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Domestic Water Quality and Sanitation in Panglao Island, Bohol, Philippines

ABSTRACT

A study on water quailty and sanitation is conducted in an urban poor district in Panglao Island, Bohol Province, Philippines. Groundwater is the main domestic water source in the resort Island, where open dug wells and piped-water from deep wells supply the domestic needs of most households. But municipal reports show that from 2000-2003, diarrhea was among the top 10 leading causes of morbidity in the municipality. Household surveys, focused group discussions, infrastructure inspection, and initial field tests showed water quality concerns in the area which include saltwater intrusion and fecal contamination, among others. The aquifer is found to have high level of chlorides (i.e., 990 to 8,550 mg/L and 387 to 8,337 mg/L during wet and dry seasons, respectively) which exceeds WHO threshold value of 250 mg/L. Water sources (wells) in the island are also contaminated in both seasons where 24 out of 26 wells are positive for fecal Coliform. Thus, long term solutions for Panglao Island are necessary to safeguard the health of water users in the island resort. One option is water connection to Bohol mainland and installing a sewerage network with centralized treatment.

Key words: *Panglao Island, PCA, Water Quality, Sanitation, Salinity, E. coli*

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INTRODUCTION

Urban poor districts are usually densely populated areas where resources are depleted first. Contamination, safe water supply depletion, disease outbreaks and other symptoms of environmental degradation happen first in areas of high population densities. Of the many known human infections, diarrhea is considered the most important public health problem worldwide (*WHO-UNICEF 2000*). WHO estimates that 88% of all cases of diarrhea globally are attributable to water, sanitation and hygiene. Children in developing countries lose 8-times more healthy per capita life years than those in developed countries from environmentally-caused diseases (*Prüss-Üstün and Corvalan 2006*). In the Philippines, diarrhea was the leading cause of morbidity in 2001; ranking 5th among the 10 leading causes of infant mortality in 1998 (*GTZ 2003*). The United States Agency for International Development (USAID) estimates that 12 Filipinos die daily due to diseases traceable to contaminated water (U*SAID 2006*) and many water-related diseases are associated with the unsanitary disposal of excreta. The World Bank estimates that the Philippines suffer $1.3 billion in losses every year due to water pollution (*World Bank 2004*). Groundwater supply is contaminated with coliform primarily due to discharges of partially treated or untreated domestic effluents (*USAID 2005*).

In the province of Bohol, where a sewerage system does not exist, households rely solely on sanitation facilities. In 2003, the service coverage of sanitary toilets in the province was 79% of the total households. This figure was below the 88% average for the entire Philippines. Service coverage was higher in the urban areas (83%) of the province than in the rural areas (77%). It is widely suggested that water, sanitation and hygiene intervention can reduce the high incidence of diarrhea by at most one-third (*Esrey et al. 1991*). In view of the above, the study was undertaken in areas identified as having the highest incidence of water-related diseases and poor sanitation coverage and practices, to meet following objectives: Assess the water quality of current supply sources, Identify the factors affecting water quality and environmental impacts of the present sanitation status and practices of the people, and Propose measures that can help improve the water quality status as well as alternative sources and strategies that can alleviate sanitation concerns in the area.

Based on the above, the research questions that are

aimed to be addressed in this study are: what are the factors that affect water quality and sanitation in Panglao Island, and how these factors can be managed to alleviate the water related problems, andprotect the health of the inhabitants. Based on this, the null hypotheses of the study are: There is no association between water treatment and ownership of latrine with water borne diseases (e.g., diarrhea); and there is no relationship between water adequacy and household income. Thus the research will involve household surveys within the urban districts of Panglao Island to baseline the water and sanitation status. Limited water quality tests will also be performed on selected water sources. It is envisioned that from this study, cost effective solutions to the identified problems such as *E. coli*, turbidity, salinity, etc.can be formulated.

Site Description

Geographic and demographic profiles. Panglao Island, a tourist destination in southwestern Bohol and having a land area of 92.4 km2, is made up of two municipalities: Dauis and Panglao. Coral reefs are found in the north and south fringes of the island which in recent times have been the subject of investigation into new species of crabs (*Davie and Naruse 2010*), banded sea snakes (Rasmussen and Ineich 2010) and others (*Anker and Marin 2009; Glover and Taylor 2013; Fedosov and Kantor 2012*). The aquatic flora and fauna of Panglao Island has been recognized as biodiverse (*Ter Poorten 2009*) but is, at the same time, under threat from the planned scale up of tourist arrivals with the construction of a new international airport in Panglao Municipality (*Bullecer et al. 2014*). Panglao Island is connected to the main island of Bohol by two bridges. The study focused on Panglao municipality.

The municipality of Panglao is in the southwestern part of Panglao Island. It faces the Mindanao Sea. Barangay Poblacion, the central district is located at a distance of about 18 km from Tagbilaran City, the provincial capital. Panglao municipality covers an area of 40.09 km^2 or 43.01% of Panglao Island's total area. The urban barangays are Bil-san, Danao, Doljo, Looc and Poblacion (**Table 1**). Doljo has the highest density i.e., 23.8 persons per ha.

The topography of Panglao Municipality is described as gently sloping as terrain gradually rises from 5 m to about 30 m above mean sea level (amsl) on the northwestern portion of the municipality.

Extreme poverty dominates the population with more than half of the urban households surveyed (58%) receiving a meager household monthly income of US$72.12 and below. At this level, quality of water supply and sanitation amenities are pushed further down the list of household priorities.

Water supply and service provision. Currently, Panglao households pay the local water works the basic rate of PhP 22.50 mo^{-1} for a minimum consumption of 5 m^3. An additional PhP 5.00.00 is paid for every cubic meter consumed beyond the minimum.

Rain is evenly distributed throughout the year in Bohol Province and only 7% of typhoons pass through. The least number of rainy days is in the months of February, March, April, and May. Northeasterly winds blow over the land during the months of May to October, and Southwesterly from November to April. Panglao Island receives an annual rainfall of 1,500 mm, which is almost even throughout. Temperatures range from 26.0°C in January to 28.2°C in August.

The study area has no rivers and creeks since the limestone landmass is permeable. All of the effective rainfall (estimated to 459 mm yr^{-1}) infiltrates as

Table 1. Population of Panglao Municipality by Barangays*.

Barangay	Population	Area (ha)	Density Per ha	Households (HH)	Persons Per HH
Bolod	1,491	597.99	2.49	274	5.44
Bil-isan	2,750	364.37	7.55	479	5.74
Danao	2,752	789.65	3.49	546	5.04
Doljo	2,615	109.88	23.80	487	5.37
Libaong	1,342	423.27	3.17	259	5.18
Looc	1,873	254.11	7.37	346	5.41
Lourdes	1,003	377.39	2.66	179	5.60
Poblacion	3,988	287.14	13.89	828	4.82
Tangnan	2,818	682.87	4.13	522	5.40
Tawala	2,784	891.80	3.12	561	4.96
TOTAL	23,416	4,778.47	4.90	4,481	5.23

*source: Panglao Municipal Planning and Development Office (*Panglao MPDO 2005*)

groundwater recharge. Geo-resistivity investigations indicated the thickness of freshwater lens is 60 m (*Pagsuyoin 2005*). Groundwater level is about 1.25 m above sea level. Panglao Island is a typical uplifted limestone oceanic island (*Husana and Yamamuro 2013*). The entire island is underlain by the Maribojoc Limestone formation.

Although the main economic driver in Panglao is tourism (*Gulayan et al. 2015*), farming, fishing, and livestock production are the major sources of income for the greater population in Panglao. Monthly household income is below PhP 5,000.00 for most (*Pagsuyoin 2005*). Majority of the households in Panglao town are connected to a Level III system, i.e., a piped water supply with a private water point (e.g., house connection) based on a daily water demand of more than 100 liters per person. However it is not connected to Bohol Water Utilities, Inc. (BWUI) of Tagbilaran City. The system is run by the municipality, which oversees the sourcing and distribution of water. Pre-treatment is insufficient—the water is salty and non-potable (*Pagsuyoin 2005*). Because of this, some houses still maintain private wells and buy bottled water for drinking and cooking, and water delivery for other domestic uses.

Half of the surveyed 150 households in the urban barangays do not have their own piped water supply. Panglao town has not yet availed of the connection with BWUI since the LGU finds the PhP 35.00 m^{-3} rate that BWUI plans to charge Panglao residents expensive. Panglao sources its water from deep wells whose salinity is high. There are no treatments performed to bring down the salinity and hardness. The water is also not chlorinated which poses possible coliform contamination.

The waterworks development plan prepared by the Municipal Planning and Development Office in 2005 includes the laying, replacement, and rehabilitation of the pipes in the network. It also plans to activate dormant deep-well sources and develop new ones. For the project to self-liquidate, the LGU is to charge a minimum fee of PhP 140.00 a month, equivalent to 10 m^3 (*Panglao MPDO 2005*). The plan does not include a water quality component.

No sewerage system exists in Panglao Island. Water for flushing or personal cleaning is not readily available in the toilets and has to be fetched. Pour-flush pit latrine is the predominant toilet (83%) while septic tanks are rarely constructed due to its high cost. The dominant geology of the study area does not influence the choice of sanitation even when municipal planners are aware of the appropriate type. Moreover, anaerobic reactions in pits produce acid that can digest limestone (*Husana and Kikuchi 2013*).

METHODOLOGY

The urban barangays of Panglao Island were used to baseline the water and sanitation status using a survey instrument. This study was then extended to the whole island in the search and possible formulation of viable means in managing the island's water and sanitation needs. The limited water supply, the occurrence of water-related diseases, and the culture-related preference for water-based sanitation facilities are factors that affect the safe water and sanitation status of the island. Panglao Island has poor sanitation facilities which can bring degradation to the environment. Poor sanitation also produces health problems both to residents and visitors. The water supply quality is low and is not attractive to tourism and to the stimulation of further economic activity. Therefore this study aims to analyze the factors and causes of water quality and sanitation problems in the island by conducting questionnaire survey and collecting primary and secondary data which will be used in the groundwater, socioeconomic and demographic analyses.

Primary Data

Site inspection of current infrastructure of wells both communal and household, of household sanitation types and construction, and of the general layout of the urban sprawl as well as indicators as to where it is going were conducted to identify problems.

Household sanitation surveys were carried out among randomly selected houses in the study area. Questions in the survey revolved around the following: socio-economic and educational profile, available water supply and sanitation facilities, practices on sanitation, incidence of diseases in the family, and attitudes toward hygiene and sanitation that point to cultural peculiarities.

The survey sample size was estimated using the following statistical formula as per *Yamane* (*1967*):

$$n = \frac{N}{(1 + Ne^2)}$$

where,
n = sample size
N = household population
e = margin of error

A household survey was conducted to find out the socio-economic and educational profile of the residents, adequacy of water supply and sanitation. Water supply and sanitation infrastructures were inspected. A household population of 3,149 and a confidence interval of 92% (8% error) give a sample size of 148 (which was rounded off to 150).A focused group discussion (FGD) was also conducted to get a better understanding of the social dimension of the water supply and sanitation problem in the island. FGD, where perceived problems and coping behavior were asked, was conducted to determine the social dimension of the lack of water supply. The assumption in the FGD is that water is also a gender issue since women normally bear the burden of water related activities such as cooking, washing clothes, cleaning, and bathing the children (*Prüss-Üstün and Corvalan 2006*).The questions posed to the participants included their day-to-day experience related to water supply, their perceived problems and their coping behavior. Finally, they were also asked what solutions they had in mind.The assumptions made in relation to the questions formulated is the fact that women have basic needs that require access to water, which are the same as well as different from those of men. Basically, and quite importantly, women are the ones who bear the burden of water related activities (e.g., cooking, washing clothes, cleaning, bathing the children, etc.) which require the use of water.

In addition to questionnaire survey and FGDs, water quality measurements were done in the field from July 2006 to March 2007. For example, Panglao town wells were analyzed for *E. coli* and chlorides (which are the notable quality parameters in an initial test conducted by the authors). Of the 386 existing wells in Panglao town, 20 (or roughly 5%) were chosen although 6 wells and water sources from Dauiswere also tested to profile the whole island. Dauis eventually was taken out of the study since it is already enjoying piped water supply from the main island courtesy of the Bohol Water District.

The sampling was done on existing wells as bore samples require equipment and knowledge of the underground profile. About 30 candidate wells from a total of 386 were identified using a map from the Panglao Engineering Office with spatial distribution as the main criteria for sampling. Final sampling locations were decided in situ depending on the accessibility of the well from the road network as well as the presence of abstraction equipment such as pumps and pails.

Tests on salinity were done on the 20 wells (**Figure 1**). Two samplings were done at a five-month interval (November 2006 and March 2007). The samples were sent to the University of San Carlos Water Laboratory and Environmental Engineering Lab of the University of the Philippines for testing using argentometrictitration. It was found that all 20 wells have salinity levels beyond Philippine National Safe Drinking-water Standards which is 250 mg/L (*DOH 2007*).

The containers for the *E. coli* test were taken from

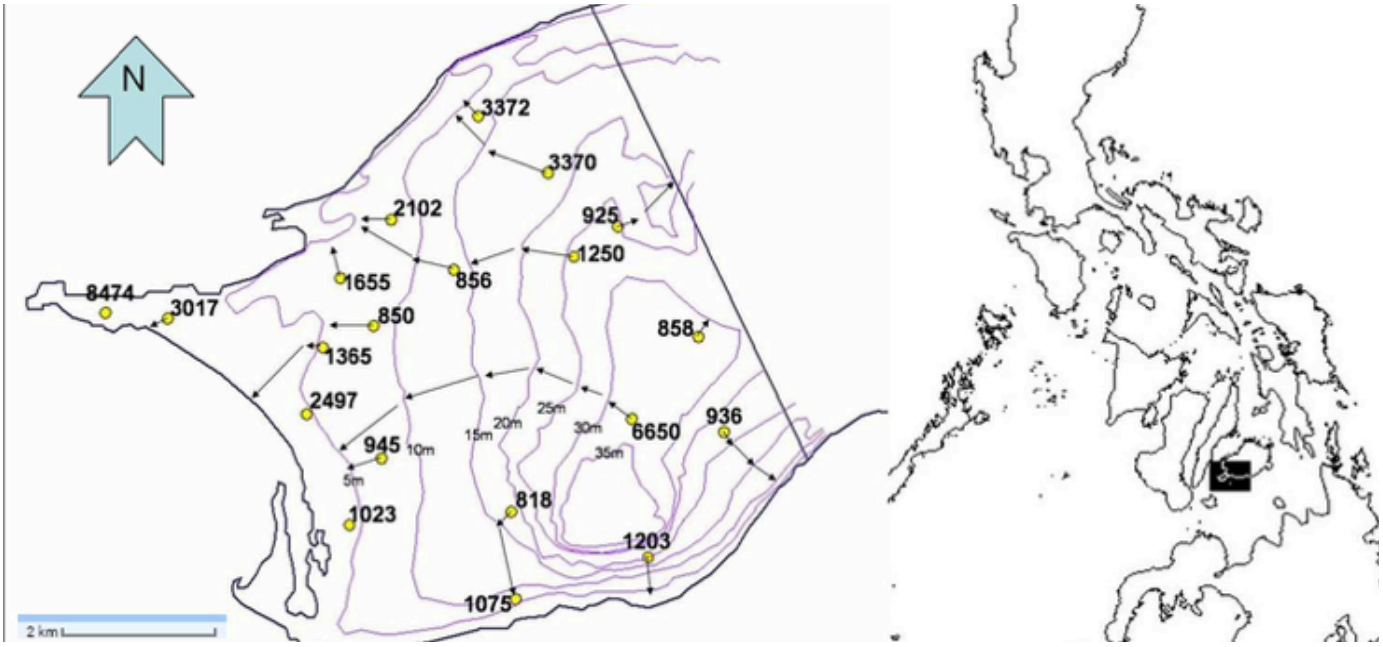

Figure 1. Contour Map & Locations of Sampled Wells in Panglao Municipality Showing Average Chlorides Values (mg/L) (2006-2007).

the Bohol Public Health Office Water Laboratory, are made of glass and are acid washed. The test used was the Most Probable Number method. Eventually, the six sites in Dauis were not pursued as they were hardly used-Dauis Municipality is connected to the Bohol Water District in the main island. There were 26 sampling locations for *E. coli* (**Figure 2**).

Secondary data from local GOs such as demography, climate, policies, and sanitation programs were also collected. Initial water quality tests included turbidity, *E. coli*, chlorides, hardness, nitrates, and sulfates.

Literature readily available outside of Panglao was limited yet information from national media indicates a high level of research activity conducted on the island. Thus, a significant portion of the field research was devoted to interviews of key informants and literature search on the archives of the provincial and municipal LGUs.

Key informants and relevant information were acquired from the Bohol Provincial Health Office Water Laboratory, the mayors, their executive secretaries, the MPDOs, the municipal engineers, MHOs, etc. as they are the most knowledgeable of the previous studies conducted in their respective bailiwicks. The line LGU agencies made available numerous literatures and pointed out institutions, both public and private, where specific data could be obtained. Secondary data collected from these sources included demography, climate, health and socio-economic profile, policies, and sanitation programs.

Parameter Sampling

Water sampling was conducted for selected water quality indicators since initial data during the survey and fieldwork indicate some quality concerns. As such, samples of groundwater and local water district supplies were analyzed. The water parameter test include the methodology employed, the entities that conducted the tests and the wells tested (**Table 2**).

The demographic data, socio-economic condition of the respondents, the present water and sanitation status, connection to the municipal pipe network, the

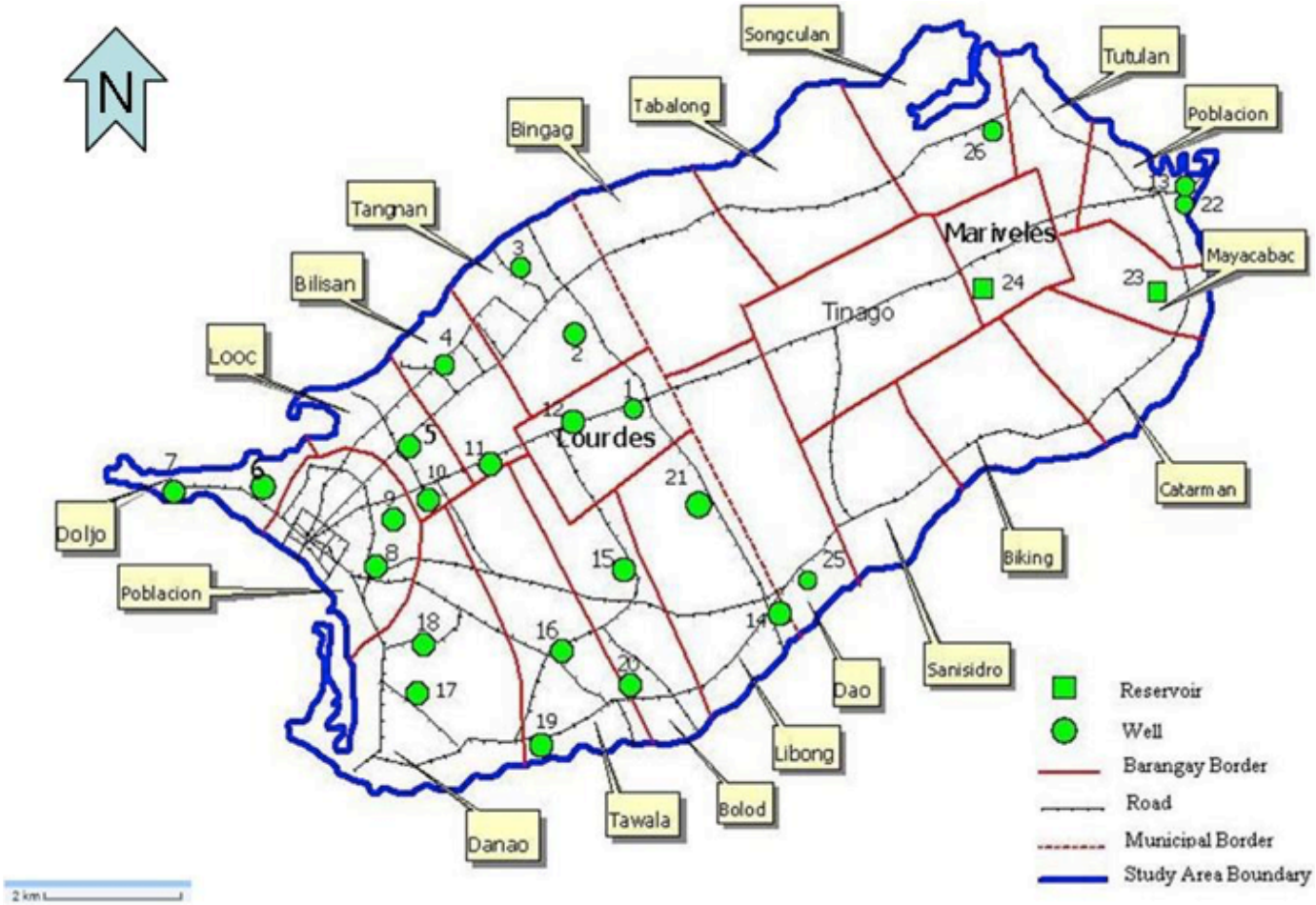

Figure 2. Location of Sampling Points for *E. coli* Test (2006-2007).

Table 2. Water quality parameter tests (standard).

Parameter	Method/Equipment	Performed by	Wells
Turbidity	Turbidity Meter	USC Water Lab and UP	3, 4, 8, 15, 19, 23-25
E. coli	MPN	Environmental Engineering Lab	1-26
	H2S Strip	Bohol PHO Water Laboratory [on site]	
Salinity	Argentometric Titration	USC Water Laboratory and UP Environmental Engineering Lab	1-20
Calcium hardness	Titrimetric	USC Water Laboratory and UP Environmental Engineering Lab	3, 4, 8, 15, 19, 23-25
Magnesium hardness	Calculation	USC Water Laboratory	3, 4, 8, 15, 19, 23-25
Nitrates	Cadmium reduction, NED colorimetric	USC Water Laboratory	3, 4, 8, 15, 19, 23-25
Sulfates	Turbidimetric	USC Water Laboratory and UP Environmental Engineering Lab	3, 4, 8, 15, 19, 23-25

household's knowledge of safe water and sanitation are expressed by way of charts, frequency tables, graphs, percentages, averages, standard deviations, crosstab tables and multiple response tables.

Pearson's Chi-Square was used to assess two types of comparison: tests of goodness of fit and tests of independence. A test of goodness of fit establishes whether or not an observed frequency distribution differs from a theoretical distribution. A test of independence assesses whether paired observations on two variables, expressed in a contingency table, are independent of each other. The non-parametric technique, chi-square test, was used when the data were measured on nominal (categorical) and ordinal (ranked) scales. It was used to compare the frequency of the categorical variables, education level of respondents, health and income, across the different categories of establishment of safe water and sanitation. Correlation was used to find out the relationship between the various kinds of independent variables of socio-demographic data and economic indicators and it is used as the analyzing tool prior to the use of the Principal Component Analysis (PCA).

Principal Component Analysis (PCA) is a technique for simplifying a data set, by reducing multidimensional data sets to lower dimensions for analysis. PCA was used to extract the main components that have high multi-colinearity of independent variables by using rotation methods: Varimax with Kaiser Normalization. The components with eigenvalues greater than one are selected as the new components. The variables with highest loading were selected and named the component depend on the commonness of the variables. The factor scores of the main components were used as the independent variables in the multiple regression analysis.

Fifty-seven of the total respondents are female and 93 are male. Most of the households have 5 members with the largest registering 10. The average household size is 4.57 persons (**Table 3**). The statistical software used for stat tests is SPSS.

RESULTS AND DISCUSSION

Demography and socio-economic conditions in the study area

Family structures such as size, number of dependents and dependency ratio were also acquired from the respondents of the six barangays (**Table 3**).

Income is an indicator of the existence of safe water and sanitation facilities. Almost 90% of the total households belong to the lowest income group (less than ₱6,000.00 monthly household income) (**Table 4**).

About 40% of the respondents have their own piped water, about 51% rely on the neighbors' piped water and 9% on open wells for their water supply (**Table 5**). Most of the wells, however are salty and are not suitable for household use. Water for domestic use takes up the bulk of

Table 3. Number of respondents interviewed in each barangay.

Name of Barangay	Interviewees	Percent
Doljo	30	20.0
Danao	24	16.0
Bilisan	21	14.0
Looc	13	8.7
Poblacion	38	25.3
Poblacion (Dauis)	24	16.0
Total	150	100.0

Table 4. Monthly income distribution of households.

Household Monthly Income (Pesos)	Frequency	Percent
<3,000 (US$ 62)	87	58.0
3,001-6,000 (US$ 62-123)	47	31.3
6,001-10,000 (US$ 123-205)	11	7.3
10,001-20,000 (US$ 205-410)	4	2.7
>=20,000 (US$ 410)	1	0.7
Total	150	100.0

Table 5. Source of water for domestic use.

Household Water Source	Frequency	Percent
Own piped water	60	40.00
Not own piped water	77	51.30
Open well	13	8.70
Total	150	100.00

water consumption in the household. Ideally, households should have it in abundant supply and readily available. Also, ideally the drinking water source is the same. But that is not the case in Panglao Island in most instances.

The respondents who have relatively high income purchase mineral water for drinking purposes. Those who cannot afford this get their drinking water from the tap. Boiling is done sometimes, but often water is just consumed directly without any prior treatment.

The Chi-square tests show that $p = 0$ which is less than $\alpha = 0.05$, and confidence interval is 99%, so that the null hypothesis that there is no association between water supply adequacy and occurrence of water-bourne diseases is rejected. It can be observed in the succeeding tables that there is a high occurrence water-bourne diseases among those households who have insufficient water supply (**Tables 6** and **7**).

Groundwater abstraction and salinity

Over-abstraction is the cause of salinity in the wells (*Panglao MPDO 2005*). An estimate of abstraction overload can be determined by plotting of the average of the chlorides per urban barangay versus the estimated abstraction rate- 27.65 m^3 yr^{-1} (*Aung 2007 and Caloza 2007*) per household, on a per ha basis. The limit is the intercept at the line at y (chlorides) equal to 250 mg/L, which is the national drinking water standard (**Figure 3**).

For the study area, the rate limit is 1.07 m^3 yr^{-1} ha^{-1}. The overload factor is computed by dividing the abstraction rate by 1.07. This in turn was used to determine the amount of intervention needed in terms of external (to the island) water supply (**Table 8**).

Table 6. Water supply adequacy vs occurrences of water-borne diseases.

Water Supply Adequacy	Occurrences of water-borne diseases				Total
	Yes		No		
	Count	%	Count	%	
Insufficient	85	85.9	14	14.1	99 (100.0%)
Average	3	23.1	10	76.9	13 (100.0%)
Sufficient	5	13.2	33	86.8	38 (100.0%)
Total	93	62.0	57	38.0	150 (100.0%)

Table 7. Chi-square test for water supply adequacy vs occurrence of water borne disease.

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	70.756	2	.000
Likelihood Ratio	74.892	2	.000
Linear-by-Linear Association	66.860	1	.000
N of Valid Cases	150		

(a) 1 cells (16.7%) have expected count less than 5. The minimum expected count is 4.94. Source: Household Survey 2006

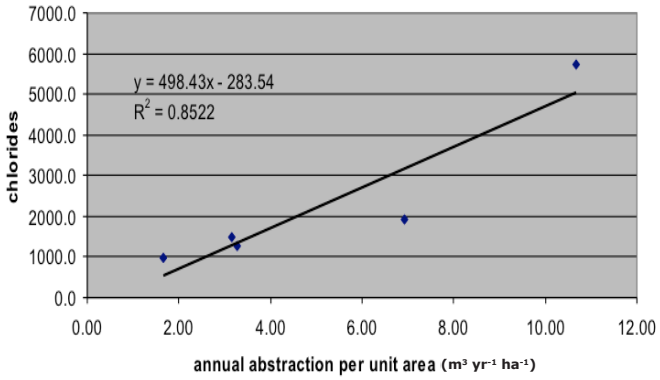

Figure 3. Graph of abstraction rate per ha vs. chlorides.

In the southern part of the island, abstraction is greater since it is the only source of water for Panglao Municipality. There is an apparent saltwater intrusion. In an interview, the in-charge of water distribution recalls that the phenomenon has been there since the middle 80's and has not shown any evidence of any reversal from that time to the present (**Table 9**).

A factor that needs to be considered when assessing the sustainability of groundwater abstraction is the natural ability of the underlying geology to maintain its structural stability, indefinitely. This may not be the case for the Pleistocene limestone that makes up the entire Panglao Island landmass. It has been identified as karstic

Table 8. Overload factor per Panglao barangay with respect to groundwater, 2006, of respondents interviewed in each barangay.

Panglao Urban Barangay	Abstraction (m^3 yr^{-1} ha^{-1})	Overload Factor (multiples)	Required Coverage
Bil-isan	3.16	2.95	66.15
Danao	1.66	1.55	35.64
Doljo	10.66	9.96	89.96
Looc	3.28	3.06	67.32
Poblacion, Panglao	6.94	6.48	84.57
Average	3.58	3.34	70.09

Table 9. Panglao wells salinity levels (as chlorides in mg/L; 2006)*.

Well	Location	Wet Season	Dry Season
1	Lourdes	990	860
2	Tangnan	3540	3199
3	Tangnan	3570	3174
4	Bil-isan	2330	1874
5	Looc	1960	1350
6	Doljo	3410	2624
7	Doljo	8550	8397
8	PobPanglao	2720	2274
9	PobPanglao	1630	1100
10	Looc	1300	400
11	Bil-isan	1300	412
12	Lourdes	1600	900
13	Tangnan	1240	633
14	PobDauis	6650	-
15	Bolod	1210	425
16	Tawala	1330	716
17	Danao	1390	500
18	Danao	1450	700
19	Tawala	1540	866
20	Bolod	1330	387

*source: (*DOH 2007*)

(*SWECO 1999*). Limestone dissolves and is prone to developing sinkholes and tunnels. Thus, saltwater intrusion may be rendered permanent if extraction is sufficiently fast leading to the possible formation of permanent tunnels that lead out to the sea. Several sinkholes, caves and caverns, which are product of chemical weathering are already found in the island. Eighteen sinkholes and dolines have been mapped. These range from 1 to 21 ha in size, with a total area of 63 ha (*SWECO 1999*).

Water quality

Approximate sampling areas from which sampling points will to be drawn were identified and an initial six wells were sampled (**Figure 4**). The samples were taken from locations outside the urban areas since Panglao Island constitutes one aquifer (10).

In light of these findings, particularly in Panglao Municipality, additional water quality tests were conducted on 20 wells selected from the identified 386 wells as per record existing in the municipality (10). These wells were tested for salinity since this is the significant quality parameter that is of concern from the previous initial sampling. Sampling was done twice recognizing the existence of two distinct seasons in the country. The first (wet) was conducted in the month of November 2006 and the other (dry) in the month of March 2007.

Tests show encroachment of salt water in all wells. This may likely mean that the whole aquifer on the side of Panglao town, if not for the entire island is over abstracted (**Table 9**).

All of the wells have chloride values beyond the Philippine safe water quality standards. The notable general downtrend from the wet to the dry cannot be explained except for the fact that there is really no marked difference between the two seasons in the island. The significant datum, however, is that all the 20 wells have been shown to be salty. Note that in the second season of sampling no value appears for Well 14. That particular well has been condemned and rendered inaccessible.

Considering that groundwater is the only source of water in the island for those who cannot afford to buy bottled water, this raises a health concern. Excessive salt intake has been associated to cardio-vascular disease and stomach cancer (*Prüss-Ustün and Corvalan 2006*). Local residents also complain that rice cooked using this water

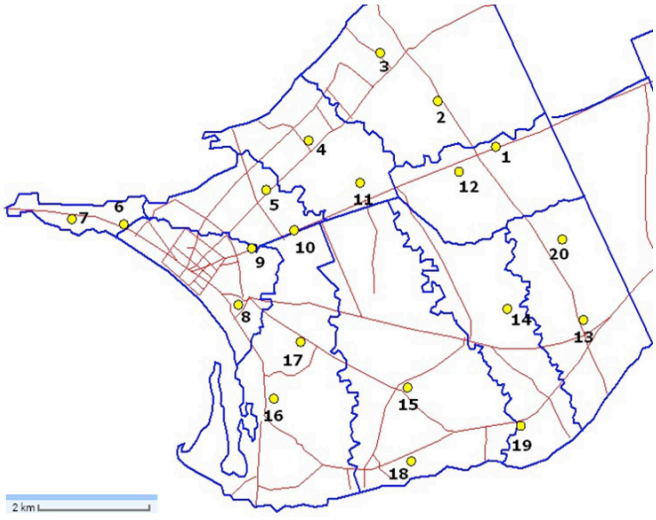

Figure 4. Location of sampled wells for salinity tests in Panglao municipality.

spoils quickly.

Some sampled wells exhibit high concentration levels of the water quality parameters especially chloride and calcium (**Table 10**). Specifically, chloride levels is more than 250 mg/L for most wells (except in Poblacion and Mayacabac), while Calcium was high in Tawala, Tangman and Mayacabac. The other water quality parameters seem to be lower than the threshold values in in wells except for Tawala where Turbidity was higher than 5 NTU.

Coliform Test

For fecal coliform tests, 26 samples were taken from the different locations (see Figure 2) in the main municipalities comprising Panglao Island (i.e., Dauis and Panglao). From the coliform tests, 24 of the 26 sampled water sources were positive for fecal contamination. This suggests that 92% of the wells tested are positive for *E. coli* and are therefore unfit for drinking purposes.

Sanitation status in Panglao Island

Most of the household sewage treatment systems found in Panglao Island are one-chambered watertight receptacles. In Philippine sanitation parlance, this is considered sanitary. Technically, these pit latrines by themselves meet the grade if, and only if, these are connected to a sewerage system. Since they are not, a water-tight closed (as opposed to open, which accepts rainwater) sewerage system is needed to close and complete the sewerage treatment loop. Interventions on the household level to mitigate the widespread fecal contamination of the island like construction of a new two- or three- chambered septic tanks are difficult options as they require considerable budget cut from the household's tight financial resources.

Exacerbating the overall pollution problem is the improper (or the lack of attention to proper) disposal of animal excreta. Most households are unaware of the correct disposal of the wastes of their domesticated animals.

Despite the 85% sanitation coverage in Panglao municipality, the absence of a sewerage network renders the water-tight toilet pits ineffective since the effluents percolate to the ground (*Husana and Kikuchi 2013*). Moreover, excreta of domesticated animals are left exposed or buried in shallow excavations. Of the surveyed households, 128 keep animals either as pets or as livestock or both. All are not aware of the special geology of the locality and its capacity to naturally remediate free lying excreta (*Zwahlen 2004*). Carbonate (karst) aquifers are particularly vulnerable to microbial and other contamination due to their high recharge rates (*Murray et al. 2007*). Contaminants easily enter the groundwater through sinkholes, and may be rapidly transported through solution channels where attenuation processes are dampened (*Drew and Hötzl 1999*). Karst systems drain out to springs, which are also preferred drinking water sources. These springs show pronounced oscillations in discharge and water quality in response to rainfall events. Even in sparsely populated karstic regions, prolonged periods of good water quality are interrupted by short microbial contamination events (*Pronk et al. 2007*). Thus, all the surveyed urban households do not know how to dispose animal excreta properly. Sanitation therefore has a direct effect on groundwater quality.

The economic status of most urban dwellers in Panglao Island makes affordability the main- if not the only- issue in water supply connection. The Poverty

Table 10. Water quality parameters in Panglao Island.

Well	Location	Parameter					
		Turbidity (NTU)	Chloride (mg/L)	Calcium hardness (mg/L)	Magnesium hardness (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)
8	Poblacion	0.12	30.4 (±0.4)	161 (0)	28.2	0.05 (0)	6.9 (±0.1)
25	Dao	3	393.147	144.024	-	-	42.578
19	Tawala	5.60	269 (0)	306 (±3)	17.2	0.01 (0)	13.8 (±0.2)
4	Bil-isan	3	1,419.836	167.026	-	-	191.606
3	Tangnan	0.06	1,722 (0)	453 (±10)	120	<DL	61.3 (±0.6)
15	Bolod	2	866.426	146.024	-	-	124.184
24	Mariveles	2	497.068	165.026	-	-	42.914
23	Mayacabac	0.06	8.10 (0)	304 (0)	8.6	0.01 (0)	5.1 (±0.1)
	Standards	5	250	300	-	50	250

NB. DL stands for Detection Limit (0.004 mg/L)
Source: *Laboratory Test Report 2006*

Database Monitoring System (*PDMS 2005*), a project of the Bohol Provincial Government, indicates that 52.5% of the urban households in the study area are below the Threshold Household Income.From the PDMS of the municipality, the urban barangays show that 15.42% of the households do not have access to sanitary toilets (**Table 11**). The FGD confirmed that households without toilets dispose of their waste by burrowing. Those who usually have an access to toilets during the day but have none at night take the same strategy when they find themselves in need of going to the toilet. Currently, a study is being done on the laying of sewerage pipes on the whole island courtesy of the USAID under the Sustainable Coastal Tourism in Asia (SCOTIA) project.

Analysis between Ownership of Toilet and Occurrence of Water Borne Diseases

As previously mentioned, diarrhea is the top ten leading causes of morbidity in the two municipalities in the period of 2000 to 2003. Thus, the rate of occurrences of water borne diseases is set as one of the survey questionnaires to find out the relationship with other factors. sIt was found that latrine ownership is related with the occurrence of Diarrhea. The Chi-square test shows that $p = 0.0$ which is less than $\alpha = 0.05$, and confidence interval is 99%, so the null hypothesis that there is no relation between ownership of latrine vs water borne diseases is rejected. Thus a conclusion that diarrhea occurs more often in households without latrine can be drawn (**Tables 12** and **13**). Thus, the null hypothesis is rejected and concludes that the diarrhea is more prevalent in household without latrine than household with latrine.

The chi-square is 12.316 on a df of 1, which has a probability under H0 = 0.000 and a confidence level interval of 99%. Thus, the null hypothesis is rejected conclusively supporting that diarrhea occurs more often in households without latrine than those that have.

Table 11. Households without access to sanitary toilets.

Urban Barangays in Panglao Island	Household Without Access	Total Household	Percent
Bilisan	111	479	23.17
Doljo	137	487	28.13
Danao	95	546	17.40
Looc	31	346	8.96
Poblacion	90	828	10.87
Poblacion, Dauis	21	459	4.58
Total/Average	485	3,145	15.42

Source: PDMS 2005, Municipalities of Panglao and Dauis

Table 12. Ownership of latrine vs occurrences of diarrhea crosstabulation.

Ownership of Latrine	Occurrence of Diarrhea				Total
	Yes		No		
	Count	%	Count	%	
With latrine	19	23.8	61	76.3	80 (100.0%)
Without latrine	36	51.4	34	48.6	70 (100.0%)
Total	55	36.7	95	63.3	150 (100.0%)

Source: Household Survey 2006

Some extreme cases highlight possible susceptibility to pathogenic outbreaks. It was found that in those cases where there are common toilet facilities, there is the instance where one such facility serves a cluster of homes averaging 30 persons per toilet. The focused group discussion also revealed that homes without toilets dispose of their waste anywhere where they can dig a hole. Those who usually have an access to toilets during the day but have none in the evenings take the same strategy when they find themselves in need of going to the toilet at night.

The survey also showed that 81% of those who have toilets actually know its type of construction. In the survey, the respondents were shown illustrations of the most common toilet facilities in use in the countryside compared to the toilet types in use in the urban barangays (**Table 14**).

Those with toilets were also asked as to how they plan to dispose sewage once the septic pit is filled. Fifteen respondents said that they would build a new one but are uncertain about their own means in financing it. Only one said that it will be evacuated and the rest have no idea.

A fecal coliform test was included in the first batch of sampling on water sources. Five sources were initially tested where three are private wells. Two wells were positive for fecal contamination. It was expected that coliform is present in the wells since it is the rainy season and free lying and ground interred excreta get entrained in the percolating rainwater. However, the lack of a sewerage system for wastewater that allows for latrine effluents to just percolate into the highly permeable limestone mass results to a continuing supply of fecal coliform to the groundwater during the dry season.

The coliform contamination and salinity levels in extant wells in this vicinity suggests, however, of a low feasibility for this recommendation as a fresh water source option. Interventions such as the connection to BWUI and the laying of sewerage network are unavoidable in

Table 13. Chi-square test for ownership of latrine vs occurrences of diarrhea.

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	12.316	1	.000		
Continuity Correction	11.153	1	.001		
Likelihood Ratio	12.455	1	.000		
Fisher's Exact Test				.001	.000
Linear-by-Linear Association	12.234	1	.000		
N of Valid Cases	150				

Table 14. Household knowledge of own-sanitation construction.

Toilet Type	Respondents	Percent
Traditional Pit Latrine	7	8.75
Pour Flush Pit Latrine	50	62.50
Ventilated Pit	1	1.25
Septic Tank	7	8.75
Not Aware	15	18.75
Total	80	100.00

the long term. Solutions on the household level such as rainwater harvesting and pit latrine retrofitting can augment water supply and mitigate groundwater contamination. Inexpensive water purification and sewage treatment modules are also available options.

Analysis of Different Income Group versus Ownership of Latrine and Level of Sufficiency

The household monthly incomes are divided by three groups, those less than or equal to ₱3,000.00 (low), between ₱3,000.00 and ₱6,000.00 (medium) and those greater than ₱6,000.00 (high). Most of the household in the study area are low income group and it is needed to find out the fluctuation of assessment of hygiene latrine and sufficient level for domestic water uses depending on income status of the household. Chi square test shows that p=0.0 which is less than α =0.05, and confidence interval is 99%, so the null hypothesis that there is no association between household income and ownership of latrine is rejected. Thus a conclusion is drawn that low income group has less toilet facilities than the medium and high income groups. The low income group has less toilet facilities than the medium and high income group (**Table 15** and **16**). Most of the households have no toilet facilities (only 26 have). All of the high income groups have toilet facilities.

The household income is also related to the level of water adequacy for domestic water use. The significant level is 0.000 and 99% confidence intervals. The null hypothesis is rejected and it can be concluded that the

Table 15. Household income group vs ownership of latrine crosstabulation.

Household monthly income (Pesos)	Ownership of Latrine				Total
	Yes		No		
	Count	%	Count	%	
<=3,000 (US$ 62)	26	29.9	61	70.1	87 (100.0%)
3,001-6,000 (US$ 62-123)	38	80.9	9	19.1	47 (100.0%)
>6,001(US$ 123)	16	100.0	0	.0	16 (100.0%)
Total	80	53.3	70	46.7	150 (100.0%)

Table 16. Chi-square test for household income vs ownership of latrine.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	47.519(a)	2	.000
Likelihood Ratio	55.249	2	.000
Linear-by-Linear Association	44.662	1	.000
N of Valid Cases	150		

(a) 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.47.

Source: Household Survey 2006

water insufficiency rate is more in low income groups than the medium and high income groups. The medium income groups have almost equal number of insufficient and sufficient water for domesticuse. For the high income group, there is only one household that have insufficient domestic water level.

In this study, a total of 150 respondents is used, and PCA is employed for data reduction and the main components with Eigen value greater than one is used for the regression analysis.

In the analysis, four components (PC) are extracted by PCA based on Eigen value greater than one and large % of variance. The cumulative % of variance is 67.675% and this means that these four components explain about

Table 17. Household income group vs level of sufficiency for domestic water use crosstabulation.

Household monthly income (Pesos)	Level of sufficiency for domestic water use						Total	
	insufficient		average		sufficient			
	Count	%	Count	%	Count	%	Count	%
<=3,000 (US$ 62)	75	86.2	9	10.3	3	3.4	87	100
3,001-6,000 (US$ 62-123)	23	48.9	4	8.5	20	42.6	47	100
>6,001(US$ 123)	1	6.3	0	.0	15	93.8	16	100
Total	99	66.0	13	8.7	38	25.3	150	100

Table 18. Chi-square test for household income group vs level of sufficiency of water for domestic water use.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	69.294(a)	4	.000
Likelihood Ratio	72.666	4	.000
Linear-by-Linear Association	62.457	1	.000
N of Valid Cases	150		

(a) 3 cells (33.3%) have expected count less than 5. The minimum expected count is 1.39.

Source: Household Survey 2006

Table 19. Rotated component matrix.

	Component			
	1	2	3	4
Family size	.958	.091	-.018	.015
Number of dependent	.936	.133	-.041	-.042
Education level	.021	.871	-.034	.109
Highest education level	.251	.673	.291	.207
Age of the respondent	-.101	-.597	.409	.100
Type of house	.043	-.035	.803	-.029
Type of roofing	.186	-.353	.608	.243
Gender of member 1	.238	-.195	-.574	.059
Occupation of respondent	-.195	-.050	-.101	.824
Monthly income (Pesos)	.207	.268	.163	.670

Table 20. Variables depending on the dominant independent variables.

Component	Name	Independent Variables
1	Household Demography	Family Size, Number of Dependents
2	Level of Education	Education Level, Highest Education Level
3	Housing Conditions	Type of house, Type of Roofing
4	Economic Conditions	Occupation of Respondent, Household Monthly Income (Pesos)

67.675% of the variation in the data. The first component explains nearly 23% of the variation in the data. The second, third, and fourth are 17, 15 and 10%, respectively and it was also found that there was not a big difference in the percentage of variance in each component. Therefore, there are four new variables and the dominant variables are chosen depending on the weight. The name of the variables can be defined depending on the commonality of the dominant independent variables of the rotated component matrix. The method of rotation used for this study is Varimax with Kaiser Normalization (**Table 19**).

The first component consists of the household demography as it is composed of family size and number of dependents in the households (**Table 20**). There are two track events that have a high weight. The second component includes education level and highest education level andis defined as the level of education in the household. The third component is under housing condition as it is composed of the type of house and type of roofing. This is one of the economic indicators and it is also related to the water and sanitation condition in the household. The last component belongs to the economic condition and it includes household monthly income and occupation of the respondent. Its percentage of variance is only 10.567% but it is one of the important factors for the indicator of awareness index. The result of the regression analysis can be used to find out the dominant factors that influence the awareness related with water and sanitation in the study area which can be determined based on weighing and index interval as per *Aung* (*2007*).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study was aimed to assess the water quality and sanitation conditions in Panglao island resort. From the primary and secondary data collected and statistical analyses done, it was found that the water quality and sanitation issues in Panglao Island are closely associated with the demographic and socio economic profiles of the residents in the municipality. Panglao Island's

water quality status is directly affected by the sanitation facilities through the limestone geologic mass. In the Municipality of Panglao, piped water has also been tested to be high in salinity. Moreover, selected wells from different parts of the town also show high levels of salinity. They also tested positive for fecal contamination.

For example, twenty sampled wells from the 386 wells sampled in Panglao Municipality sent for chlorides testing have chlorides ranging from 990 to 8,550 mg/L in November 2006 and 387 to 8,397 mg/L in March 2007. In the fecal coliform testing, 24 of the 26 sampled wells in Panglao were positive for *E. coli*. This suggests that most of the wells are unfit for drinking purposes.Water sources in addition to dug wells have to be harnessed for the town to augment its safe water supply.

As reflected in the principal components analysis, the key indicators affecting sanitation include demography, education, house conditions and economic status. Poor water connection and quality, poverty, lack of sewerage and sanitation facilities (e.g., toilets) are among the main factors that affect the quality of life especially the incidence of water related diseases.

Moreover, the water quality and sanitation issues in the study area are also linked together through the underlying geology. And because of the unique characteristics of the island's limestone geology, water issues have reached health hazard levels. The aquifer has a low abstraction capacity, that is, it only allows abstraction of 1.07 m^3 of water from a one hectare area annually. It is also observed that the groundwater is over-abstracted by 3.34 times in the study area and extraction should take note of the limitations of the limestone geology. Additional sources outside of dug wells have to be harnessed, because, although the permeability of limestone allows easy recharge, it also gives easily for seawater to encroach into the aquifers if over-abstraction is not controlled.

Current economic activities, particularly tourism, are hampered by the lack of quality potable water. And revenues from economic activities, in turn, are too small to support the financial burden of a comprehensive water treatment facility with an attached commercial grade sewerage network. In view of the economic situation of the majority of the households, piped water from the Bohol mainland is not feasible at BWUI quoted price. The financial burden in the installation of a sewerage system is high and in view of the economic status of most of its constituents, outside assistance from the national government or private international funding agencies is needed. Exacerbating the overall water situation is the lack of attention to proper disposal of animal excreta. Even though the total sanitation coverage in Panglao island is high (i.e., 85%), the necessary complement of a sewerage network however is not in place. Thus, the watertight toilet receptacles are rendered ineffective.

Recommendations

This research is an assessment study of the water quality and sanitation status of the resort island and recommendations have been proposed to address/ alleviate the environmental concerns in the area. So far, no improvements or management interventions have been undertaken, so the research, even done some years ago, still provides a basis for management and policy decisions by LGUs and MCPO. Recommendations are proposed based on the limitations and findings of the study. In this research, primary data collection, although done covering both dry and wet seasons, was only undertaken in one year, so findings can be inconclusive because the effect of seasonal changes over a long period on water quality and sanitation was not captured. So it is recommended that more data from different seasons over a longer time base should be collected. This will improve data adequacy and quality. The findings of the study, on the other hand, showed that water quality indicators such as chloride, turbidity, *E. coli*, etc. are beyond acceptable levels so some recommendations are proposed which consist of possible strategies or options which can alleviate the water quality and sanitation problems in the study area. This includes both structural and nonstructural measures which are based on the factors that are associated with water issues in the area.

The LGUs, as a matter of policy, should continue to aim for 100% sanitation coverage with individual pipe water and toilet for each household. Connection to Bohol Water Utilities, Inc. (BWUI) is a long-term policy option for Panglao Municipality. The advantage is that it is safe and the quality is assured although the cost is higher. Household connection will eliminate the disadvantages that lack of quality water brings with it for women- trips to fetch water are shortened if not eliminated, hygiene practices regularized, no public exposure when bathing, etc. Panglao Municipality may keep its old water supply network so that its present supply which has quality issues can still be used for the non-crucial domestic water needs of the household.

Panglao should also lay a sewerage network with centralized treatment to mitigate groundwater fecal contamination and prevent seaward coliform transport.

Panglao is home to diverse flora and fauna containing newly discovered marine species. This, however, will not prevent saltwater intrusion. Panglao Municipality may keep the old supply network for non-potable use. These recommendations can be done in phases with the initial stage setup along the resort areas.

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