0010	0.006
Sb	<0.01*	<0.01*	0.02	0.006	0.0050	0.02
Zn	<0.002*	<0.002*	5.0	5.0		
Cu	<0.002*	0.021	1.0	1.3 (at tap)	0.0020	0.200
Fe	<0.002*	0.040	1.0	0.3	0.200	

*Method Detection Limit
**Reporting Limit

[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)

The above results indicate that the concentrations of all the heavy metals in the water for both water sources were very low so that in most cases the exact concentrations could not be exactly established. The important thing is that they are all below the maximum allowable limits. In the light of these findings, it is of utmost importance that the government, from local to national level, should initiate actions to sustain the quality of the freshwater supply and to protect this vital resource from the deleterious effects of human activities.

3.3 Microbiological Characteristics

One important requirement for drinking water is that it should be free from waterborne pathogens. This is usually assessed by the coliform test: total coliform and *E. coli* test. Table 4 shows the results of total coliform and *E. coli* test on the upland and coastal freshwaters.

Table 4. Total coliform and *E. coli*

Freshwater Source	Location	Total Coliform (cfu/100 mL)	*E. coli*
	Villanueva	TNTC	Present
Upland	Jasaan	TNTC	Present
	Claveria	TNTC	Present
	Salay	TNTC	Present
Coastal	Kinoguitan	TNTC	Present
	Balingoan	TNTC	Present
	PNSDW Std.1	<1; not more than 5% of samples positive in a month	Absent
Standards	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)
[3]Drinking Water Directive-European Union (1998)
[2]Drinking Water Standards and Health Advisories - USEPA (2012)
[4]Guidelines for Drinking Water Quality-WHO (2011)

As shown, the upland and costal freshwater systems are heavily contaminated with fecal matter as manifested by the high total coliform count and the presence of *E. coli* in all samples. In addition, it is most likely that pathogenic microorganisms are present in the waters since the total coliform and *E. coli* are indicator species for pathogens. Disinfection, therefore, is a strict requirement for both upland and coastal freshwaters prior to the distribution of the waters for drinking. Failing to disinfect the waters is a serious threat to human health considering that these waters are primary sources of drinking water in the respective communities. A water system with microbial contamination can be treated with chlorine, chlorine dioxide, ultraviolet light, ozone, or distillation.

4. Conclusion and Recommendations

Based on the physico-chemical characteristics, the spring water sources, both upland and coastal freshwaters, are very acceptable. They all passed the standard limits set by the PNSDW, USEPA and EU but with the upland coming out better in this aspect. Both kinds of waters are also free from dangerous levels of heavy metals and other metals since concentrations are below the local and international standards. However, the upland and coastal freshwaters in Misamis Oriental are not totally safe. Both are high in total coliform and positive in *E. coli*. This is an obvious manifestation of fecal pollution and possible pathogenic contamination in the water systems.

In the light of these conclusions there is a need for the following: development and implementation by the government of programs and policies to maintain the upland and coastal drinking water supply of Misamis Oriental free from physico-chemical problems and metallic contaminations by protecting this vital resource from the deleterious effects of human activities; continued monitoring of the water quality in terms of the physico-chemical, metallic, and microbiological parameters; and regular disinfection of the water systems.

5. References

CBCL Limited, (2011). Study on characteristics and removal of natural organic matter in drinking water systems in Newfoundland and Labrador, from http//www.env.gov.nl.ca/env/waterres/reports/drinkingwater/NOM_Study_August_19_2011. pdf.

DOH, (2007). Philippine National Standards for Drinking Water 2007, from http://www.lwua.gov.ph/downloads_10/Philippine%20National%20Standards%20for%20Drinking%20Water%202007.pdf

European Union, (1998). Council directive on quality of water intended for human consumption, from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF

Guillermo, T., (2002). Degradation of water sources. 7th National Senior Educators Assembly in Environmental Protection and Management, from http://www.emb.gov.ph

Hach Company, (2013). Organic carbon, total. Hach Company/Hach Lange GmbH, 1989–2013, from http//www.OrganicCarbonTotalDirectTNT_DOC316.53.01093.pdf.

Liniger, H., and Weingartner, R., (1998). Mountains and freshwater supply, from http://www.fao.org/docrep/w9300e/w9300e08.html

Miller, G.T., (2000). Living in the Environment, Brooks/Cole, Cengage Learning, 20 Davis Drive, Belmont CA 94002-3098, USA.

PCARRD, (1991). Standard Methods of Analysis for Soil, Plant Tissue, Water and Fertilizer. Los Baños, Laguna, Philippines.

Soh, Y., Roddick, F., and Leeuwen, J., (2008). The future of water in Australia: The potential effects of climate change and ozone depletion on Australian water quality, quantity and treatability, from http://www.search.proquest.com/pqcentral/docview /22171507/A18A3C21F87D4ODAPQ/3?accountid=141440

USEPA, (2012). Drinking water standards and health advisories, from http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf

Wetzel, R.G., (2001). Limnology - Lake and River Ecosystems 3rd Ed. San Diego. Academic Press.

WHO, (2011). Guidelines for drinking water quality 4th Ed., from http:// www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/