ASSESSMENT OF FRESHWATER QUALITY OF DIFFERENT DEEPWELL SOURCES IN WESTERN MISAMIS ORIENTAL, PHILIPPINES

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ABSTRACT: *The quality of groundwater from main deepwell sources of seven (7) municipalities in Western Misamis Oriental, Philippines were determine to see how these may have been impacted by natural events and anthropogenic activities. The study looks at the well waters' physico-chemical properties (temperature, pH, turbidity, conductivity, TDS, salinity, chlorides, TOC and total hardness) and their microbiological (total coliform and E. coli) characteristics. The physico-chemical properties of groundwater samples were found to be within the Philippine National Standards for Drinking Water (PNSDW)/US-EPA except for the TDS, chlorides and hardness of some sources. Well waters from both Initao and Gitagum municipalities have TDS values of 643.2 mg/L and 578.4 mg/L, respectively, as compared to PNSDW/US-EPA standard limit of 500 mg/L. These same two municipalities Initao and Gitagum as well as the municipality of Libertad also have chloride levels beyond the 250 mg/L limit of PNSDW/US-EPA/EU with values at 360, 318 and 277 mg/L respectively. The Libertad sample also registered a total hardness of 407.5 mg/L $CaCO_3$ as compared to the 300 mg/L PNSDW limit. These mentioned three (3) municipalities are noticed to have similar geologic structures. All well waters from the seven municipalities, however, failed in total coliform. Escherichia coli were also found in well waters from four (4) municipalities including Laguindingan, Lugait, Gitagum, and Libertad. The presence of these pathogens in the well waters needs to be addressed to make the waters suitable for human consumption.*

Keywords: groundwater, deepwell, physico-chemical, microbiological

1. INTRODUCTION

Water is an abundant deposit needed by all living things to survive. The quality of water has however deteriorated with time because most people are taking it for granted. No one seems to mind the negative impact of human activities to water quality until disaster happens. Nowadays, access to clean and safe water becomes mandatory and government policies, regulations and guidelines are getting stricter [1].

The Water Environment Partnership in Asia [2] with thirteen partner countries in the region: Cambodia, China, Indonesia, Japan, Republic of South Korea, Lao PDR, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand and Vietnam, addressed the critical situation of water quality in the said region. The Philippines reported that generally, the quality of groundwater and marine coastal waters is good but surface water quality deterioration in the urban areas need to be addressed, although there are signs of improvement in some waters based on monitoring results conducted by the Sagip Ilog Program. As a whole, the 13 member countries are making the protection of drinking water sources to be of top priority policy area.

The various freshwater resources in the province of Misamis Oriental, Philippines have been generally assumed safe except on the basis of sound scientific evidence. In addition, so much have transpired (both man-made and natural) through time that may have drastically altered the characteristics of the waters.

The area covered in this paper includes seven (7) municipalities in the western part of the province of Misamis Oriental and these are namely: Lugait, Libertad, Gitagum, Naawan, Laguindingan, Initao and Alubijid all lying near the coastal areas facing the Macajalar Bay and Iligan Bay where people get their drinking water source from ground water through deepwells. Lugait, a highly industrialized zone where one of the biggest and oldest cement factory exist, has scarce or limited water supply. The town of Initao is a tourist attraction having a protected forest and wildlife in the coastal area but with limited water supply just like Lugait. The municipality of Naawan, with agriculture as its major economic activity, is endowed with abundant water supply unlike the situation of its neighboring towns, Lugait and Initao. The towns of Laguindingan and Alubijid are only 5.1 km apart but water supply is abundant in the latter. Laguindingan town is a commercial and agricultural area where the electric power plant (MORESCO) and the new international airport (Laguindingan Airport) are located. Alubijid is highly agricultural with coconut as the major crop, and the nearness of the town to Laguindingan has afforded Alubijid access to economic development. Likewise, the towns of Gitagum and Libertad are also highly agricultural but unlike Libertad, Gitagum has scarce water supply. These seven municipalities under study showed varied geological classifications which can directly or indirectly influence the quality of water from deepwell sources.

In this study, the quality of groundwater from main deepwell sources of the said seven (7) municipalities in Western Misamis Oriental, Philippines were determine to see its present status that may have also been affected by natural events and anthropogenic activities[3,4,5]. Quality assessment was done in terms of their physico-chemical characteristics and microbiological properties.

2. EXPERIMENTAL DETAILS

Sampling. The deepwells were sampled 3~4 times during the period July 2013 to March 2014. Water samples were collected either from sampling cocks of deepwell pumps (Naawan, Alubijid, Initao), or water reservoir (Laguindingan), or tap (Lugait, Libertad, Gitagum). The faucets were allowed to flow sufficiently prior to either flaming or scrubbing with cotton soaked in 70% ethyl alcohol, depending on the type of pipe used. For physico-chemical characteristics, the water samples were stored in clean, acid-washed plastic containers, and for microbiological tests, sterile plastic containers were utilized. All samples were immediately placed in a covered polystyrene foam box with ice.

Physico-chemical Tests. The parameters selected for inclusion are: appearance, pH, turbidity, conductivity, temperature, total dissolved solids (TDS), salinity, chlorides, total hardness, and total organic carbon (TOC). The following analyses were conducted on-site: appearance, turbidity, pH, temperature, conductivity, TDS, and salinity. Appearance was determined via ocular inspection. The pH of water was analyzed using a portable pH meter (Hach sension + pH1) that was calibrated with pH 7.0 and pH 4.0 buffers. Temperature was taken using portable digital thermometer calibrated in parallel with Hg thermometer. A digital multi-meter (Hach sension5) was used to analyze conductivity, TDS, and salinity. The chloride content of the sample was calculated from the salinity value. The turbidity was analyzed by portable turbidimeter (Hach 2100Q). Total hardness was analyzed in the laboratory following the standard EDTA titration method.

The TOC was analyzed using the method developed by Hach Company. The inorganic carbon in the sample is first removed by sparging under acidic conditions using a special vial system containing an inner tube. Then, the organic carbon is converted into carbon dioxide (CO_2) gas via persulfate digestion that occurs outside the inner tube. The carbon dioxide produced diffuses into a pH indicator reagent inside the inner tube forming carbonic acid which changes the pH and the color of the indicator solution. The color change is measured at wavelengths 430 nm and 598 nm [6].

Microbiological Tests (Total Coliform and Escherichia coli). The testing of *E. coli and total coliform count* in water samples made use of the membrane filtration method. In this method, sample was vacuum filtered through a membrane filter. Under aseptic condition inside a laminar flow hood, the membrane filter was then transferred to a sterile petri dish with an agar cultured media, and incubated at 35±5 ºC for 24h in an inverted position. The colony growth was examined after the incubation period.

3. RESULTS AND DISCUSSION

Physico-chemical Characteristics. Table 1 shows the results of the physico-chemical analyses of water samples from the seven municipalities. The temperatures of the well waters ranged from 26.9 ºC (Naawan) to 30.3 ºC (Gitagum). Waters taken from the main source showed lower temperature while those from reservoir and tap had elevated temperatures due to exposure of these two sources to ambient temperature. High water temperature enhances the growth of microorganisms and may increase problems related to taste, odor, color, and corrosion [7].

The pH values ranged from almost neutral (pH=6.99, Gitagum) to slightly alkaline (pH=7.78, Naawan) which were within the permissible limits set by PNSDW/WHO/EU/USEPA [8]. It has been reported that the pH of most raw or natural water lies within the range 6.5-8.5 in the absence of iron sulfide minerals [9]. Alkaline compounds in water such as bicarbonates, carbonates, and hydroxides remove hydronium ion and thus lower the acidity of water, that is, increased the pH [15]. Soil water in contact with organic matter or with iron sulfide minerals that is present in coal or shale bedrock can have low pH like 4 or lower. Conversely, reactions between groundwater and carbonate strata where it flows can result in pH values as high as 8.5 [10]. The pH is important in water system operations. Values outside of the pH range 6.5 to 8.5 is undesirable since this can lead to dissolution of high concentrations of some metals which might pose health hazards; and for effective disinfection with chlorine, the pH should preferably be less than 8 [7].

Turbidity is a measure of the amount of suspended material in water. All samples in this study had turbidity values lower than the PNSDW/EPA standard limit of 5 NTU. The turbidity was highest for Lugait sample at 1.06 NTU followed by Laguindingan at 0.94 NTU and the lowest turbidity of 0.18 NTU for Alubijid. Consumption of highly turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants. High turbidity can also stimulate the growth of bacteria during storage [11,12].

Conductivity is a measure of the ability of water to conduct electricity and it is highly dependent on the amount of dissolved solids in water. It can help locate pollution sources as polluted water usually has higher values than unpolluted one [12,13]. Among the selected well samples, the Initao sample registered the highest conductivity of 1,301.2 μS/cm and Naawan the lowest at 652.2 μS/cm. All values obtained were lower than the standard 2,500 μS/cm set by Drinking Water Directive-European Union [14]. Conductivity is often used as a surrogate of salinity measurements and is considerably higher in saline systems than in non-saline systems; dry periods tend to increase conductivity while during wet season, conductivity and salinity decline as the concentration of salts become more dilute [15].

Sources of salinity include urban and rural run-off containing salt, fertilizers and organic matter. The salinity values of the water samples ranged from 0.3 ppt to 0.6 ppt with Initao and Gitagum registering the highest value while Naawan and Lugait had the lowest value. While appropriate concentration of salts is vital for plants and animals, salinity that is beyond normal range is harmful to any species and will cause stress or even death.

The total dissolved solids of water from the various towns ranged from 314.1 to 643.22 mg/L. The lowest TDS was observed with the Naawan samples while the highest TDS was observed with the Initao samples. While all other water samples were within the permissible limit, the recorded 643.2 mg/L TDS value for the Initao sample and 578.4 mg/L for Gitagum were beyond the limits set by PNSDW and USEPA. TDS value has an important effect on the taste of drinking water. Palatability of water with TDS of less than 600 mg/L is generally considered to be good and becomes increasingly unpalatable at TDS levels greater than 1,200 mg/L. Water with extremely low concentrations of TDS however may be unacceptable because of its flat, tasteless taste ([2].

Table 1. Physico-Chemical Characteristics of Freshwater from Deepwell Sources in Seven Towns of Western Misamis

Parameter	Town Source of Deepwell Water							Standard Limits		
	Alubiji	**Initao**	**Naawa**	**Laguindi**	**Gitagu**	**Liberta**	**Lugait**	**PNSD**	**USA[b]**	**EU[c]**
Appearance	Colorle	Colorle	Colorle	Colorless,	Colorle	Colorle	Colorle			Acceptable; no
Temp (°C)	27.9	27.8	26.9	29.2	30.3	29.8	27.4			
pH	7.32	7.10	7.78	7.11	6.99	7.25	7.12	6.5-8.5	6.5-	6.5-9.5
Turbidity	0.18	0.24	0.29	0.94	0.11	0.16	1.06	5	5	Inoffensive
Conductivity	842.6	1,301.2	652.2	854.7	1.173	992	714.7			2,500
TDS	411.5	643.2	314.1	415.0	578.4	487.0	348.0	500	500	
Salinity	0.4	0.6	0.3	0.4	0.6	0.5	0.3			
Chlorides	221	360	180	240	318	277	184	250	250	250
TOC	14.7	16.8	11.0	18.3	36.0	18.2	16.2			
Total	270.0	234.8	147.0	74.33	200.7	407.5	162.8	300		

[a]Philippine National Standards for Drinking Water (2007) [b]Drinking Water Standards and Health Advisories- USEPA (2012)

But more than affecting the taste, higher TDS is known to cause gastrointestinal irritation to human beings while prolonged intake of water with high TDS is suspected to cause kidney stones and heart diseases. The high TDS value found in water samples from Initao and Gitagum may be due to anthropogenic sources such as domestic sewage, industrial waste, septic tanks, agricultural activities and may also be influenced by rock-water interaction [16].

The recorded total hardness values ranged from 74.33 to 407.5 mg/L $CaCO_3$ with the lowest value for the Laguindingan sample and highest for Libertad. All total hardness data of water samples from all locations have values that are within the PNSDW standard limit of 300 mg/L $CaCO_3$, except for Libertad. There are, however, reports that hardness of 150-300 mg/L and above may cause kidney problems and kidney stone formation [16].

Total hardness is caused primarily by the presence of cations such as calcium and magnesium and water that contains these at amounts greater than 120 mg/L are considered hard. Aside from possible health effects, hard waters are undesirable as they form scales on boilers, cooking utensils and pipes that carry hot water or steam and they reduce the ability of soap to produce lather thus is unsuitable for domestic use.

The chloride content for all samples fell within the maximum standard limit except for the Initao, Gitagum, and Libertad samples that registered a 360, 318, and 277 mg/L chlorides, respectively, as compared to the standard limit of 250 mg/L. Although chloride plays a role in balancing the level of electrolyte in blood plasma, higher level of chloride, however, may cause some physical disorders. Higher consumption of chloride causes hypertension, risk for stroke, osteoporosis, renal stones and the likes in human beings.

Chloride in drinking water may come from natural resources, sewage and industrial effluents, urban run-off and saline intrusion. The high level of chloride in the deepwell water sample collected from Initao, Gitagum, and Libertad may be due to similarity in their geological structures.

The TOC values of the water samples are in the range of 11.0 to 36.0 mg/L with Gitagum the highest and Naawan the lowest. The TOC test was done to test the water sample for presence of organic contaminants which may be a threat to public health.

Microbiological Analysis. Table 2 shows the presence of coliforms in all the water samples indicating some health risks because even with low levels of coliform, waterborne disease outbreaks have occurred in the past. Many water standards, therefore, have set the goal for the maximum contamination level for coliform, which is a useful indicator of pathogens, to be practically zero.

Table 2. Microbiological Analyses of Freshwater Taken from the Main Deepwell of the Seven Towns of Western Misamis Oriental, Philippines

Town	Parameters	
	Total coliform (cfu/100 mL)	***E. coli***
Alubijid	14.0	Absent
Initao	58.4	Absent
Naawan	82.7	Absent
Laguindingan	TNTC	Present
Gitagum	TNTC	Present
Libertad	TNTC	Present
Lugait	TNTC	Present
PNSDW std[a]	<1; Not more than 5% of samples positive in a month	Absent
USA std[b]	<1; Not more than 5% of samples positive in a month	Absent
EU std[c]		Absent
WHO std[d]		Absent

aPhilippine National Standards for Drinking Water (2007) [8]
[b]Drinking Water Standards and Health Advisories-USEPA (2012)[17]
[c]Drinking Water Directive-European Union (1998)[14]
[d]Guidelines for Drinking Water Quality-WHO (2011)[7]

Also of particular interest was the presence of *E.coli* in water samples collected from Laguindingan, Gitagum, Libertad, and Lugait. Such presence of *E.coli* represents a direct health risk since it is indicative of fecal contamination and waterborne pathogen exposure that may cause illness and even deaths for those with weak immune system. This indicates that a pathway exists from waste sources such as septic tank or animal feedlot runoff and the like. With the presence *E.coli* and of the too numerous to count (TNTC) total coliform, the raw deepwell water samples from the seven municipalities are considered unfit for human consumption, unless regular treatment for disinfection, such as chlorination, is applied.

4. CONCLUSIONS

While there were a few individual values for some locations that exceeded the standards for some of the selected physico-chemical parameteres, like TDS, chlorides and hardness, these are not that critical and thus the said well water samples are considered generally good in this aspect.

The water samples, however, are generally microbiologically unsatisfactory even for those which came from points of sampling after the chlorine disinfection. This alarming failure to pass the microbial standards is a reminder of the need to review the disinfection schemes applied by the said municipalities as well as to study other disinfection procedures that does not produce carcinogenic or toxic side-reaction products where local data are practically not available.

And considering the increasing extent at which man, through his varied activities, impacts the environment and the more extensive changes brought about by natural events, especially climate change, there is a real need to re-monitor the quality of water after a certain interval to provide sound bases for planning and action in the management of the freshwater resources of the province.

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