Groundwater Quality Assessment in Malapascua Island, Cebu

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INTRODUCTION

Vital to our daily lives is water. Water is needed by every living organism in this earth. Monitoring the quality of surface water will help protect our waterways from pollution and our local and national governments use monitoring information to help control pollution levels (Southwest Florida Water Management District, n.d.). Human and environmental health is influenced by water quality and humans have important roles in water conservation but understanding precisely how we impact our water supply can be done through using the information from water monitoring.

Many microorganisms are found naturally in fresh and saltwater. These include bacteria, cyanobacteria, protozoa, algae, and tiny animals such as rotifers. These can be important in the food chain that forms the basis of life in the water. However, the presence of other disease causing microbes in water is unhealthy and even life threatening for humans. For example, bacteria that live in the intestinal tracts of humans and other warm blooded animals, such as *Escherichia coli, Salmonella, Shigella, and Vibrio*, can contaminate water if feces enters the water. Contamination of drinking water with a type of *Escherichia coli* known as O157:H7 can be fatal.

To determine whether water has been contaminated by fecal material, a series of tests are conducted to indicate the presence or absence of coliforms. The coliform group is comprised of Gram-negative, nonspore-forming aerobic to faculatively anaerobic rods which ferment lactose to acid and gas. Two organisms in this group include *E. coli* and *Enterobacter*. However, only *E. coli* is the true fecal coliform from warm-blooded animals and the presence of this organism in water supply is an evidence of recent fecal contamination.

Malapascua Island is situated in the Visayan Sea, 6.8 kilometres (4.2 mi) across a shallow strait from the northernmost tip of Cebu Island. Administratively, it is part of the insular barangay of Logon, Daanbantayan, Cebu. Malapascua is a small island, only about 2.5 by 1 kilometer (1.55 by 0.62 mi), and has eight hamlets. It has a population of around 4000, and most of the islanders derive their livelihood from tourism, while some still rely on subsistence fishing, farming and boat building.

Today, Malapascua remains a beautiful island, as yet unspoiled by tourism, with white sandy beaches, surrounded by clear blue waters. In the island, water is still sourced from ground wells which the locals use for their daily household activities. These include cooking, bathing, washing and even for drinking.

MATERIALS AND METHODS

Malapascua island was visited last January 10, 2016 by a group of biologists from University of San Carlos. Water samples from ten (10) deep wells in southern part of the island were taken and analyzed (Figure 1). Physico-chemical parameters such as temperature, pH, conductivity, and salinity were measured on site. Some water samples collected were brought to the University of San Carlos Biology Laboratory for bacteriological analysis and total suspended solid measurements.

Figure 1. Location of sampling stations in Malapascua island.

Physico-chemical Parameters

<u>Temperature</u>

An alcohol thermometer was used to take the temperature of the water samples. The thermometer was immersed 2 cm below the water surface and a span of 2 minutes was allowed to pass before recording the temperature reading. Three trials were made for the parameter and they were all recorded in °C.

<u>pH</u>

A digital pH meter (BANTE 920) was used to record the pH of the water sample. The pH meter was calibrated by immersing it in distilled water until the reading gave a constant 7. The pH of the water samples was recorded by immersing the sensor of the meter about 2 cm below the surface and 3 trials were done.

<u>Salinity and Conductivity</u>

A salinity-conductivity meter (YSI 30) was utilized to determine the salinity and conductivity for the water samples. For seawater, the salinity was determined through a refractometer because its salinity would go beyond the capacity of the device. The probe of the meter was placed below the water surface until it would reach a depression in the meter. After waiting for a minute, the salinity and conductivity could be read alternately by pressing a button. Salinity was recorded in parts per thousand (ppt) and conductivity in $\mu S\ m^{-1}s^{-1}$. Three readings were taken for all the water samples.

Total Suspended Solids: Gravimetric Method

A glass filter paper was labelled at the side using a fine marker, after labelling, the filter paper was accurately weighed on an analytical balance and was placed on the Buchner funnel. The set up consisting of a Buchner Funnel placed on top of a Buchner flask with a hose attached to the Buchner flask and to the suction to suck the water out from the funnel to the flask to separate the water from the suspended solids was prepared. After the water was filtered out, it was heated in the oven for one hour at about 110°C. After heating, it was cooled in a desiccator and was weighed in the analytical balanced after it was cooled. The data was recorded and calculated by subtracting the initial weight from the final weight and was divided by the volume of the water sample.

Biological parameters: *Coliform Count*

Presence of coliforms was tested by three principal tests. The presumptive, confirmed and completed tests.

1. Presumptive test: A series of lactose broth tubes were inoculated with measured amounts of water samples (0.001, 0.1 and 1 mL) using a pipette. After inoculation, the tubes should be incubated for 24 hours. Gas production in any one of the tubes is presumptive evidence for the presence of coliforms. The MPN (most probable number) of coliforms in 100 mL of water sample was estimated by the number of positive tubes.
2. Confirmatory test: The tubes with the water samples that produced gas will be confirmed for the presence of coliforms by this test. Two methods were performed for this test. One was by using EMB (eosin methylene blue) agar plates streaked with material from the tubes containing gas. After streaking the plates were inverted and incubated for 24 hours. Presence of green metallic sheen is indicative of the presence of *E. coli* and presence of pink to brown coliform colonies indicates the presence of

Enterobacter. The other method was by inoculating BGLB (Brilliant Green Lactose Bile Broth) with material from the positive tubes. Presence of gas and white precipitate would mean positive results.

3. <u>Completed test:</u> EC broth tubes with Durham tubes were inculated with material from the BGLB with gas production and incubated for 24 hours. For the testing of water, wastewater and shellfish, the development of turbidity and gas production within 24 hours at 44.5ºC indicates the presence of fecal coliforms.

RESULTS AND DISCUSSION

On-Site Measurements

The summary of on-site measurements is given in Table 1. Salinity is the total concentration of all dissolved salts in water. These electrolytes form ionic particles as they dissolve, each with a positive and negative charge. As such, salinity is a strong contributor to conductivity. Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or deionized water can act as an insulator due to its very low (if not negligible) conductivity value. Sea water, on the other hand, has a very high conductivity. Temperature is an important factor to consider when assessing water quality. In addition to its own effects, temperature influences several other parameters and can alter the physical and chemical properties of water. In this regard, water temperature should be accounted for when determining the metabolic rates and photosynthesis production, compound toxicity, dissolved oxygen and other dissolved gas concentrations, conductivity and salinity, oxidation reduction potential (ORP), pH and water density. The pH can affect the solubility and toxicity of chemicals and heavy metals in the water

Table 1. Physico-chemical on-site measurements.

Station no. Well	GPS Points	Elevation (m)	Height (cm) from the surface to water	Ave. Salinity (ppt)	Ave. Conductivity (μS)	Ave. Temp. (°C)	Ave. pH
1	N 11°19.708 E 124°07.035	12	181	1.3	2651	28.7	8.2
2	N 11°19.787 E 124°07.111	13	72	2.2	4124	28.4	7.5
3	N 11°19.786 E 124°07.150	11	157	0.7	1316	28.9	7.6
4	N 11°19.770 E 124°07.204	13	176.7	0.8	1545	28.6	7.9
5	N 11°19.730 E 124°07.172	13	180	1.0	1994	28.5	7.5
6	N 11°19.691 E 124°07.157	12	178	1.7	3340	29.1	7.4
7	N 11°19.959 E 124°06.915	18	160	0.5	978	30.2	7.6
8	N 11°19.893 E 124°06.863	15	180	1.5	2737	29.6	7.3
9	N 11°19.754 E 124°06.919	21	200	1.8	3426	29.6	7.4
10	N 11°19.850 E 124°07.162	12	138	0.6	1285	30	7.3

As compared to the DAO 34 or DAO 26 water quality standards, the physico-chemical parameters measured on-site were within the standards (Table 2), except for conductivity. Although there are no standards stipulated by DAO 34 or DAO 26 in regards to conductivity for both surface water or drinking water the Mary River Catchment Coordinating Committee

(MRCCC) of Australia have established standards in regards to water quality and conductivity in 2013. The conductivity range of acceptable human consumption is 0–800 ɥS/cm for good drinking water and irrigation, 800–2500 ɥS/cm can still be utilized but the lower end of this range is preferable, whereas values of over 2500 ɥS/cm is not recommended for human consumption. It is stated in the 2013 MRCCC standards that the upper conductivity limit of 3000 ɥS/cm could still be used but is highly not recommended.

Table 2. Water quality criteria for conventional and other pollutants (DAO 34).

PARAMETER	UNIT	CLASS AA	CLASS A	CLASS B	CLASS C	CLASS D (b)
Color	PCU	15	50	(c)	(c)	(c)
Temperature (d) (max. rise in deg. Celcius)	°C rise		3	3	3	3
pH (range)		6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.0 - 9.0
Dissolved Oxygen (e) (Minimum)	% satn mg/L	70 5.0	70 5.0	70 5.0	60 5.0	40 3.0
5-Day 20°C BOD	mg/L	1	5	5	7(10)	10(15)
Total Suspended Solids	mg/L	25	50	(f)	(g)	(h)
Total Dissolved Solids	mg/L	500 (i)	1,000 (i)	-	-	1,000 (i)

Although there does not appear to be any significant value of pH levels for surface water or drinking water extreme pH such as less than 4 or greater than 10 could cause significant health issues but are otherwise included for uniformity. Temperature should not rise greater than 3°C over the ambient temperature on a monthly basis, longt-erm monitoring of these wells need to be conducted in order to monitor the temperature fluctuations.

Laboratory Analyses

Total Suspended Solids:

Total suspended solids in the sampled and analyzed ground waters are below the standard level set by DAO 34 which is 50 mg/L for class A (drinking) water (Table 3).

Table 3. Total suspended solids in Malapascua groundwater samples.

Well	TSS (mg/L)
1	2.7
2	5.7
3	0.375
4	0.419
5	0.002
6	0.006
7	0.003
8	0.005
9	8.45
10	1.43

(a) (b)

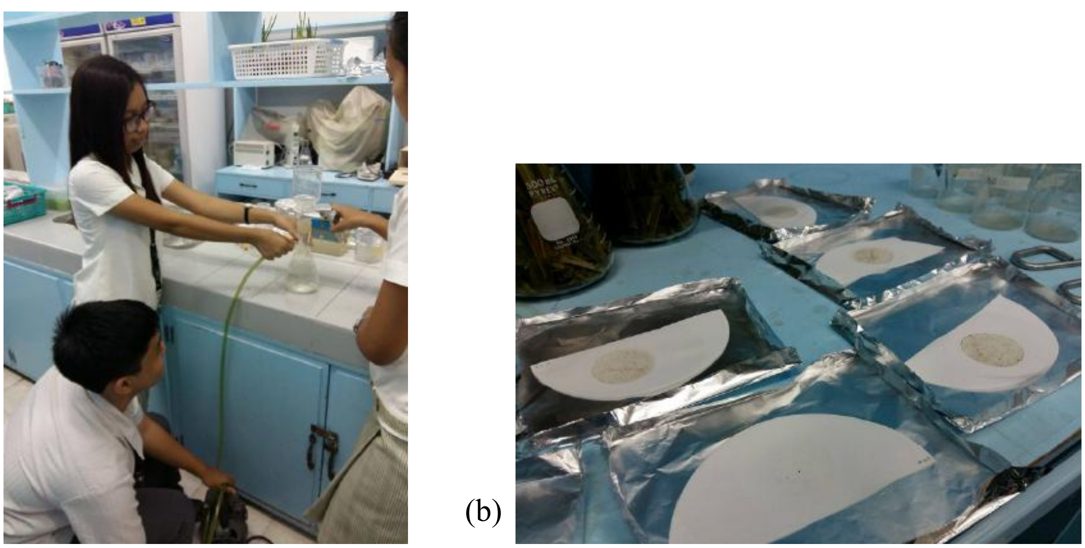

Figure 2. (a) Measuring TSS; (b) Filtered TSS on filter papers

Water Bacteriology:

Water samples from all wells were positive for the presence of lactose fermenting bacteria indicated by the formation of gas and white precipitate during the presumptive test (Figure 3).

Figure 3. Gas formation and white precipitate formation in the presumptive test.

Likewise, all water samples that gave a positive result during the presumptive test also showed positive results for BGLB broth confirmatory test (Figure 4). This result confirmed that coliforms were present in the water samples taken from the wells.

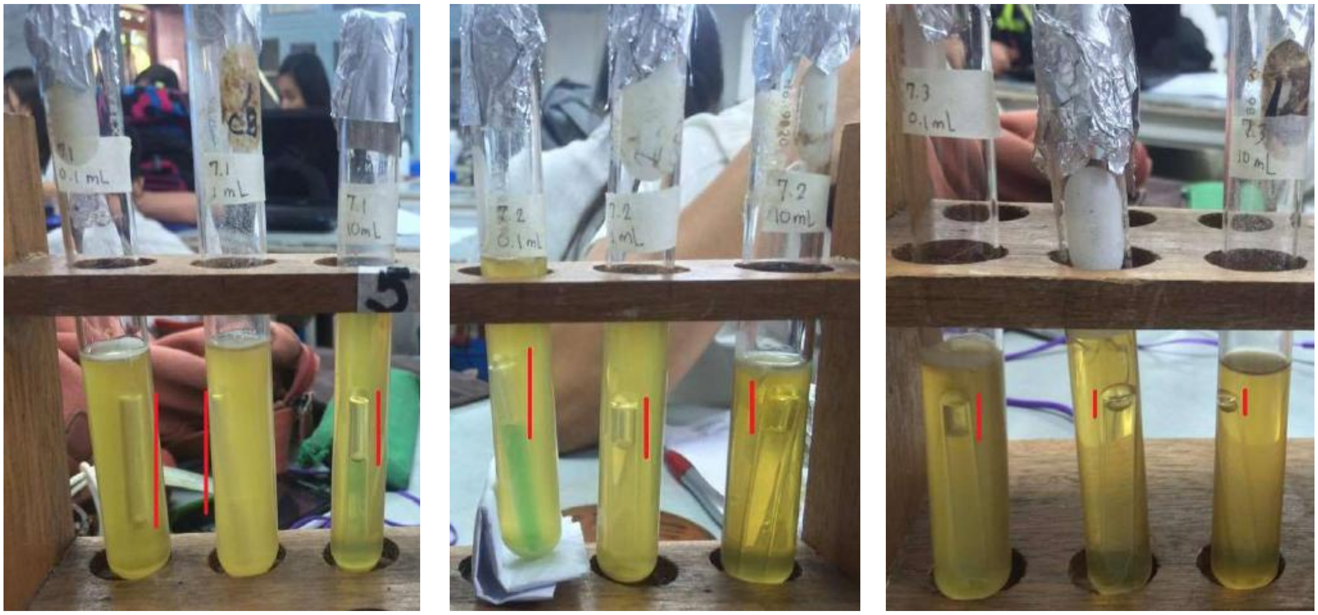

Figure 4. Gas formation in the tubes on comfirmatory tests.

Similarly, all the water samples gave a positive result for the EMB confirmatory test. Colonies showed a dark center with greenish metallic sheen (Figure 5) and this indicates the presence of *Escherichia coli* in the water sample while colonies with the mucoidal, convex and brownish colour indicated *Enterobacter* colonies in the water sample.

Figure 5. Bacterial (*E. coli*) colonies showing the characteristic greenish metallic sheen in EMB.

Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material. Water pollution caused by fecal contamination is a serious problem due to the potential for contracting diseases from pathogens. Frequently, concentrations of pathogens from fecal contamination are small, and the number of different possible pathogens is large. Testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present.

The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply. Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. Fecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms. *Escherichia coli* (*E. coli*) is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only *E. coli* is generally not found growing and reproducing in the environment. Consequently, E. coli is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.

Water usage and classification in the Philippines is followed in accordance to the DENR Administrative Order No.34 Series of 1990 which states that the quality of Philippine waters shall be maintained in a safe and satisfactory condition according to their best usages. For this purpose, all waters shall be classified according to the following beneficial usages: Class AA that is intended primarily for having watersheds which are uninhabited and otherwise protected and require only approved disinfection in order to meet the National Standards for Drinking Water (NSDW) of the Philippines; Class A for water supply that will require complete treatment in order to meet the NSDW; Class B for primary contact recreation; Class C as fishery water, recreational water class II and industrial water supply class I; Class D for agriculture, irrigation, and as industrial water supply class II.

Human and animal feces may pollute ground and surface water. Wells are a greater cause for concern because they don't often have any disinfecting system. Sources of drinking water can still become contaminated through naturally occurring chemicals and minerals, local land use practices (pesticides, chemicals, animal feeding operations), malfunctioning wastewater treatment systems like sewer overflow and nearby septic tanks (CDC, 2015). Furthermore, a missing or defective well cap may be cracked, letting in contaminants; contaminant seepage through the well casing allow water that has not been filtered through the soil to enter the well ; and contaminant seeping along the outside of the well casing.

If coliform bacteria are present in your drinking water, your risk of contracting a water-borne illness is increased. According to Centers for Disease Control and Prevention (2014), although most kind of *Escherichia coli* are harmless, others can make humans sick. Some pathogenic *E.coli* that causes urinary tract infections, respiratory illness, bloodstream infections and diarrhea can be transmitted through contaminated water. Other kinds of *E.coli* are used as markers for water contamination. Best way to protect the person against *E.coli* infections is to avoid swallowing water that is found to be contaminated.

CONCLUSION

The waters from the sampled wells in Malapascua island is not suitable for human consumption.

RECOMMENDATION

In regards for short-term solutions, boiling of the water prior to utilization and/or chlorination would be the best course of action to render the medium relatively safer. For long-term consideration water treatment facility is highly needed for safer drinking water. Likewise, restrictions on the current practice and utilization of the wells should be implemented. There should also be proper wastewater treatment for sewage water in order to reduce the contamination of the water supply in the wells.

Furthermore, monitoring of the well waters must be conducted on a regular basis. Active commitment of all stakeholders for a safe drinking water in Malapascua must be pursued.

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