

WATER QUALITY OF TRADITIONAL COMMUNAL DRINKING WELLS: THE CASE OF A FISHING COMMUNITY IN PANUKULAN, POLILLO ISLAND, QUEZON, PHILIPPINES

Arthur J. Lagbas^{1,2*} and Consuelo Dl. Habito¹

¹ Faculty of Management and Development Studies, University of the
Philippines Open University, Los Baños, Laguna, Philippines

² College of Arts, Sciences and Technology, De La Salle Araneta University,
Salvador Araneta Campus, Victoneta Avenue, Malabon City, Philippines

*Corresponding author: arthur09lagbas@gmail.com

ABSTRACT – In distant island communities like Polillo Island, adequate supply of freshwater and potable water is becoming a problem due to increasing population and climate change. Traditional communal drinking wells are reliable sources of potable water but groundwater is vulnerable to contamination from a range of sources. A study was conducted to assess the water quality of three traditional communal drinking wells in Barangay Libo and Barangay Pandan in the Municipality of Panukulan, Polillo Island, Quezon. Water samples were collected in May 2014 and November 2014, and the physico-chemical and microbiological parameters were characterized. Physico-chemical analysis showed that water samples are within the limits recommended by the Philippine National Standards for Drinking Water (2007). Microbiological analysis indicated total coliform and fecal coliform contamination and the possibility of the presence of water-borne pathogenic microorganisms. Data from the barangay health station showed that incidence of diseases associated with consumption of contaminated water are rare possibly because the local people may have developed partial immunity. This study indicates that well water if consumed untreated is not suitable for human consumption due to fecal coliform contamination. Use of disinfectants and implementation of protection measures to wells is necessary to improve the groundwater quality.

Keywords: Water quality, traditional communal drinking well, physico-chemical, microbiological, Panukulan, Polillo Island

INTRODUCTION

Access to safe and sustainable drinking water source is a worldwide major problem. This problem is most evident in low income rural communities in developing countries, and in isolated island communities where distribution of water through piped network is not possible. For this reason, most people rely mainly on rainwater harvesting and groundwater sources for their household needs. The traditional sources of drinking water which include rainwater, boreholes, natural spring, and hand dug wells are considered as indispensable sources by the rural sectors. However, the safety and quality of these water sources, particularly hand dug wells, depend on environmental factors, management of resource users, proximity to pollution sources and other risk factors. The most vulnerable to chemical and microbial contamination are the hand dug wells (Liddle et al 2015, Wuta et al 2015, Kamanula et al 2014,

Table 1. Location and characteristics of traditional communal drinking wells in Panukulan, Polillo Island.

Type of water source	Protection feature	Location and surrounding area
<i>libis</i> well	concrete internal casing, concrete mouth casing, concrete cover, concrete surrounding pavement	Barangay Libo, near rice field and houses, a few meters away from a shallow well used for bathing and washing clothes
<i>lawis</i> well	concrete internal casing, concrete mouth casing, iron sheet cover, concrete surrounding pavement	Barangay Libo, inside a private lot, near a rice field and houses, a few feet away from a deep well used for bathing and washing clothes
well	no internal casing, concrete mouth casing, plastic screen cover, concrete surrounding pavement	Barangay Pandan, upland, in the middle of a coconut farm and surrounded by trees and small plants, far from houses
spring	no protection	Barangay Kinalagti, upland, in the middle of coconut farm, far from houses

Libis well is located in a private lot and in a low density residential area. It was designated by the barangay local government as a common property well. The well is shallow and was manually dug in sandy bedrock. The well is fully protected; has concrete internal casing, concrete mouth casing, concrete cover, and concrete surrounding pavement. A manual pump was installed to collect water. According to local people, *libis* well does not dry up in summer season. On one hand, *lawis* well is inside a privately owned lot and is near a rice field. *Lawis* well is deep compared with *libis* well and was manually dug in solid bedrock. The internal casing, mouth casing, and surrounding pavement is concrete, and the mouth is covered with a rusty iron sheet. Like *libis* well, *lawis* well does not dry up in summer season and is continuously fed by groundwater recharge.

Collection of water samples

Water samples in drinking wells and spring were collected between 0500H to 0630H on May 30, 2014 and November 8, 2014. Water samples were also collected in two private rainwater concrete tanks for comparison.

Three 500 ml water samples were collected using a plastic bucket traditionally used by the local people. Polyethylene bottles were rinsed with water samples three times before they were filled to capacity. For water sampling in *libis* well, water was pumped out for two minutes to discharge stagnant water that had stood for a period in the service pipeline. The sample bottles were rinsed three times before collection.

Samples for microbiological test were collected in 120 ml sterile bottles. The mouth of the sampling bottle was sprayed with 70% ethanol and a nylon string previously disinfected with 70% ethanol was tied on the mouth of sampling bottles. The sampling bottles were plunged into the well below the water level until the bottles were filled then pulled out and the mouth of the bottle was sprayed with alcohol before covering.

Physico-chemical analysis

The water samples were analyzed for the following water quality parameters: chloride, electric conductivity, fluoride, nitrate, pH, salinity, total iron, total hardness, and total dissolved solids (TDS). Color was observed by visual inspection of water while odor and taste were determined by sensory evaluation. The pH was determined using a BECKMAN pH meter and RoHS PH-009(I)A pen type pH meter. Chloride content and total hardness were determined following the American Public Health Association Standard Methods for the Examination of Drinking Water and Wastewater (APHA 1992). Conductivity, salinity and TDS were determined using EZDO 7200 pen type pH meter and HM Digital Water Tester (AP-1). Fluoride, nitrate, and total iron were analyzed using Hach DR 3900 spectrophotometer. Results were compared to the limits recommended by the PNSDW (2007).

Microbiological analysis

Water samples were analyzed for total coliform and fecal coliform using multiple tube fermentation method and heterotrophic plate count (HPC) using pour plate method. All samples were analyzed following the methods recommended by the National Reference Laboratory, Department of Health. Results were compared to the limits recommended by the PNSDW (2007).

Barangay health profile

Health records which contained the demographic profile of patients, symptoms and diagnosis of health worker were obtained from Barangay Health Station on May 29, 2014 to check for cases of diseases associated with consumption of contaminated water. Available data at the time of collection were from April 18, 2012 to May 20, 2014.

RESULTS AND DISCUSSION

In Barangay Libo the traditional drinking wells, *libis* well and *lawis* well, had adequate supply of freshwater year round. *Libis* well serves as the main source of clean and safe drinking water of Barangay Libo and other nearby barangays. This well is located a few meters away from houses and a rice field. This well is protected with concrete cover and a pipe is connected to a manual pump to extract the water. A few meters away from *libis* well is a shallow well traditionally used for bathing and washing clothes only. Like *libis* well, this well is also a few meters away from houses and rice fields. Often, the water used for feeding the pump in *libis* well comes from the shallow open well. Another source of drinking water is *lawis* well, a privately owned well located at the foot of a hill beside a rice farm. This well is few meters away from a non-drinking well which is used for bathing and washing clothes.

The other communal drinking water sources are located in Barangay Kinalagti and Barangay Pandan. However, unlike *libis* well and *lawis* well, the spring in Kinalagti and hand dug well in Pandan are located in the remote part of the barangay. Both water sources are within a coconut forest and far from the barangay road. Local people said that Pandan well and Kinalagti spring dry up in summer season.

In all wells, the local people use a bamboo pole with plastic bucket to collect water. The plastic bucket and bamboo pole are only replaced when they are damaged, and because these are traditionally used every day without soaping or disinfection, the plastic bucket and bamboo pole could be a source of microbial contamination. When not in use the plastic bucket is hung on tree branches.

Physico-chemical quality of well water

As presented in Table 2, the physico-chemical parameters of well water samples changed with season, and were within the recommended limits of the PNSDW (2007), except for the water pH of *lawis* well and shallow well in Barangay Pandan which were below the recommended limit of the World Health Organization (pH range: 6.5-8.5). The chloride decreased in the following order: *libis* well > *lawis* well > Pandan well, and was slightly higher in November water samples. High chloride in water gives a salty taste and causes formation of deposits in kettle. Electric conductivity ranged from 171-603 $\mu\text{S}/\text{cm}$ (May) and 78-605 $\mu\text{S}/\text{cm}$ (November). Total hardness ranged from 36-276 mg/l (May), 27-350 mg/l (November), and was higher in November samples than May samples. Hard water, which is high in calcium and magnesium, causes formation of deposit in kettle, and prevents dissolution of soap and detergent, but is not a health hazard (Moyo 2013). Iron was only detected in highest concentration in *lawis* well. High iron concentration has no health implications (Moyo 2013). Fluoride was not detected in the May samples. Fluoride in water contributes to the development of healthy teeth but concentration in excess of 1.5 mg/l can lead to mottling of teeth and skeletal fluorosis (Pritchard et al 2008). Nitrate was detected only in May samples of *lawis* well and *libis* well; both wells were near the rice farm. The possible source of nitrate is inorganic fertilizers applied to rice fields during farming season. The below detection limit of nitrate in November samples could be due to the dilution effect during wet season. High level of nitrate may cause methaemoglobinaemia (Moyo 2013). Water pH ranged from 6.13-7.33 (May) and 5.9-7.6 (November). This could be due to higher dissolution of many substances when groundwater is abundant during the rainy season. Acidic water in which the pH is less than 6.0 (Pritchard et al., 2007) can cause corrosion of protection material in well such as metal internal casing. Salinity ranged from 51-301 ppt (May) and 40-83 ppt (November). TDS ranged 65-402 mg/l (May) and 49-294 mg/l (November), and was lower in November than in May possibly due to dilution effect during rainy season (Pritchard et al 2007) and groundwater recharge (Wuta et al 2015). High TDS makes the water unpalatable to drink (Pritchard et al 2008).

Comparison of the water quality characteristics of the three drinking wells showed that the water quality of Barangay Pandan well was superior, while *libis* well exhibited the highest chloride, conductivity, salinity, total dissolved solids and total hardness. This could be attributed to the fact that *libis* well was located a few meters away from the shoreline. The results also confirmed local peoples' observation that *libis* well water was slightly salty. A comparison of the water pH of *lawis* well to other studies showed similarity to the water pH of wells along a dambo transect in Chihota, Zimbabwe (6.32-6.39) (Wuta et al 2015) and water pH (mean pH=6.5) of shallow wells within dolomite-limestone formation in Ndora, Zambia (Liddle et al 2015). On one hand, Barangay Pandan well was located in upland, vegetated area and far from the seashore, hence the conductivity, chloride content and salinity were low compared with *libis* well and *lawis* well. Total iron of well waters was three times higher compared with spring water and about eight times higher compared with rainwater, while fluoride was not detected in May samples. Water samples in *lawis* well had the highest total iron content. Iron contamination probably originated from the rusty iron sheet cover used to protect its opening from materials accidentally falling on the well such as leaves, stems, plastics and feces of birds and fruit bats which could be a source of fecal coliform contamination. Nevertheless, the total iron concentration was far below the limit recommended by the PNSDW. Meanwhile the electric conductivity, hardness and salinity of spring water collected in Barangay Kinalagti were comparatively lower than well water samples. Rainwater harvested in a private concrete storage tank in November 2014 had a pH value of 8.88 and was comparable to rainwater pH (range: 7.63-8.80, mean: 8.35) in Kefalonia Island, Greece (Sazakli et al 2007). On the other hand, in a study conducted by Moon et al (2012), the pH of rainwater

samples in Jeju volcanic island, Republic of Korea, from June to October, 2008, was in the range of 3.1-7.4 (mean=5.2). This study showed that rainwater in Polillo Island is not acidic. In an unpolluted island community like Polillo Island, where freshwater is scarce, rainwater harvesting is of great socio-economic importance due to its practicability (rainwater is collected at or near the point of consumption), low operation cost, low maintenance cost, and few negative environmental impacts. Rainwater has usually superior chemical and physical properties than groundwater which is relatively subject to contamination. Besides the organoleptic characteristics of rainwater such as color, taste, smell and turbidity are highly acceptable to local people.

Simple regression (Figure 3) and correlation analysis were performed using Microsoft Soft Excel and MINITAB version 15. Correlation analysis revealed significant positive correlation between chloride and conductivity ($p=0.004$), chloride and total hardness ($p=0.004$), chloride and salinity ($p=0.004$), chloride and TDS ($p=0.021$), conductivity and total hardness ($p=0.000$), conductivity and salinity ($p=0.000$), conductivity and TDS ($p=0.000$), total hardness and salinity ($p=0.000$), total hardness and TDS ($p=0.000$), and salinity and TDS ($p=0.000$) at $p=0.05$ (Table 3).

Table 2. Physico-chemical properties of water samples collected in May 2014 and November 2014.

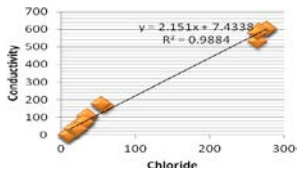
Parameters	May 2014				November 2014				PNSDW Limit ^e
	LaW	LiW	PW	KS	LaW	LiW	PW	RW	
Chloride ^a	17.40	29.69	11.40	12.60	30.8	43.6	18.7	5.70	250
Conductivity ^b	171 ^d	603.3 ^d	103.67 ^d	31 ^d	172 ^d	605 ^d	78 ^d	0 ^d	-
Fluoride ^a	nd	nd	nd	nd	0.02	0.01	0.02	nd	1.0
Total hardness ^a	55.56	276.51	36.38	20.26	59.4	349.6	27.1	10.13	300
Total iron ^a	0.173	nd	0.05	0.02	0.04	<0.01	<0.01	nd	1.0
Nitrate ^a	0.53	0.67	nd	nd	nd	nd	nd	nd	50
pH	6.37 ^d	7.33 ^d	6.13 ^d	6.13 ^d	6.33 ^d	7.60 ^d	5.90 ^d	8.88 ^d	-
Salinity ^c	82 ^d	301 ^d	51.3 ^d	51.3 ^d	83 ^d	310 ^d	40 ^d	0 ^d	-
TDS ^a	116 ^d	402 ^d	65 ^d	65 ^d	84 ^d	294.33 ^d	49 ^d	0 ^d	500

Note: Data are average of three trials. LaW means *Lawis* Well, LiW means *Libis* Well, KS means Kinalagti Spring, PW means Pandan Well, RW means rainwater, nd means not detected, ^aunit is mg/l; ^bunit is $\mu\text{S/cm}$, ^cunit is ppt, ^dmeasured on site

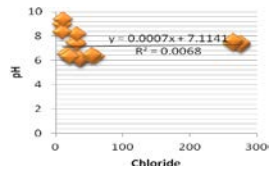
Table 3. Pearson correlation coefficients between different physico-chemical parameters.

	Chloride	Conductivity	Total hardness	Nitrate	pH	Salinity
Conductivity	0.848*					
Total hardness	0.849*	0.980*				
Total iron	-0.209	-0.199	-0.299			
Nitrate	0.085	0.400	0.253			
pH	0.015	0.230	0.323	-0.054		
Salinity	0.850*	1.000*	0.985*	0.381	0.237	
TDS	0.747*	0.976*	0.923*	0.554	0.195	0.971*

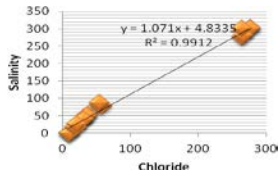
Note: *significant at p=0.05



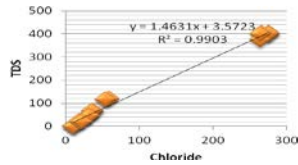
a



b



c



d

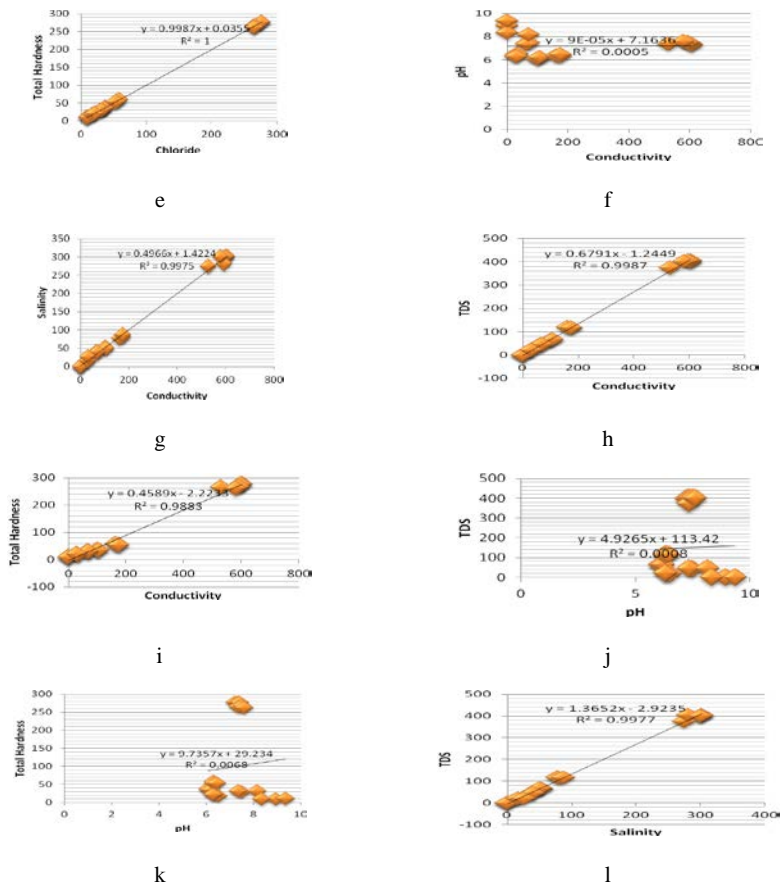


Figure 3. (a) Scatter plot of (a) chloride and conductivity (b) chloride and pH (c) chloride and salinity (d) chloride and TDS (e) chloride and total hardness (f) conductivity and pH (g) conductivity and salinity (h) conductivity and TDS (i) conductivity and total hardness (j) pH and TDS (k) pH and total hardness (l) salinity and TDS

Microbiological Analysis

Total coliform and fecal coliform

Fecal coliform and total coliform of well water samples except rainwater showed that the microbiological quality exceeded the limit of the PNSDW (2007) (Table 4). This makes the well water unsuitable for drinking without any treatment. The World Health Organization guidelines for drinking

water quality recommend that there should be no trace of total or fecal coliform. However, following the PNSDW (2007), if the total and fecal coliform count exceeded 1.1 most probable number (MPN) per 100 ml, water is deemed to be microbially contaminated and is unfit for human consumption. Water samples, which showed positive result for total coliform test, contained *E. coli* but may also contain a variety of environmental bacteria which do not necessarily indicate fecal contamination from human and animal wastes. On the other hand, fecal coliform is more specific for *E. coli*, indicating contamination by mammal and bird feces and signifying the presence of pathogenic bacteria and viruses which are responsible for water-related diseases such as cholera, typhoid and other diarrheal-related diseases (Pritchard et al 2008). Multiple possible sources of microbial contamination are contaminated buckets, ropes and bamboo rod used for scooping water, point and non-point sources (grazing animals, rice farms, landfill sites, road runoff and septic tanks), hydrogeological properties (bedrock type, subsoil type and subsoil thickness) (Hynds et al 2014, Malaguerra et al 2013), and climatic and seasonal factors (Zabed et al 2014, Richardson et al 2009, Pritchard et al 2008, Sazakli et al 2007). Microbial water quality deteriorates during wet season (Pritchard et al 2008, Pritchard et al 2007; Howard et al 2003) and the risk of *E. coli* detection was greatest if the water samples were obtained one day after heavy rainfall (Richardson et al 2009; Howard et al 2003). High incidence of water-borne diseases occurred in wet season (Bordalo and Savva-Bordalo 2007). The possible explanation is the rapid movement of pollutants from fecal matter and solid wastes (which are usually found in surface soil) to groundwater and increased turbidity level during rainy season. Colloidal particles which make the water turbid are favourable for microbial growth (Pritchard et al 2007, Howard et al 2003).

Heterotrophic Plate Count

The heterotrophic plate count (HPC) results of water samples collected in May 2014 are presented in Figure 4. HPC test showed that *libis* well had the largest number of colonies indicative of the presence of many microbial populations (Figure 4a). On the other hand, spring (Figure 4d) and rainwater samples (Figure 4e) showed lowest number of microbial colonies.

Table 4. Fecal Coliform (FC) and Total Coliform (TC) result of water samples

Source of water	May 2014		November 2014	
	Most probable number per 100 ml		Most probable number per 100 ml	
	Fecal coliform	Total coliform	Fecal coliform	Total coliform
<i>Libis</i> well	> 8.0	> 8.0	> 8.0	> 8.0
<i>Lawis</i> well	> 8.0	> 8.0	> 8.0	> 8.0
Kinalagti spring	> 8.0	> 8.0	> 8.0	> 8.0
Pandan well	> 8.0	> 8.0	> 8.0	> 8.0
Rainwater	< 1.1	< 1.1	> 8.0	< 1.1

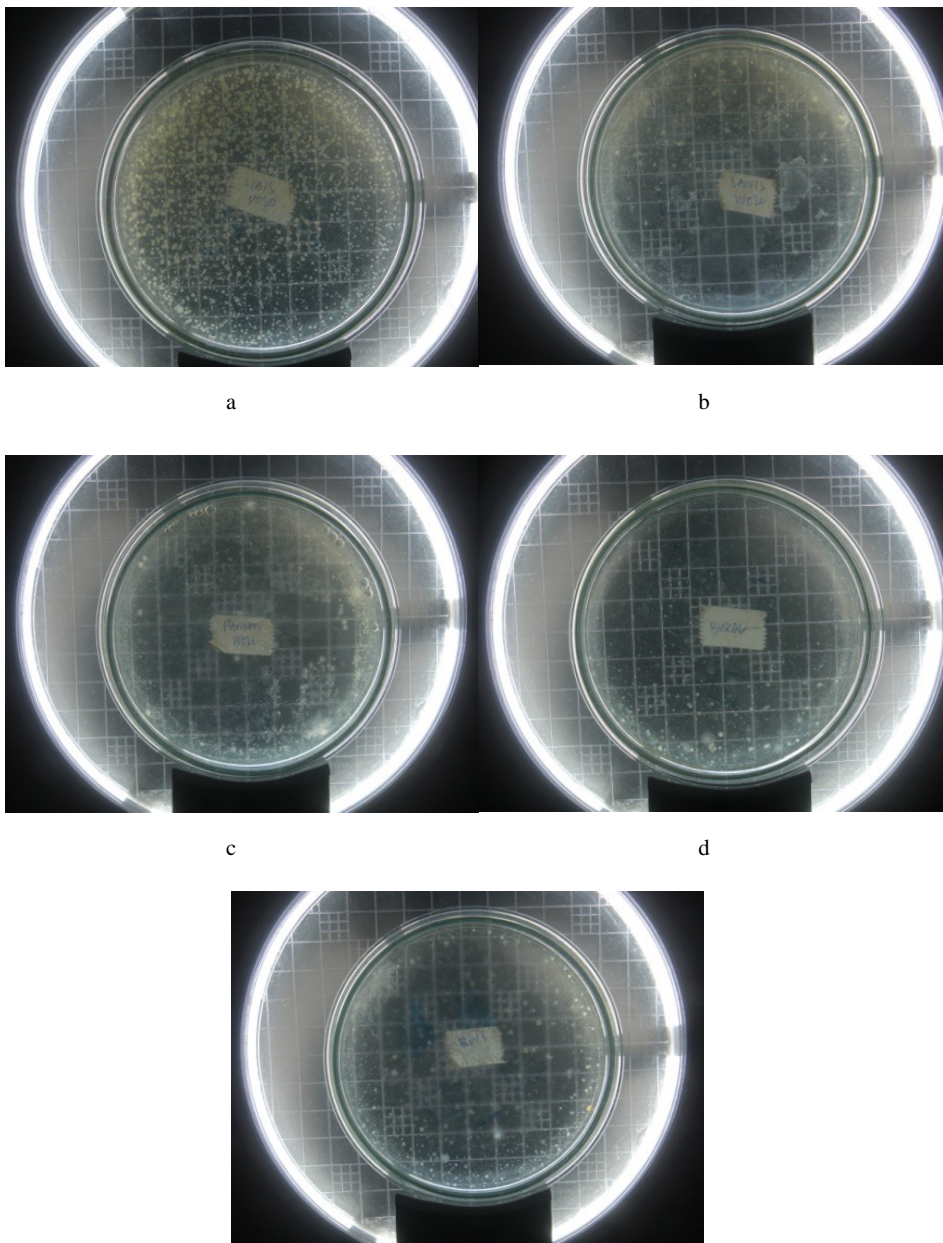


Figure 4. Heterotrophic Plate Count (HPC) of (a) *libis* well, (b) *lawis* well, (c) Pandan well, (d) Kinalagi spring, (e) rainwater from a private tank.

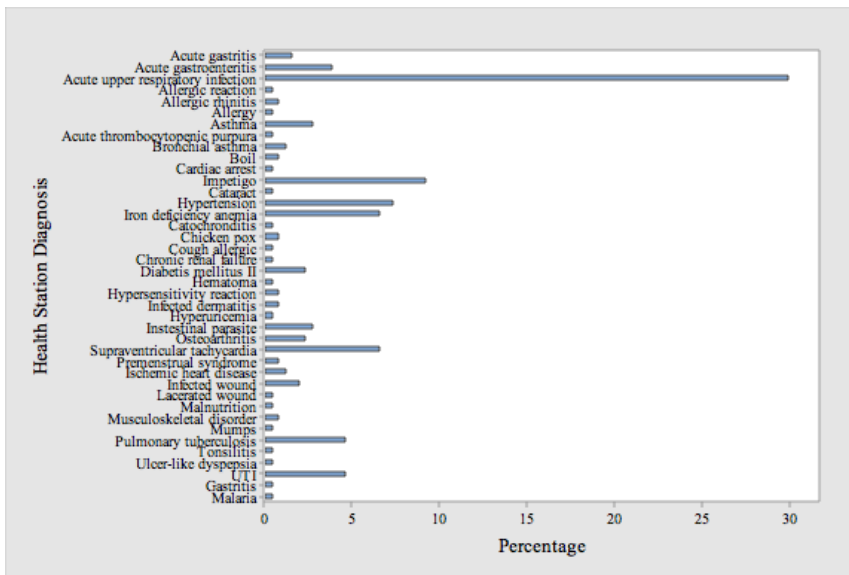
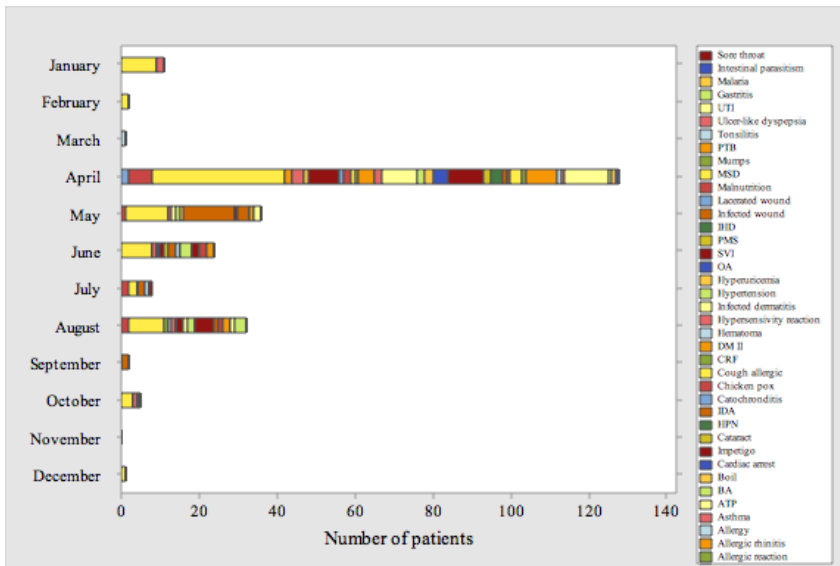


Figure 5. (a) Occurrence of health problems per month from April 2012 to May 2014. (b) Percentage of health problems from April 2012 to May 2014.

Barangay health profile

Health records (Figure 5a) showed highest recorded number of patients during the month of April followed by the months of May, August and June. There were no patients reported for the month of November. Acute upper respiratory infection (AURI) was the most frequently encountered health problem (Figure 5b). Furthermore, it showed that AURI was most common in children age 1 to 10 years old, while the less frequently reported health problems were iron deficiency anemia, urinary tract infection, systemic viral infection, pulmonary tuberculosis, hypertension (HPN), acute gastroenteritis (AGE), impetigo, diabetes mellitus (DM), asthma, boil, acute gastritis, intestinal parasitism, allergy, ischemic heart disease (IHD), gastritis, tonsillitis, dermatitis, musculoskeletal disorder (MSD), chicken pox, dyspepsia, premenstrual syndrome (PMS), and other disorders. Illnesses suspected to be related or associated with consumption of contaminated water were acute gastritis, acute gastroenteritis, gastritis and urinary tract infection, but these are rarely reported.

CONCLUSION

Hand dug wells in Polillo Island are the only reliable source of potable and drinking water to the local people and their suitability for providing safe water must be evaluated. In this study, the waters in communal drinking wells, spring and harvested rainwater are suitable for human consumption in terms of physico-chemical parameters of the PNSDW (2007). However, microbiological characterization revealed that the well water samples were contaminated by fecal and coliform bacteria, making it unfit for human consumption without treatment. The sources of contaminants were not conclusively identified in this study. The validity of the microbial test result should be checked by conducting *in situ* microbial testing. Rainwater quality was of comparable quality with purified water in terms of physico-chemical parameters and has low fecal and coliform count, thus rainwater harvesting is seen as the safest source of drinking water. However, the quality of rainwater is affected by the availability, management, and maintenance of rainwater collecting tanks.

Based on the patient records of Barangay Health Station, there was no incidence of illnesses associated with consumption of microbiologically contaminated water such as diarrhea, cholera, typhoid fever and urinary tract infection. However, the low incidence of suspected water-borne diseases does not guarantee that the communal drinking wells are safe for human use. People should observe precautionary measures to ensure safety of their drinking water such as disinfection by chlorination and full protection of wells. While it is possible that the level of microbial pathogens in well water is low or negligible when tested *in situ*, the local people, most especially the adults in the community, may have developed partial immunity to the microorganisms because of continuous exposure (Richardson et al 2009 and the references therein).

RECOMMENDATION

This study recommends the following:

1. Water from all communal wells should be boiled, treated with inexpensive disinfectant or powdered seeds of *Moringa oleifera* (Pritchard et al 2009) before use, most especially water from *libis* well because this showed the highest microbial colony count.
2. The use of iron sheet as cover for *lawis* well should be replaced by corrosion resistant material to reduce iron contamination.

3. Provide internal casing, mouth casing and cover to the well in Barangay Pandan to reduce its vulnerability to contamination. Concrete well opening should be constructed and elevated above the ground surface to prevent direct ingress from overland flow particularly during rainy season (Liddle et al 2015).
4. The water pH of *lawis* well and Pandan well can be increased by adding inexpensive material such as oyster/clam shells to drinking water containers (Bordalo and Savva-Bordalo 2007).
5. During rainy season when water quality deteriorates (e.g. increased turbidity) during rapid groundwater recharge, drinking water should be collected before heavy rainfall event.

STATEMENT OF AUTHORSHIP

This study was part of the special problem of the first author for the Master of Environment and Natural Resources Management at the University of the Philippines Open University. Data collection and analysis, key informant interviews and final paper was done primarily by the senior author with significant contributions from the other author.

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