WATER QUALITY TESTING AND WATER USE ASSESSMENT IN CAPIZ PROVINCE, PHILIPPINES

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1 Introduction

1.1 Water Quality Initiative in Capiz Province

The "Water Quality Testing and Water Use Assessment" project undertaken by the MIT team began in response to a request by the Provincial Health Office (PHO) in Capiz Province, Philippines for expert advice to support its drinking water quality testing, specifically the type of water quality tests that should be performed and the overall research design. Civil and Environmental Engineering Department Senior Lecturer, Susan Murcott, recommended specific state-of-the-art test methods for quantification of *E.coli* in drinking water as well as the involvement of a Masters of Engineering team in collaboration with the test program. Until 2009, Capiz had never performed any drinking water quality testing on the various drinking water sources (wells, springs, surface water and piped supplies) used throughout the province, with the exception of those performed in the Roxas City municipal water treatment plant. The main PHO participants in this project included Jarvis Punsalan, MD, MPH, Director of Public Health (DPH) of the Capiz PHO; Jane Delos Reyes, Engineer, coordinator of the water quality testing program; Leo Biclar, medical technician responsible for processing and interpreting the Quanti-Tray® tests; and Sanitary Inspectors (SIs) at the provincial and municipal levels who were in charge of collecting the water samples and processing and interpreting one of the field-based microbiological tests used.

During Fall 2008, Dr. Jarvis Punsalan received funding from the European Commission, the Philippines Department of Health (DOH) and United Nations Children's Fund (UNICEF) to set up a water quality testing laboratory at Roxas Memorial Hospital, in Roxas City, to test for microbiological contamination. He contacted Susan Murcott, for advice on the types of microbiological drinking water quality tests to conduct, and she recommended two types of tests: Quanti-Tray® and EC-Kit. Quanti-Tray® is an enzyme-substrate coliform test (Standard Methods 9223) based on Most Probable Number (MPN) and has been approved by the US EPA and is in use in more than 30 countries worldwide (IDEXX, 2010a). The EC-Kit is a new portable microbiological field test kit comprised of two, easy-to-use tests: the 10-mL Presence/Absence (P/A) Colilert® and the enumerative test: 3M™ Petrifilm™. Susan also recommended the use of additional field-based tests to be used in Capiz Province: the hydrogen-sulfide (H_2S) bacteria test (H_2S test).

During 2009, Capiz's PHO purchased Quanti-Tray® and EC-Kits. An incubator, ultraviolet (UV) light and Quanti-Tray® sealer were also purchased in order to conduct the Quanti-Tray® tests. In May 2009, "A Single Drop" trained the Capiz PHO staff, municipal health officers and SI's on how to

sample water sources, use the EC-Kit and interpret the sample results. The Quanti-Tray® equipment finally arrived in November 2009, and as part of that purchase, the laboratory staff of the PHO's Roxas City office received training from the suppliers in the set up and use of the Quanti-Tray® system. From October to December 2009, in collaboration with the MIT team, the PHO developed a water quality assessment survey designed to test 1,000 different water supplies from all 16 municipalities and Roxas City. The testing program started in December 2009. This would be the first-ever comprehensive drinking water quality testing in the province.

1.2 Water Sources in Capiz

According to the National Statistical Coordination Board (NSCB) (2009) of the Philippines, as of 2000, 119,000 households in Capiz (or 92%) have access to an improved drinking water supply (NSO, 2002).

The Capiz PHO currently uses four water source categories to designate their drinking water source types: Levels 1, 2 and 3, and Doubtful sources. Levels 1 through 3 sources fall under the U.N.'s "improved" category, whereas Doubtful sources are "unimproved." A summary of the Capiz and corresponding U.N. designations is presented in Table 1-1. These designations and abbreviations, as defined by the Philippines government, will be used throughout this study to describe water source levels and types.

Table 1-1. Capiz PHO water source designation and corresponding U.N. designation category.

U.N. Designation Category	Capiz PHO Designation	
	Category	**Source Type**
Improved	Level 3 (L3) (piped connection on premises)	▪ Water district ▪ Local water utilities administration ▪ *Barangay* (village) waterworks system
	Level 2 (L2)	▪ Gravity protected spring with pipe distribution to communal tap stands ▪ Deep well with pump, with pipe distribution to communal tap stands
	Level 1 (L1)	▪ Shallow well pump ▪ Jetmatic pump with or without motor ▪ Deep well pump ▪ Protected dug well ▪ Protected spring without distribution ▪ Rainwater catchment (ferro-cement tank)
Unimproved	Doubtful (D)	▪ Open dug well ▪ Unprotected spring ▪ Surface water (rivers, streams, creeks) ▪ Others

1.3 Drinking Water Standards

The most recent version of the Philippines National Standards for Drinking Water (PNSDW) was published in 2007 by the National Department of Health (DOH, 2007). The first standards were published in 1993. It is stated explicitly that these standards are based on recommended guidelines and criteria by international organizations such as the World Health Organization (WHO) and the U.S. Environmental Protection Agency. The 2007 document contains 82 different standards for biological, chemical, physical and radiological compounds; these include new additions of emerging chemicals such as pesticides and trihalomethanes (THMs). Microbiological parameters to be tested include total coliform, fecal coliform (*E.coli*), and heterotrophic plate count (HPC). These microbiological standards are required for water treatment works, consumer's taps, refilling stations, water haulers/vendors, and service reservoirs. The only microbiological standard for Level 1 sources is the fecal coliform standard.

1.4 Objectives

The main objectives of the project were to: (i) conduct microbiological and chlorine residual tests on untreated and treated water supplies, respectively, and (ii) apply the results of the microbiological tests and sanitary surveys to identify at-risk water supplies in order to make recommendations for potential infrastructure upgrades and improvements to these drinking water systems. The water use assessments were designed to capture as much information as possible throughout the month of January 2010 regarding the context and stakeholder perspectives regarding water uses and needs in Capiz Province. The recommendations include both immediate and long-term remedial measures.

Additionally, given the limitations in developing countries of using standard, laboratory-based test methods for drinking water quality analysis, there has been the need to research and develop low-cost, field-based methods for performing these tests. Therefore, another project objective was to verify the accuracy of selected field-based microbiological test methods (Colilert® and Petrifilm™ (EC-Kit), H_2S test) by comparing these to a standard methods test (Quanti-Tray®). The overarching motivation behind the project was to provide reliable water quality test results, in addition to useful, realistic and sustainable suggestions and recommendations for the PHO and for all the citizens in Capiz regarding their drinking water quality.

2 Sampling Design

Both the water quality testing program and the sanitary surveys made use of a stratified sampling design. In other words, samples were not randomly selected from the entire water level spectrum (Doubtful to Level 3), but were rather selected within their own subpopulation (i.e. water level). This means that a set number of samples per subpopulation were first determined, and then samples within their subpopulation were randomly selected for testing. The reason for this, as opposed to a purely random sampling program, was based on the overall study objectives of the PHO/MIT team, which was to make best use of limited test resources to identify sources most at risk. Therefore, these goals were accomplished by skewing the sample selection process towards Doubtful, Level 1 and known contaminated sources.

2.1 Study Design for Microbiological Tests

The study design was originally prepared by Punsalan and Reyes, in collaboration with Susan Murcott, Tom Mahin of the Massachusetts Department of Environmental Protection and the MIT team (Table 2-1).

The number of villages or sampling zones for each municipality was computed based on a ratio of 1 sampling zone for every 5,000 population (e.g. a municipality with a population of 30,000 would have 6 sampling zones selected). Zones were distributed according to the ratio of water sources accessed by the residents of the particular municipality.

Water samples were randomly selected: the names of qualified villages or zones per town were put in a box and drawn randomly with 25% additional names drawn as reserve in case of inaccessibility of initially selected sources. Water source selection was based on accessibility and their use by at least ten nearby households in the sampling zone:

- For each selected zone having doubtful sources, five of these sources were randomly selected and tested.
- For each village randomly selected for Level 1 supply testing, five Level 1 water sources were randomly selected for testing.
- For each village randomly selected for Level 2 supply testing, one reservoir was randomly selected and five of its outlets were tested. Water sources tested were the reservoir outlets. A maximum of five outlets per reservoir were tested.

- For each village randomly selected for Level 3 supply testing, five households accessing water from these sources were randomly selected and tested per zone. Water sources tested were every tenth household within the zone until the needed number of samples (five) was attained.

The only exception to the aforementioned study design was the Level 3 water supply for Roxas City. Since all of Roxas City has a piped and chlorinated water supply, this was tested separately using chlorine residual testing instead of the bacteriological testing which was thought better used for non-treated supplies.

2.2 Chlorine Residual Tests

The Capiz PHO was interested in assessing the free chlorine residual in the distribution network for Roxas City and the Municipalities of Panay, Panitan, and Ivisan. These supplies are all Level 3 and were assessed using the Hach® Free Chlorine Pocket Colorimeter II Test Kit at randomly selected sample locations. SIs from Roxas City and the Municipalities of Panay, Panitan, and Ivisan were trained by the MIT team in the use of this test kit and they decided on five sampling spots per *barangay* to provide preliminary free chlorine test results of Level 3 water supplies. In total, 85 samples were collected: 50 in Roxas City, 15 in Panay, 15 in Panitan, and 5 in Ivisan.

2.3 Sanitary Surveys

In total 52 Sanitary Surveys were conducted during January 2010 using WHO templates. The site selection was made based on a combination of water quality results, specifically results that indicated intermediate, high or very high *E.coli* concentrations, and/or where doubtful or Level 1 sources were being tested and where community members were available to take part in the assessments.

The sanitary survey forms were finalized with the Sanitary Engineer in Capiz Province to ensure that they were in line with their existing methods and regulations. The general templates for the WHO Drinking Water Guidelines Sanitary Inspection forms for the specific water source types found in the Philippines (e.g. dug wells, springs, rainwater collection, piped supplies, tubewells) were printed in advance and brought to the Philippines for direct use or modification as needed (WHO, 1997i).

Table 2-1. Research and Sampling Design.

Municipality	NUMBER OF VILLAGES	WITH DOUBTFUL ACCESS? (Y/N)	WITH LEVEL 1 ACCESS? (Y/N)	WITH LEVEL 2 ACCESS? (Y/N)	WITH LEVEL 3 ACCESS? (Y/N)	TOTAL HOUSEHOLDS (2008 DATA)	ESTIMATED POPULATION	APPROXIMATE NUMBER OF VILLAGES TO BE SELECTED AS SAMPLING ZONES	Doubtful		Level 1		Level 2		Level 3		TOTAL SAMPLES
									# OF VILLAGES	# OF SAMPLING SOURCES	# OF VILLAGES	# OF SAMPLING SOURCES	# OF VILLAGES	# OF SAMPLING SOURCES	# OF VILLAGES	# OF SAMPLING SOURCES	
Cuartero	22	Y	Y	Y	N	5340	28733	6	1	5	4	20	1	5	0	0	30
Dao	20	Y	Y	N	N	6071	36233	7	1	5	6	25	0	0	0	0	30
Dumalag	19	Y	Y	Y	Y	5989	30669	6	1	5	3	15	0	0	2	10	30
Dumarao	33	Y	Y	Y	Y	8459	47686	10	1	5	5	25	1	5	3	15	50
Ivisan	15	Y	Y	Y	Y	5223	28702	6	1	5	3	15	1	5	1	5	30
Jamindan	30	Y	Y	Y	N	6683	40186	8	1	5	6	30	1	5	0	0	40
Maayon	32	Y	Y	Y	N	7411	38687	8	1	5	5	25	2	10	0	0	40
Mambusao	26	Y	Y	Y	Y	8220	43533	9	1	5	4	20	1	5	3	15	45
Panay	42	Y	Y	N	Y	9162	48036	10	1	5	6	30	0	0	3	15	50
Panitan	26	Y	Y	Y	Y	8033	44320	9	1	5	5	25	0	0	3	15	45
Pilar	24	Y	Y	Y	Y	8165	46031	9	1	5	4	20	1	5	3	15	45
Pontevedra	26	Y	Y	Y	Y	9141	47449	10	1	5	5	25	1	5	3	15	50
Pres. Roxas	22	Y	Y	Y	Y	5842	32573	8	1	5	4	15	1	5	2	10	35
Sapian	10	Y	Y	N	N	5105	27109	5	1	5	4	20	0	0	0	0	25
Sigma	21	Y	Y	Y	Y	6260	32380	9	1	5	5	15	1	5	2	10	35
Tapaz	58	Y	Y	Y	Y	9384	52164	10	1	5	5	25	1	5	3	15	50
Roxas City	47	Y	N	N	Y	27817	148809	30	5	20	15	70	0	0	10	50	140
TOTAL	473	17	16	13	13	142305	773300	160	21	100	89	420	12	60	38	190	770

3 Water Quality Test Methods

The two microbiological drinking water quality tests used for the PHO's water quality assessment program were Quanti-Tray® and EC-Kit. In addition, the H_2S tests were being researched as potential complementary tests to the EC-Kit, to be verified during the Capiz Province water quality testing program.

3.1 Quanti-Tray®

The IDEXX Quanti-Tray® and Quanti-Tray®/2000 are enzyme-substrate coliform tests (Standard Methods 9223) that use semi-automated quantification methods based on Most Probable Number (MPN).

The enzyme substrate test uses hydrolysable substrates for the detection of both total coliform and *E.coli* enzymes. When the enzyme technique is used, the total coliform group is defined as all bacteria possessing the enzyme β-D-galactosidase, which adheres to the chromogenic substrate, resulting in release of the chromogen (the sample changes color and becomes yellow). *E.coli* bacteria are defined as bacteria giving a positive total coliform response and possessing the enzyme β-glucuronidase, which adheres to a fluorogenic substrate and results in the release of the fluorogen, and hence causing the sample to fluoresce under UV light (APHA, AWWA, WPCF, 2007).

The MPN method is an important quantitative tool in estimating the microbial population present in a water sample. It uses multiple qualitative (P/A) data points (for Quanti-Tray®, the number of positive wells out of 50 wells and for Quanti-Tray®/2000, the number of positive large wells out of 49 and the number of positive small wells out of 48) to generate a maximum probability coliform count per 100 mL value, given by a standard MPN table. Inadvertently, the Quanti-Tray® tests purchased by the Capiz PHO and used during the Capiz laboratory analyses were the regular 50-well Quanti-Tray®, whereas the Quanti-Tray® tests purchased at MIT and used during the laboratory studies were the Quanti-Tray®/2000.

The Quanti-Tray® provides bacterial counts (of total coliform and *E.coli*) as low as 1 MPN/100mL and up to 200.5 MPN/100 mL of sample, whereas the Quanti-Tray®/2000 provides a bacterial count as low as 1 MPN/100mL and up to 2419 MPN/100 mL. Both tests have a better than 95% confidence limit compared to multiple tube fermentation (IDEXX, 2010b).

In retrospect, it would have been more useful for the Capiz PHO to purchase the Quanti-Tray®/2000 since many of the water samples tested using Quanti-Tray® had results that were

higher than the Quanti-Tray® detection limit (200.5 MPN/100 mL). However, since the Capiz PHO was testing drinking water samples, there was no reason to suspect that so many drinking water samples might go above the Quanti-Tray® detection limit.

The Quanti-Tray® is easy-to-use, rapid and accurate. However, one of the main drawbacks of the Quanti-Tray® is its cost, since Quanti-Tray® requires the use of an expensive sealer, and the trays and reagents are particularly expensive ($21/test in Capiz), especially in developing countries (hence the urgency of research and development in simple, low-cost methods).

3.2 EC-Kit

A portable microbiology laboratory testing kit was initially developed by Robert Metcalf, PhD, Professor of Microbiology at California State University at Sacramento, one of the original founders of Solar Cookers International. Susan Murcott then modified the testing kit to include a waist belt incubator, which incubates water samples using body temperature alone. The waist belt incubator serves as a cheaper, portable, and more convenient alternative to traditional incubators that are costly and require electricity. She also created several different model sizes of the product and branded the product as "EC-Kit."

The EC-Kit contains two complementary tests for *E.coli*: the Colilert® 10-mL P/A test, and 3M™'s Petrifilm™ test. The Colilert® P/A test is the same reagent as in the Quanti-Tray® tests, only it is given in a 10-mL predispensed sample. However, the 10-mL Colilert test has a lower detection level equivalent to 10 colony forming units (CFU)/100 mL, whereas Quanti-Tray® has a lower detection limit of 1 MPN/100 mL[1]. In the 10-mL Colilert test, the substrate is hydrolyzed by the total coliform by-products, and reacts with a specific enzyme found in *E.coli*. A positive result is given by a yellow sample (presence of total coliforms), or a sample that fluoresces under long-wave UV illumination in the dark (presence of *E.coli*) after 24-hour incubation (Gerba, 2000). The Petrifilm™ test provides a quantitative count of total coliform bacteria colonies (red colonies with gas bubbles + blue colonies with gas bubbles after 24-hour incubation) and *E.coli* colonies (blue colonies with gas bubbles after 24-hour incubation) with a 1-mL sample volume.

In addition to the two tests, the kit also includes 100-mL sterile sample bags, individually wrapped, sterile 3.5-mL pipettes, a UV light, batteries, cardboard squares, rubber bands, and a waist belt incubator.

[1] CFU values represent a direct plate count of bacterial colonies. MPN values are statistical estimates that represent the "Most Probable" CFU count given a set of discrete presence/absence data points. In this project, CFU and MPN values were taken to be directly equivalent.

The EC-Kit is simple, low-cost and easy-to-use. The most promising features of the EC-Kit are that it can be used by virtually anyone who receives the brief 15- to 30- minute training, and that bacterial incubation are all performed using the waist-belt incubator, so it is completely portable and does not require the use of an expensive laboratory incubator and electricity.

One of the drawbacks of the Petrifilm™ is that the open package must be used within one month. A refrigerated package, however, can last up to one year. Chuang (2010) has verified the EC-Kit against Quanti-Tray® through extensive testing both in Capiz Province and at the MIT laboratory.

3.3 H_2S test

The H_2S test using the original medium (M1) is a well-known, simple and low-cost P/A test, developed by Manja, Maurya and Rao (1982). The test identifies the presence of H_2S-producing bacteria, associated with fecal contamination in a volume of water, which has been shown to correlate with the presence of fecal contamination.

Venkobachar, Kumar, Talreja, Kumar and Iyengar (1994) later developed a second test medium (M2), which consisted of the original M1 medium with the addition of L-cystine, which was shown to increase the sensitivity and reliability of the H_2S test (Pillai, Mathew, Gibbs, & Ho, 1999).

The M2 test medium was used throughout the water quality testing program in Capiz Province in January 2010 for all sample sources: from open dug wells (doubtful sources) to piped, chlorinated tap water (Level 3 sources). Since the H_2S test reagent includes a chlorine-neutralizing compound (sodium thiosulfate), the H_2S test is a suitable microbiological test for chlorinated water supplies (see Appendix VII).

Another H_2S test used in this study is the industry-made HACH Pathoscreen™. This test uses a powder-form, dehydrated H_2S test reagent, suitable for a 20-mL or 100-mL sample volume.

3.4 Chlorine Residual

Hach® Pocket Colorimeter II Test Kit is a portable device that can be used to detect the concentration of free chlorine residual in water. The device requires the addition of 25-mL of DPD (N,N-diethyl-p-phenylenediamine) free chlorine reagent to the sample to quantify the free chlorine residual concentration (Hach, 2009). A reaction of the DPD reagent turns the water sample pink in the presence of chlorine. The sample, with the added reagent, is read by the device in comparison to a blank sample. The concentration level is determined using the Beer-Lambert Law; by measuring the absorption of wavelengths as light is passed through the sample. The suggested

range for measuring chlorine concentrations with this device is 0.1 to 10.0 mg/L. Concentrations found below this level may be inaccurate, but still indicates low concentrations of free chlorine if not the entire absence of free chlorine.

4 Water Quality

4.1 Water Quality Standards

4.1.1 Microbiological Standards

To frame the results within the Philippines context, the National Standards for Drinking Water state that, using standard methods of analysis (DOH, Philippines National Standards for Drinking Water , 2007):

- Total coliforms should be at a conformity risk level (<1 cfu/100mL) for 95% of samples taken in a given time period (defined based on sample location)
- *E.coli* test must give a result of <1.1MPN/100mL

The Code on Sanitation (DOH, 1995) states that water should not be supplied for public use unless a level of treatment has been provided based on the following water quality results for coliform organisms.

Table 4-1. Water Quality Results and Corresponding Treatment (DOH, 1995).

Water Quality Results (MPN/100 mL) WHO Risk Levels	**Treatment**
<50 MPN/100 mL Conformity, Low and Intermediate Risk Levels	Water sources that fall in this category are characterized as "low degree of contamination" and require disinfection alone.
>50 MPN/100 mL and <5,000 MPN / 100 mL High and Very High Risk Levels	Water sources that fall in this category are characterized as "high degree of contamination" and require "complete treatment".

The WHO has developed Risk Levels for categorizing *E.coli* contamination within their Drinking Water Quality Guidelines (Table 4-2).

Table 4-2. WHO Risk Level corresponding to *E.coli* level in sample
Adapted from WHO (1997) by changing thermotolerant coliform to *E.coli* (Doyle & Erickson, 2006) (Metcalf, 2006).

Risk Level	*E.coli* in sample (CFU/100 mL)
Conformity	<1
Low	1-10
Intermediate	10-100
High	100-1000
Very High	>1000

The results from the Quanti-Tray® and other microbial water quality tests are framed according to these risk levels. The type of Quanti-Tray® system used in Capiz Province, only allows detection up to 200.5 CFU/100 mL; thus, the risk levels for the water quality test program are defined as Conformity, Low, Intermediate or High/Very High.

4.1.2 Chlorine Residual Standards

According to the WHO, after at least 30 minutes of contact time, "the minimum residual concentration of free chlorine at the point of use should be 0.2 mg/L" (WHO, 2008). The Philippines DOH requires free chlorine residual concentrations for Level 2 and Level 3 water supplies to ensure that the water remains disinfected. According to the Department of Health (DOH, 1995), the free chlorine residual at any point that reaches the consumer as well as the any point in the distribution system must be between 0.2 mg/L (DOH Min) and 0.5 mg/L (DOH Max).

4.2 Microbiological Test Results

The following graphs present the water quality results for the test period from December 2009 – March 2010. In total there were 569 samples collected over this period, and the majority of these were from Doubtful and Level 1 sources due to the stratified sampling design.

4.2.1 Results by Municipality

First, the *E.coli* Risk Levels are presented per municipality by risk levels. This data presentation method (Figure 4-1 and Table 4-3) in terms of risk level categories is useful for officials at the municipal level to develop priority action plans. Additionally, Appendix I contains graphical results by water source category for each municipality.

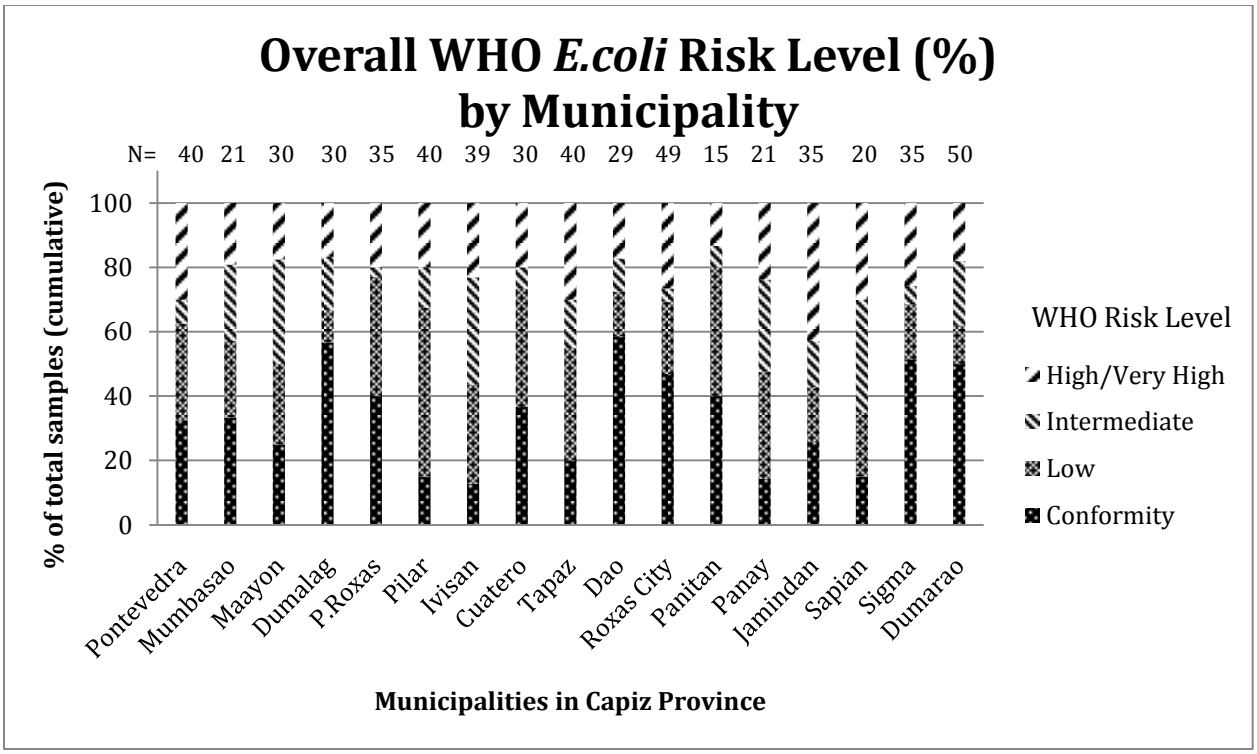


Figure 4-1 Risk Level (%) by municipality determined from samples collected January-March 2010.

Table 4-3 Percent water source category sampled by Municipality

Municipality	% D	% L1	% L2	% L3
Pontevedra	10	53	13	25
Mumbasao	24	76	0	0
Maayon	13	63	25	0
Dumalag	13	53	0	33
Pres, Roxas	14	43	14	29
Pilar	13	50	0	37
Ivisan	18	64	18	0
Cuartero	3	63	33	0
Tapaz	0	63	38	0
Dao	14	86	0	0
Roxas City	2	98	0	0
Panitan	0	100	0	0
Panay	24	76	0	0
Jamindan	14	71	14	0
Sapian	0	100	0	0
Sigma	14	43	14	29
Dumarao	10	50	10	30

Figure 4-1 presents the overall risk level for all the samples collected in each municipality during December 2009-March 2010. Because of the unequal number of samples collected per municipality, Table 4-3 provides a percentage of each source category tested to show the relative percent in each category. For example, Jamindan had one of the highest percentages of high risk water quality results. A potential reason for this is that of the 15 water samples collected from this municipality, 85% were from Doubtful or Level 1 sources. Similarly, samples collected from Sapian were all from Doubtful and Level 1 sources; Figure 4-1 shows that this municipality also has a comparatively high percentage of high risk sources. However, Table 4-3 shows that Sigma had the highest percent of Level 2 and Level 3 sources sampled from January-March (43%), and this municipality showed one of the lowest percentages of water samples of conformity, indicating that the relationship between low risk level and Level 2 or Level 3 source type does not always hold true.

4.2.2 Results by Source Category

Due to the difficulty in observing trends in water quality data presented by municipality, the Risk Levels are next presented by source category both in absolute sample numbers (Figure 4-2) and by cumulative percent (Figure 4-3).

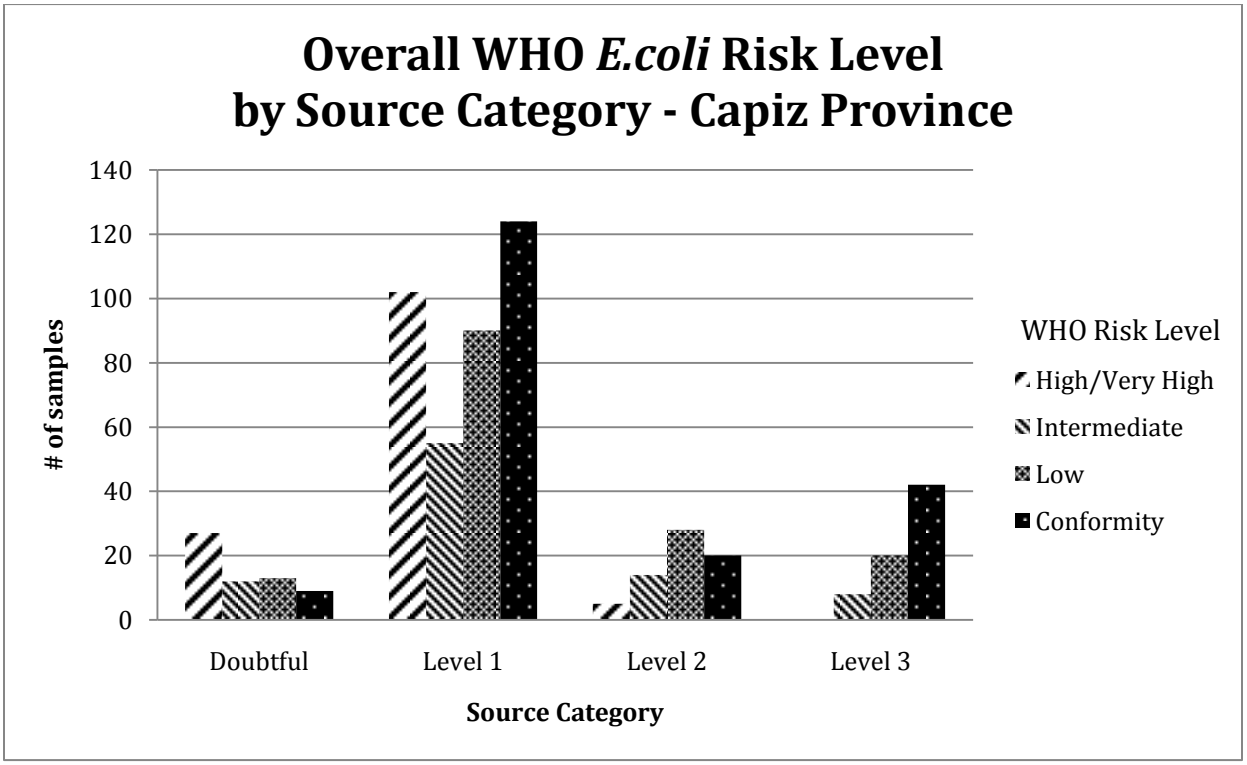


Figure 4-2. Overall WHO *E.coli* Risk Level and Number of Samples by Source Category

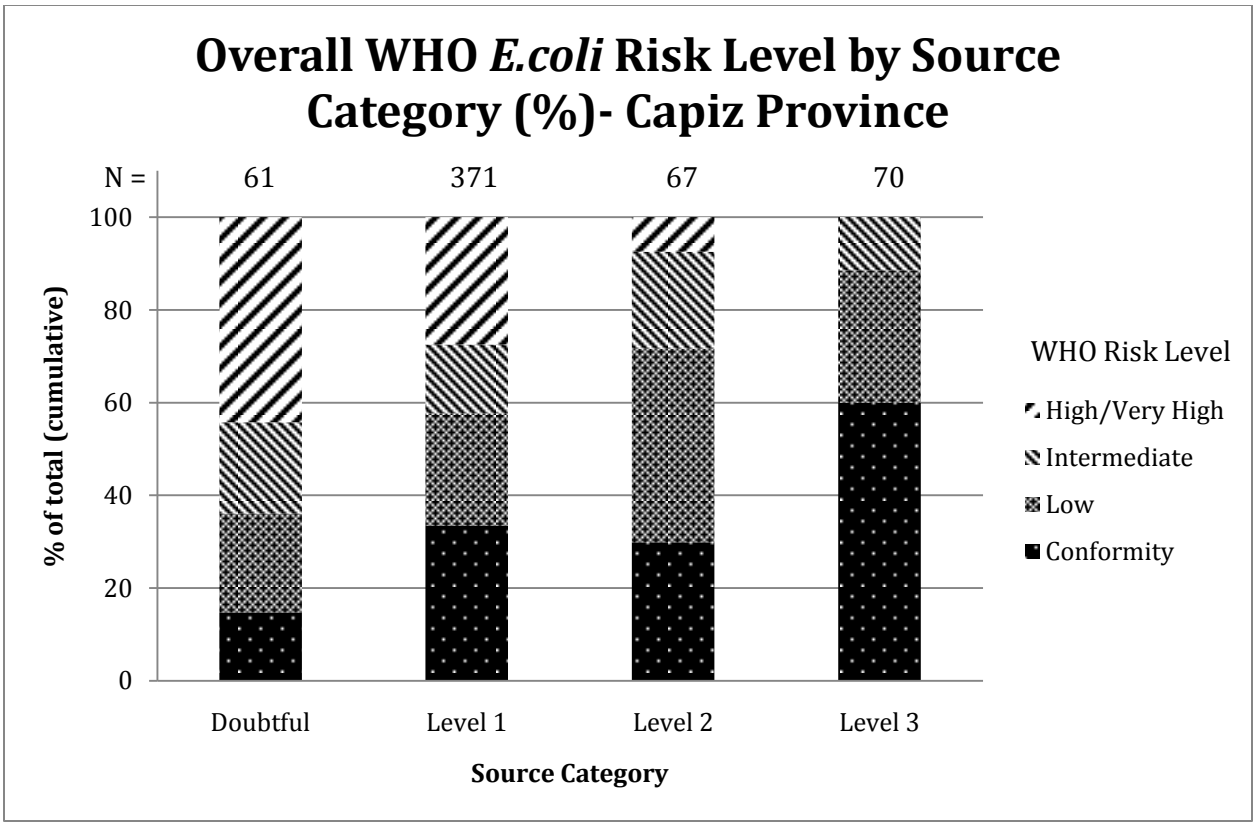


Figure 4-3. Overall WHO *E.coli* Risk Level by Water Source Category (%)

Figure 4-3 shows a decreasing trend in high risk levels from Doubtful through to Level 3 sources. Of the 61 Doubtful water sources sampled, 64% were categorized by intermediate and high risk levels; comparatively, only 11% of Level 3 sources were of intermediate risk and none of the 70 samples collected were of high risk. Similarly, an increasing trend in conformity levels was seen from Doubtful to Level 3 sources. These Level 3 sources were generally small village systems which employed sand filtration and/or chlorination treatment prior to distribution. Roxas City, Panay, Panitan and Ivisan Level 3 treatment distribution systems were tested with using chlorine residual tests, which are covered in Section 4.3, and so are not represented among these Level 3 data.

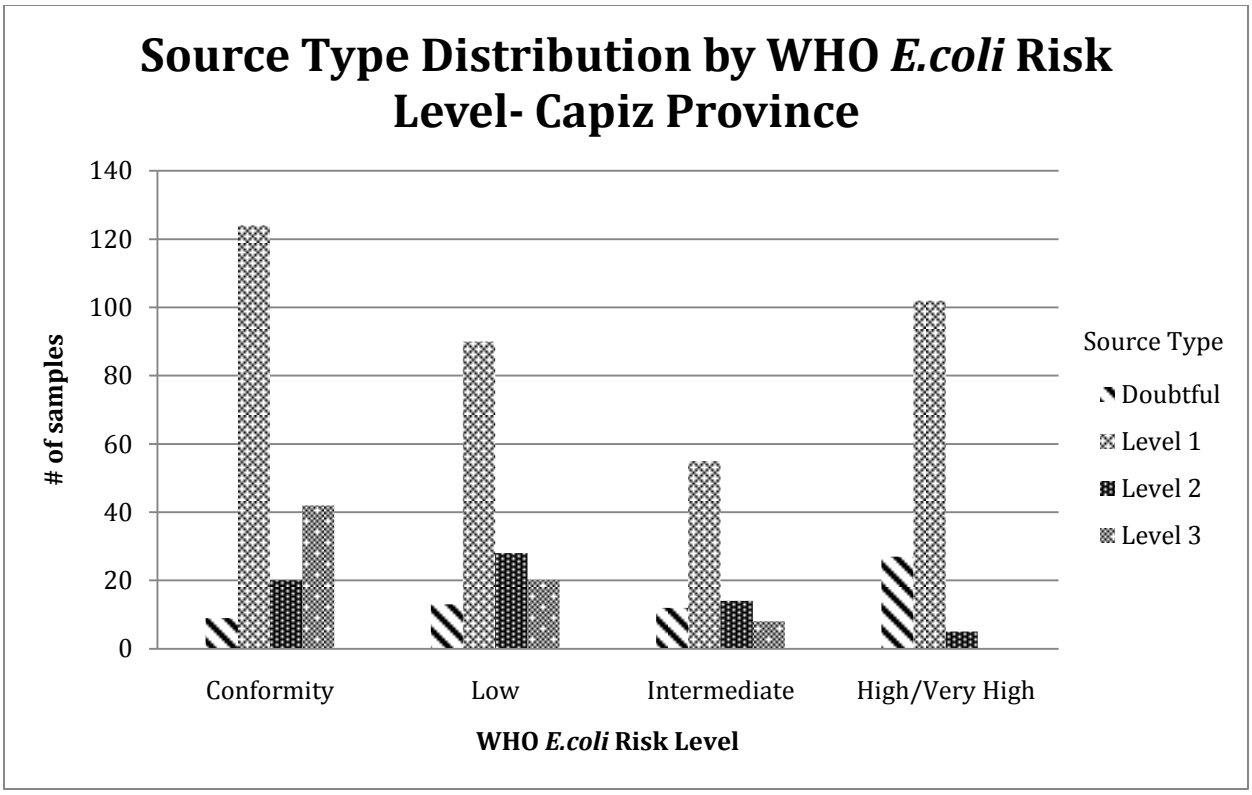


Figure 4-4. Source Level distribution by WHO *E.coli* Risk Level

Figure 4-4 shows a different representation of the water quality results. When grouped according to WHO Risk Level, Level 2 and Level 3 are seen in greater proportions in the conformity and low risk level categories. Doubtful is also in greater proportion in the high/very high category. Level 1 samples, however, are seen in large number throughout the risk level categories, potentially illustrating the range of water quality within the different Level 1 source categories and/or within a particular source type of different age, condition, and maintenance.

4.2.3 Results by Source Type

Finally, water quality test results are grouped according to specific water source types within each water source category. Table 4-4 below contains the legend for the water source codes for the entire test program.

Table 4-4 Water Source Codes for each Water Source Category in Capiz Province

Water Category	Water Source Code	Water Source Type
Doubtful	OD	Open dug well
	US	Unprotected spring
	SW	Surface water (Rivers, streams, creeks)
	OT	Others not mentioned above
Level 1	SWP	Shallow well with pump (<60 ft)
	JMP	Jetmatic Pump w/ or w/o motor
	DWP	Deep well with pump (>60 ft)
	PDW	Protected dug well
	PS	Protected dug well w/o distribution
	RW	Rain water catchments (ferro cement tanks)
Level 2	GPS	Gravity protected spring w/ pipe distribution, Communal tap stands
	DWP	Deep well w/ pump w/ pipe distribution, Communal tap stands
Level 3	WD	Water Districts
	LWUA	Local water utilities administration
	BAWASA	*Barangay* waterworks system

Just as there is considerable variation in the sample size of each water source category, as shown in Table 4-3, so too there is a considerable variation in the sample size for each of the different water source types due to the stratified sampling methodology.

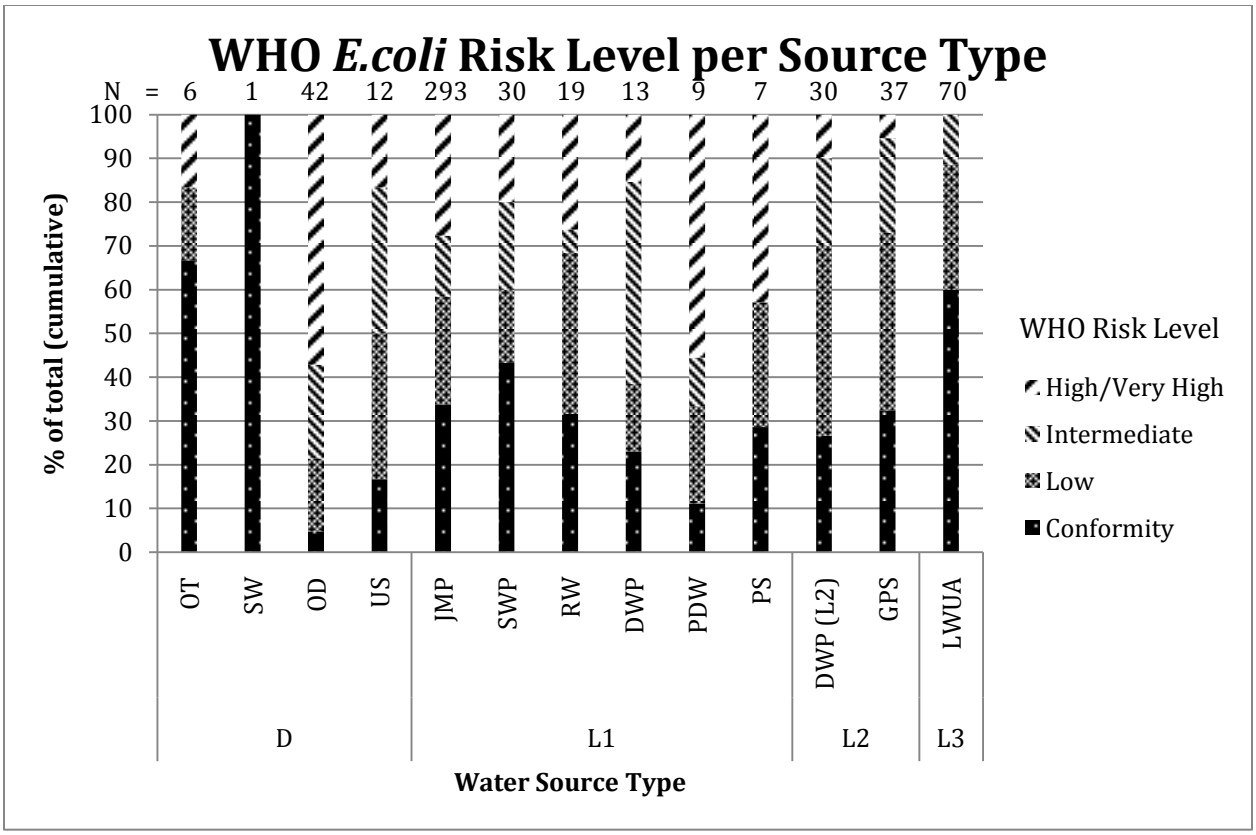


Figure 4-5. Overall WHO risk level by specific water source type (%)

Of the Doubtful sources, 78% of the open dugwells (OD) tested were in the Intermediate or High/Very High Risk Levels. Fifty percent of unprotected spring (US) sources were in the Intermediate or High/Very High Risk Levels. For Level 1 sources, which were 65% of the total water quality test program sample size, the percent of sources with Intermediate or High/Very High Risk Levels decreased from protected dugwells (PDW), deep well pumps (DWP), protected springs (PS) to jetmatic pumps (JMP); with 67%, 61%, 43% and 42% respectively. It is of note that of the Level 1 sources tested, rainwater source (RW) showed the highest percentage of low risk and conformity water quality levels (69%). This has implications for recommendations which should be made by the PHO for those without access to Level 2 or Level 3 sources. However, it should be noted that of the Level 1 sources, only JMPs and SWPs had a significant (N>30) sample size.

Within the Level 2 sources, gravity protected springs (GPS) appears to have marginally higher water quality than deepwell pumps (DWP) (boreholes); 73% of samples were in conformity and Low Risk Levels, and 5% in the High/Very High Risk Level, compared to 70% and 10% respectively. Level 2 and Level 3 source types all showed 70% or more of samples in the Conformity to Low Risk Levels. This indicates a decreased likelihood of contamination in water source types that have

piped distribution or in systems that receive treatment prior to distribution; this is demonstrative of the potential health benefits of increasing the proportion of the Capiz population with access to these services. Recommendations based on these water quality results, along with other assessment results are contained in Section 7.

4.3 Chlorine Residual Results

Figure 4-6 shows the results of the 85 free chlorine residual tests completed in January 2010 for Roxas City, Panitan, Ivisan and Panay. The figure has drawn in 2 horizontal lines at the 0.2 and 0.5mg/L chlorine residual concentration levels showing the WHO/DOH minimum level and DOH maximum level for chlorine residual after 30min of contact time, at any point in the distribution system. Unfortunately, only 17.6% of the samples met the WHO and DOH standards (see Appendix II for results at the city and municipal level). Moreover, the results show that, of the 50 samples collected in Roxas City, only 10 (20%) of these met the WHO and DOH standards. Five of the 15 samples (33%) collected in Panitan met the standards, while two of the samples that met the standards had chlorine residual concentrations of 0.2 mg/L, which is the absolute lowest acceptable concentration. None of the samples collected in Ivisan and Panay met the standards. Again, the recommendations to address these chlorine residual results are presented in Section 7.

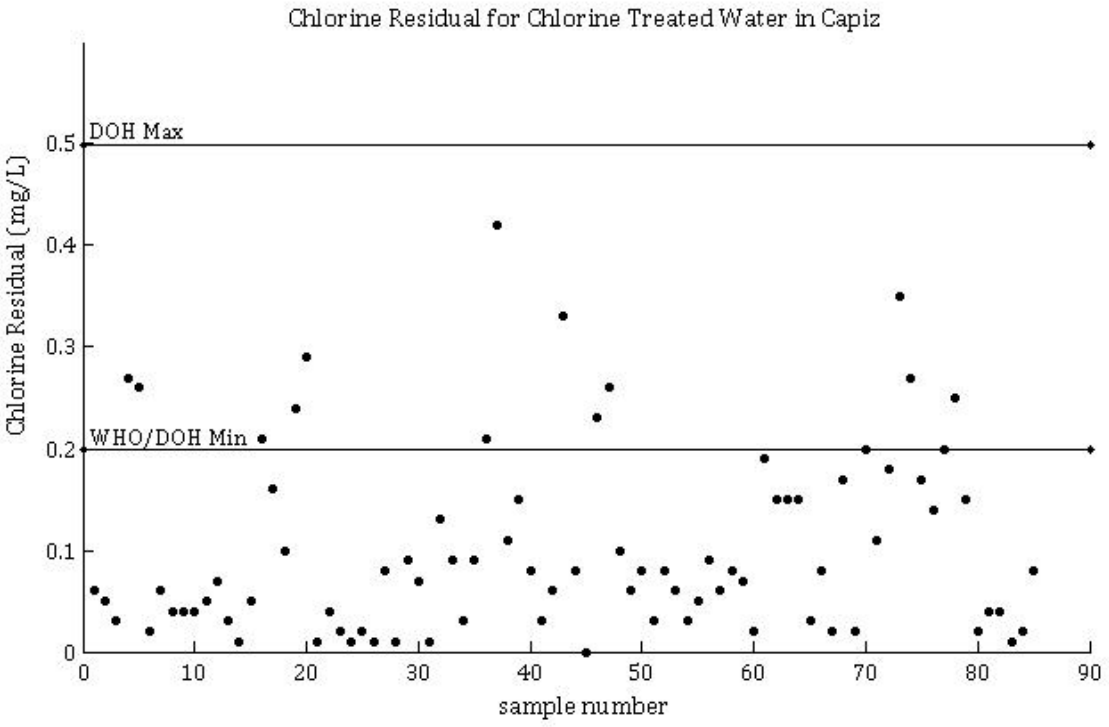


Figure 4-6. Free Chlorine Residual for Roxas City, Panitan, Ivisan and Panay

5 Sanitary Survey Results

5.1 Presentation of Sanitary Survey Results

Water system assessments firstly included an assessment of the drinking water quality in terms of *E.coli* and chlorine residual, as compared to WHO Water Quality Guidelines, along with national or local standards. The subsequent component of the overall system assessment included a sanitary inspection, which primarily involved identification of system deficiencies with respect to infrastructure and the proximity of physical hazards to the water source.

Sanitary inspections are defined as "an on-site inspection and evaluation […] of all conditions, devices, and practices in the water-supply system that pose an actual or potential danger to the health and well-being of the consumer" (WHO, 1997i). They are complementary analyses to water quality tests in that they identify the potential hazards which cause poor water quality results (i.e. livestock watering occurring near the source where water quality analysis has found the presence of *E.coli*). Sanitary inspection reports are usually structured as a checklist of components from the water source through the distribution channels where hazards may be present.

Table 5-1 shows the Risk Level according the Sanitary Survey form by percentage. This is followed by the survey results by municipality with the number of sources surveyed in each area (Figure 5-1) and the survey results by water source type (Figure 5-2).

Table 5-1. Risk level of sources surveyed (by percentage).

Risk Level	Percent of sources surveyed (%)
Low	2
Intermediate	21
High	54
Very High	23

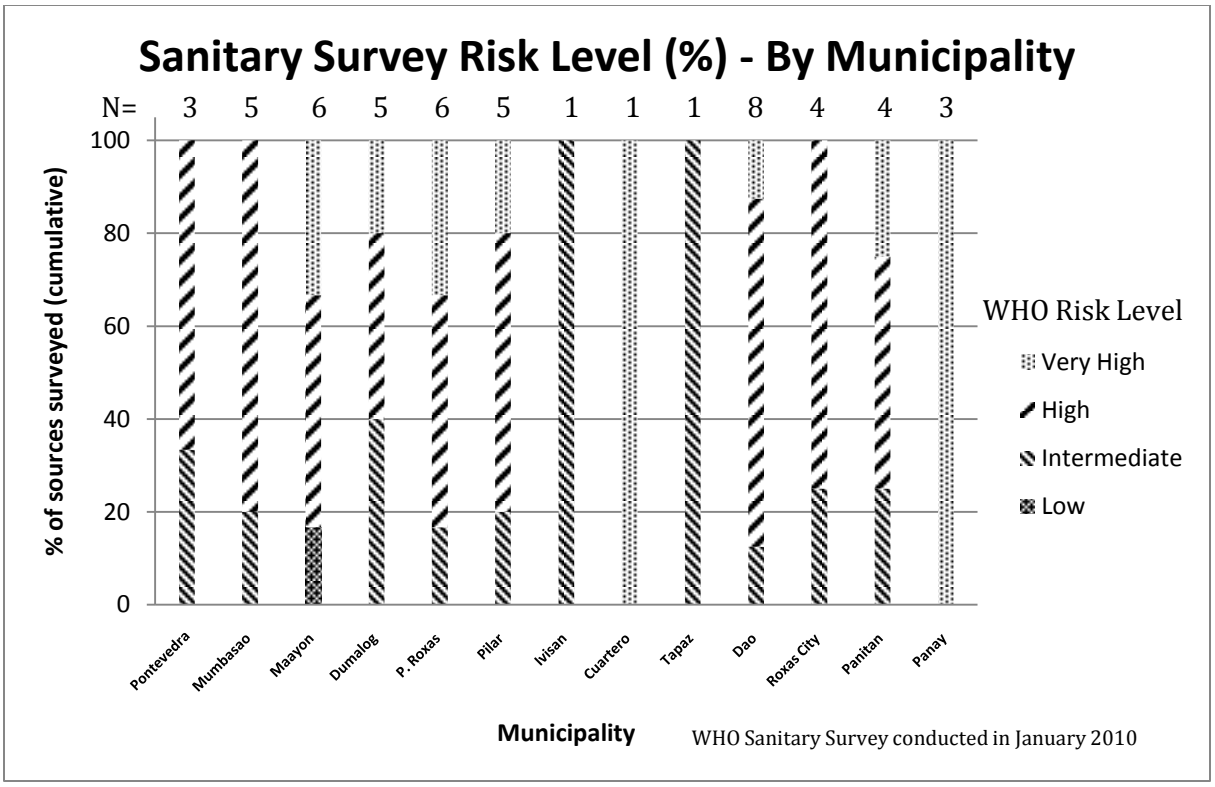


Figure 5-1. Sanitary Survey Risk Levels by municipality

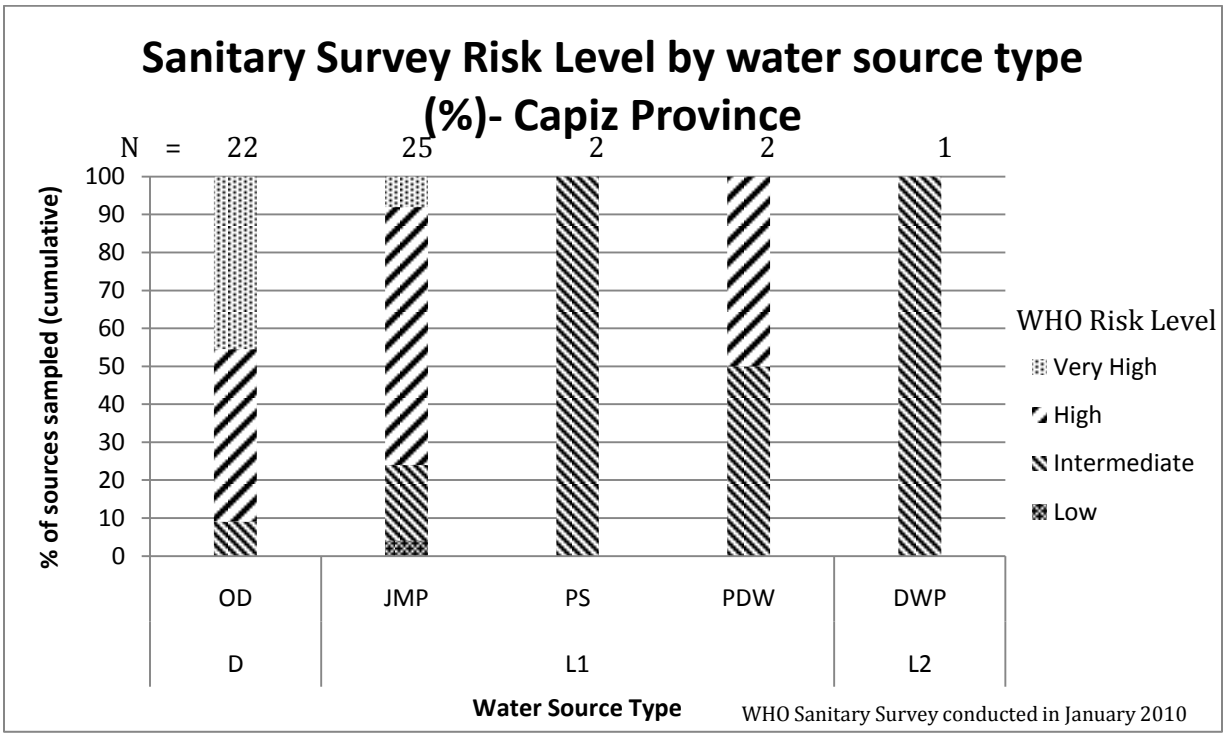


Figure 5-2. Sanitary Survey Risk Level by water source category and type based on % of sources surveyed

5.2 Discussion of Sanitary Survey Results

The Sanitary Surveys revealed a number of hazardous activities taking place around water sources. The specific hazards noted for each source type are summarized in Appendix III. The hazards varied per source type; however, the lack of site protection from access by animals was noted in almost every site inspection. Additionally, the proximity of septic tanks, lack of drainage channels (enabling pooled water), and animal waste were found to be consistent hazards.

Table 5-1 shows that 54% of the Sanitary Surveys resulted in sources categorized as High Risk according to the survey risk levels. The proportion of Intermediate Risk Level and Very High Risk Level were very similar, 21% and 23% respectively. Only 2% of the sources surveyed had sufficiently few hazards to be categorized as Low risk, which indicates that 98% of the sources surveyed were of Intermediate, High or Very High risk.

By water source type, the Sanitary Survey results from all the municipalities combined show that ODs had the highest risk, followed by JMPs. Of the Level 1 source types, JMPs were found to have the highest risk. However, it should be noted that there were considerably more JMPs visited than other Level 1 source types due to the stratified sampling design (Figure 5-2).

As Figure 5-2 shows, ODs showed the highest percentage of High and Very High Risk Level based on the hazards identified during Sanitary Surveys. 90% of ODs surveyed showed High or Very High Risk Levels, followed by 76% of the JMP sources surveyed. PS and PDWs generally showed lower risk levels; however there were only two of each of these source types visited, and more surveys would have to be conducted to say conclusively if these sources are lower risk (according to the WHO risk designations) than ODs and JMPs. The only Level 2 source sampled (DWP) was found to have an intermediate risk level for contamination. This score was due to lack of a drainage channel, lack of fencing around the borehole, less than 1m diameter concrete platform around well-head and a loose well-seal.

6 Complimentary Field-Based Microbiological Tests

The recommendations for using and integrating new, field-based tests for microbiological testing in developing countries are presented here.

Part of this project included assessing the accuracy of the EC-Kit tests (Colilert and Petrifilm™ tests), and H_2S tests (laboratory-made: 10-, 20- and 100-mL sample volume and industry-made HACH 20-mL sample volume), through comparison with a standard method tests: Quanti-Tray®.

The following briefly summarizes the statistical analyses' key findings for the field-based, microbiological tests as single tests, and as test combinations.

6.1 EC-Kit (Colilert® and Petrifilm™)

In assessing the accuracy of various microbiological tests as a means of testing water quality, there were two statistical analyses used. Given the designations of unimproved and improved water sources, the author assumed that an unimproved water source corresponded to the Philippines designation of a Doubtful water source, and an improved water source corresponded to Levels 1 through 3.

To calculate error and reduction in error, we used the following formula:

$$\lambda = \frac{\text{(Error without conditional information) - (Error with conditional information)}}{\text{(Error without conditional information)}}$$

This formula, as applied to the statistical analyses of this study, may be rewritten as:

$$\lambda = \frac{\text{(Error from knowing water source type) – (Error from knowing water source type and additional water quality test)}}{\text{(Error from knowing water source type)}}$$

The λ value, defined as "proportional reduction in error," is a measure of how good one becomes at making predictions. In other words, λ, the proportional reduction in error, represents how much knowledge one gains by obtaining water quality test results compared to assuming contamination level based on improved/unimproved water source type.

Through statistical analyses, the correlation between each Colilert® and Petrifilm™ with Quanti-Tray® is statistically significant. Colilert® and Quanti-Tray® complied with one another

for 388 of the 521[2] samples collected in Capiz Province, and 133 samples did not comply with each other. Of the 133 samples, 32 of these were false positives and 101 were false negatives. Petrifilm™ and Quanti-Tray® yielded the same result for 459 of the 521 samples, and there were 62 out of 521 samples where the two tests were not congruent with each other. Of these 62 samples, 19 were false positives and 43 were false negatives. The false negatives had Petrifilm™ indicating a higher risk level category than Quanti-Tray®. While ideally one would hope for perfect congruence of the two test methods, it is preferable to have over-reporting of risk (false positives) than under-reporting of risk (false negatives).

The results of calculation error and λ are in Table 6-1 for the various options for EC-Kit. For both unimproved and improved water sources, the addition of both tests in the form of an EC-Kit would improve predictions by 60-63% (highlighted rows in yellow in Table 6-1).

Table 6-1: Error and Proportional Reduction in Error for Unimproved and Improved Water Sources

Tests	Error	Proportional Reduction in Error (λ)
Unimproved + Quanti-Tray®	15%	
Unimproved + Colilert®	12%	25%
Unimproved + Petrifilm™	37%	-138%
Unimproved + EC-Kit (exact match)	25%	-63%
Unimproved + EC-Kit	6%	63%
Improved + Quanti-Tray®	64%	
Improved + Colilert®	27%	58%
Improved + Petrifilm™	39%	39%
Improved + EC-Kit (exact match)	29%	54%
Improved + EC-Kit	6%	60%

The error for improved and unimproved water sources with Colilert® and Petrifilm™ tests reported the percentage frequency of the red-shaded areas in Table 6-2 and Table 6-3. For unimproved water sources, the addition of only a Petrifilm™ would actually lead the user to err more often, whereas the addition of only a Colilert® test would improve predictions by 25% (and hence resulting in a 12% error instead of 15%). For improved water sources, the addition of a Colilert® or Petrifilm™ test would improve guesses by 58% and 39% respectively.

[2] The difference between these 521 samples and the aforementioned 569 water samples is the lack of EC-Kit data available at the time of analyses for 48 data points. The 569 water samples only evaluated Quanti-Tray® results.

The "exact match" method reports the percentage frequency of the red-shaded areas in Table 6-2 and Table 6-3. This is useful information for verification of EC-Kit, but not as useful for water quality testing, meaning that with the EC-Kit, an overestimate of the risk level still yields useful information for someone interested in testing their water quality. So, the error values of interest actually follow the red-shaded areas in Table 6-4.

Table 6-2: Calculations for Error for Colilert® or Petrifilm™

		Quanti-Tray®	
		Presence	Absence
Water Source Type + Additional Test	Presence		
	Absence		

Table 6-3: Calculations for Error for EC-Kit (exact match)

		Quanti-Tray®		
		Conformity/Low	Intermediate	High/Very High
Water Source Type + EC-Kit	Conformity/Low			
	Intermediate			
	High/Very High			

Table 6-4: Calculations for Error for EC-Kit

		Quanti-Tray®		
		Conformity/Low	Intermediate	High/Very High
Water Source Type + EC-Kit	Conformity/Low			
	Intermediate			
	High/Very High			

6.2 H_2S Test

Through correlation analyses, it was shown that the H_2S test results (for laboratory-made reagent: 10-, 20- and 100-mL sample volume and industry-made HACH test 20-mL sample volume) were correlated, in a statistically significant way with Quanti-Tray®.

In general, all the H_2S tests had high true results values, although the 20-mL laboratory-made H_2S test had the highest percentage of true results (84%) when tests were compared to Quanti-Tray®.

The false positive values for the H_2S tests were high (9% to 16% for the 10- and 100-mL sample volume, respectively); whereas the FN values for the H_2S tests were low (4 to 11% for the 100- and 10-mL sample volume, respectively). The high percentage of false positive results is probably due to the H_2S tests all detecting H_2S that may not come from H_2S-producing fecal bacteria. For example, in groundwater, H_2S is often present due to natural geohydrological sources and to anthropogenic impacts other than fecal contamination (Sobsey & Pfaender, 2002). This phenomenon is particularly of interest in this study since most drinking water samples from Capiz Province (136 samples) were groundwater collected from wells and spring sources.

In general, it was noted that as the sample volume of the H_2S test increased, sensitivity also increased from 84% for the 10-mL test to 94% for the 100-mL test, which means that the higher volume test can detect more true positives; whereas specificity decreased considerably from 72% for the 10-mL test to 53% for the 100-mL test; which means that the higher volume test detects less true negative results.

Also, the positive predictive value for the 10- and 20-mL tests were similar at 85% to 86%, but was much smaller for the 100-mL test (53%); in other words, when a larger sample volume is used, a positive test is no longer directly synonymous with presence of fecal contamination. Finally, negative predictive value increased with increasing sample volume from 69% for the 10-mL test to 82% for the 100-mL test, which means that a when a larger sample volume is used, a negative test becomes more likely to reflect true absence of fecal contamination.

The detection limit of the H_2S tests was also evaluated. As expected, it was found that the 100-mL H_2S test had the lowest detection limit (7.5 MPN/100 mL), whereas the other H_2S tests all failed to detect samples that had an *E.coli* concentration greater than 45 MPN/100 mL (i.e. Intermediate Risk Level).

It was found that, for unimproved sources, the laboratory-made H_2S tests had a 9% error and 0% proportional reduction. This means that for unimproved sources, the addition of the laboratory-made H_2S tests did not improve the error. The addition of the HACH H_2S test had a 21.2% error and a -133% proportional reduction in error, which means that the HACH H_2S test actually increased the error. Moreover, for improved sources, the H_2S tests (laboratory-made and HACH) had an error that ranged from 20% to 29% and a 61% to 44% reduction in error for the 20-mL and 100-mL laboratory-made H_2S test, respectively.

7 Recommendations

The water source improvement recommendations are based on the results from the Sanitary Surveys, Key-Informant Interviews and Water Quality results. The following chapter presents recommendations for conducting regular water quality tests using standard methods and/or field-based microbiological tests, for conducting regular site inspections; and for improving the water quality and infrastructure through a series of incremental improvements over the short, medium and longer term.

7.1 Water Quality Sampling Frequency

7.1.1 Microbiological Tests

The Philippines National Standards for Drinking Water states that the minimum frequencies for sampling public drinking water supply systems range from once monthly to once every three months, or more for populations >100,000 (Table 7-1) (DOH, 2007).

Table 7-1. Microbiological Sampling Frequency for Public Water Sources (DOH, 2007)

Source and Mode of Supply	Population Served	Minimum Frequency of Sampling
Level 1	90-150	Once every three months
Level 2	600	Once every two months
Level 3	<5,000	One sample monthly
	5,000-100,000	One sample per 5,000 population monthly
	>100,000	20 samples and additional one sample per 10,000 population monthly
Emergency Supplies of Drinking Water	n/a	Before delivery to users
Water Refilling Stations[1]	n/a	1 sample monthly
Water Vending Machines[1]	n/a	1 sample monthly

n/a: not applicable
[1]: product water

Prior to the development of a microbiological water quality testing laboratory in Capiz, this testing frequency was not possible. However, with this development and with the completion of this study, which provides a baseline on which to improve, it will be possible for efforts to be aligned with these recommended sampling periods.

7.1.2 Chlorine Residual

The 85 samples tested for chlorine residual in Roxas City, Panay, Panitan and Ivisan showed very poor compliance with the DOH's mandated range for free chlorine residual in the distribution system. On-going chlorine residual testing is needed to identify where and why these 3 municipalities and Roxas City are not meeting the required DOH standard for chlorine residual. The sample sites were unknown in relation to the distribution system. Therefore, the distribution system map should be matched with all results to understand what portions of the network is problematic.

The water discharged from the water treatment plant(s) should be disinfected to ensure that the DOH standard of 0.2 mg/L to 0.5 mg/L of free chlorine can be found at all points in the distribution system. Testing should be done at the treatment plants and at locations throughout the distribution system to determine an upgraded chlorine dosing regimen. Beside chlorine dosing at the water treatment plant(s) there may be the need for intermediate chlorine dosing treatment.

Proper chlorine dosing should be handled according the Philippine's Water Supply Regulations and WHO guidelines. It is critical that testing for chlorine residual be conducted properly according the equipment's directions at the site of treatment and throughout the distribution network. Proper testing is necessary to ensure the accuracy of results and the corresponding analysis of the problem of why significant portions of the network are not meeting the free chlorine residual standard.

7.2 Site Inspections

The results from the Sanitary Surveys detailed in Section 5.1 reveal infrastructure faults and the lack of site protection around both private and public water sources. Cumulatively, these hazards translate to Intermediate/High/Very High risk levels for 98% of the sources surveyed and provide causal links to the microbial contamination found in many of the water sources. The completed WHO Sanitary Survey forms for each respective municipality from the field work in January 2010 should be entered into a database and then passed along in hardcopy and electronic form to the SIs from each respective municipality. This should occur during education and training session(s) so that these hazards get highlighted. Graphical results in Appendix III show the breakdown of infrastructure faults for each source type surveyed, which allow infrastructure repairs to be prioritized based on the availability of time and resources. One of the immediate issues is that infrastructure faults such as damaged concrete platforms, lack of drainage channels, loose entry points and faulty pumps require materials and labor to remedy. Interviews with local government members suggest that these resources are locally available. Consistent access to capital and

operating funds are needed to ensure that infrastructure is safely maintained at the sources. This will be discussed further in Section 7.4.

Hazards from lack of site protection can be reduced with education and/or regular monitoring. Both of these activities can be conducted at the present time, with the present capacity of the Capiz Provincial Health Office, and without financial obstacles to overcome. Nevertheless, the time and commitment that is required to introduce new attitudes and behaviors relating to water safety present significant challenges and thus need to be addressed immediately.

There are only 1-2 SIs per municipality, with the exception of Roxas City. Because of this reality, it is necessary to extend education regarding water source safety to the local level. Capiz Province has a total of 473 *barangays* (Province of Capiz, Philippines, 2009), which means that there are roughly 20-30 *barangays* per municipality. It is recommended that there be an annual or semi-annual education session for both SIs and a representative from each *barangay* council (*barangay* appointed) in every municipality. This will ensure that consistent information is presented and will also allow open dialogue between *barangays*. The sessions should include the creation of community (*barangay*) maps of communal/public water sources, as well as an annual inspection schedule for Sanitation Inspectors to visit each *barangay*.

Following these educational sessions, it should be the *barangay* officials' responsibility to report back to their respective communities with the information they have been provided. This will include:

- Copies of schematics
- Forms for control measures (Appendix IV)
- Sanitary Surveys
- Water quality test results for *E.coli* and chlorine residual

Community assemblies should be scheduled where the information can be disseminated to the general public and appropriate action taken to protect the public water sites. *Barangay* Health Workers (BHWs) should be present at these information sessions, and should be given the information required to be able to identify hazards around water sources. These officials operate at the household level, and therefore can serve as important advocates of water safety around private water supplies.

The WHO recommends that Sanitary Surveys be conducted six times per year for open dug wells and four times per year for protected dugwells, springs and tubewells (WHO, 1997i). These should be conducted by *barangay* council members with support from SIs. The selected representative from each *barangay* council should be responsible for carrying out these regular inspections. A municipal committee could enforce this at the local level, and they would report to the Provincial Sanitary Engineer with the results from the surveys for maintenance of that data in the database and control measures taken. These efforts need to be aligned with water quality testing programs. Records need to be kept in order to monitor progress and track changes over time with respect to water quality and source protection measures; these should be maintained in the database, along with hardcopies.

7.3 Improving At-Risk Supplies

7.3.1 Short term

The required education that should be disseminated can be broken down into three components:

1. Basic water cycle and groundwater flow diagrams.
2. Above and subsurface structural components of the different water source types.
3. Descriptions of all hazardous activities around water sources and the distances within which these must be avoided in order to protect supplies (Appendix IV- Control Measures).

There are a number of web-based resources, which can be readily accessed to supplement this effort, based on the preferences of those in charge of implementing the education program. Table 7-2 below provides a list of recommended resources.

Table 7-2. Recommended Web Resources for Developing Education Programs

Author	Description	Source (weblink)
World Health Organization	Water Safety Plans	http://www.who.int/water_sanitation_health/dwq/gdwq3_4.pdf
World Health Organization	Sanitary Survey Templates	http://www.who.int/water_sanitation_health/dwq/2edvol3h.pdf
US Environmental Protection Agency	Information about source protection (activities around wells)	http://cFalse Positiveub.epa.gov/safewater/sourcewater/sourcewater.cfm?action=Assessments&view=general
The National Groundwater Association	Schematics of groundwater flow and the hydrologic cycle	http://www.ngwa.org/public/gwbasics/index.aspx

The next important consideration for developing the education strategy in Capiz Province is the decision of how the education should proceed between groups, and subsequently how the coordination of the information can be maintained.

In creating a municipality wide education session, there is the potential for alliances to be created to make water safety a collective priority. By organizing the event to bring together individuals nominated by the individual *barangays,* there is an opportunity to formally create an organization of people interested in water issues and invested in their communities' drinking water supplies. The municipal sessions will allow experiences and knowledge held at the *barangay* level to be shared, so that the communities can learn from each other. Thus, the formal creation of a municipal consortium to coordinate activities and to manage technical and financial resources could be highly beneficial for the municipalities of Capiz Province. Strong municipal level organization within the Municipal and Rural Health Units was consistently seen through fieldwork, and the organization at the provincial level has already been displayed through numerous national awards and through the existence of this PHO/MIT collaboration, which was initiated by the PHO, a further testament to their pro-active leadership.

7.3.2 Medium term

While Capiz is building technical and financial capacity to improve existing sources and to increase access to safe drinking water supplies, an interim solution is household water treatment and safe storage (HWTS). However, it should be stated that these options are always useful for providing an additional barrier of protection against microbial contamination. There are a variety of HWTS options, and the ones recommended here have been selected based on environmental and socio-economic factors observed during the fieldwork in January 2010. However, community participation, education and responsibility for the HWTS systems must be included when making decisions about which technology(s) to move forward with; as this is the only way to ensure long-term sustainability of the intervention. Disinfection, flocculation/disinfection and filtration technologies are suggested. For safe storage, the use of by-definition 'safe' storage vessels were sporadically seen in Capiz, however the widespread dissemination of these vessels is recommended to supplement household water treatment efforts.

The list of the recommended household water treatment products and safe storage containers can be found in Appendix V.

7.3.3 Long-term

The long-term goal must be to increase piped Level 3 supplies of treated/safe water so that all of citizens have access (both upland and lowland dwellers), as well as to ensure the safety of existing Level 3 supplies through proper chlorine residual dosing and monitoring. Thus, it is necessary to develop a strategic plan for incremental improvements and upgrades to both the infrastructure and the management and organization required to maintain the safety of the supplies. Capacity building will be extremely important to move towards adherence to the existing Philippine National Standards for Drinking Water and to the practices and procedures outlined in the Code on Sanitation in the Philippines- Chapter II Water Supply. The following section is broken down into four proposed focus areas for the PHO in moving forward after water quality results have been analyzed:

1. Regulatory Framework: The required alignment with the existing Regulatory Framework to enforce monitoring and testing of supplies, along with codes for the construction of new water source infrastructure
2. Management: Management roles clearly defined and enforced, along with training officials to assist in the maintenance and upkeep of supplies
3. Training: Training of local citizens as water source technicians
4. Funding: Funding to finance improvements in capacity and infrastructure

Regulatory Framework

The National Department of Health (DOH) has already created regulatory guidelines for both drinking water quality standards and for implementing rules and regulations of the Code on Sanitation with respect to drinking water supply.

- Implementing Rules and Regulations of the Code on Sanitation of the Philippines- Chapter II Water Supply (1995)
- Philippine National Standards for Drinking Water (2007)

While straightforward in theory, in practice these guidelines require significant local capacity and resources to implement. The number of Sanitary Inspectors per capita in Capiz Province is illustrative of the current gap between needs and the capacity at the provincial level to implement this national framework. That said, Capiz has taken an important first step by establishing a water quality laboratory and most importantly by actually conducting a baseline assessment of water quality around the province. Without this data, the province is not in a position to petition for

action at the national level. The water quality results presented in Section 5.3 present a snapshot picture of the current water quality around the province. The data allows the PHO to establish a clear case for why national level support is required to improve the situation for the citizens of Capiz. However, it is necessary for the province to first review the existing regulatory framework and to be able to detail exactly what they need to move forward- in terms of current lack of technical personnel, resources for carrying out educational and local level training sessions, development of a data management system, implementation of HWTS, and funds for setting up on-going water quality testing for *E.coli* and chlorine residual, among other capacity building requirements.

In order to align the provincial efforts with the existing regulations, it is recommended that the PHO director and Provincial Sanitary Engineer, in consultation with all relevant stakeholders, develop a strategic plan for incremental improvement of the infrastructure and management of Capiz water supplies for the next 3-5 years using this report as a foundation. Important items to address are summarized as follows:

1. Procurement of stores of safe storage containers. Citizens should be made aware that they are available, and if they are requested they should either be sold at cost or supplied by the province if funds can be made available. Boiling or household chlorination for drinking water should be recommended (as per the Annex in Chapter II *Water Supply*), while the feasibility for introducing and testing other household water treatment systems is explored through the contacts listed in Appendix V.

2. Development of a schedule for education and training sessions outlined in Section 7.3.1. This effort will allow an assessment of the current local capacity, aside from the SIs, to become involved in monitoring, maintenance and management of water supplies. Official records of the contact information of the members of the proposed municipal consortiums for water safety should be created, along with the data they collect in a central database. Subsequently, a list should be compiled of any gaps in personnel- per municipality- which currently prevent the required frequency of site inspections and collection and performance of microbiological testing, using a standard method test or a verified field-based test (from Section 6.1).

3. Development of a publically-accessible database describing the total number, type, and age of public '*barangay* funded' water sources, along with the estimated number of people served by these sources and the distance from households in each municipality. A stepwise plan to incrementally increase access to Level 2 and/or Level 3 sources, while relegating Doubtful and Level 1 sources to livelihood and non-drinking uses should be outlined. Additionally, measures planned to increase access to improved water services for people living in the upland areas should be detailed.

4. Based on the database and water quality results by source type, develop a plan for allocating annual funds for source upgrades in the order of need.

5. Assessment of the technical capacity (personnel, time) within the PHO to analyze water samples from around the municipality, using Quanti-Tray® and/or field-based methods. Assessment of the funds required to conduct the minimum number of recommended samples per water source type as recommended in the National Standards for Drinking Water (and Table 7-1) using Quanti-Tray® and/or any of the microbiological field-based tests mentioned above.

6. Development of regulations requiring regular water quality sampling of bottled water filling stations. Details should include the pricing structure, permitting and enforcement plan and the sampling schedule per municipality (see Section 8 of Chapter II- *Water Supply*).

7. Development of database for well-drilling companies, both local and provincial companies. This should include details of the measures being taken to move towards enforcement of the permitting, included the required personnel to coordinate this effort. Also, the steps to develop the legal framework for contractors to adhere to standard construction and operating procedures should be detailed. These procedures are contained in Section 3.4 of Chapter II- *Water Supply*. Section 4 of the document describes the required 'Drinking Water Site Clearance'.

Management

Provincial water utilities are well positioned to assist local level efforts at management and organization. Information can be shared about resources for monitoring and inspection, and they can potentially help with setting up a system for database management and a schedule for monitoring. They might also be able to assist with acquisition of spare parts and provision of technical support in repairing/maintaining infrastructure. Case studies from elsewhere in the Philippines have demonstrated the potential for these larger, well-established and better funded organizations to act as advisors on technical and financial management systems (WorldBank, 2003; WorldBank, 2004).

While there may be institutional barriers preventing this from becoming an ongoing partnership, it is still recommended that the Local Water Utility Administration be approached by the PHO and asked to participate in the respective municipal consortium(s) if it is created, or at the very least to host a meeting to involve them in the local level planning since they are important stakeholders in the communities they serve.

Training

There have been examples from elsewhere in the world which have shown the potential for local citizens to be trained as water source technicians (Mikelonis, 2008; Mudgal A. , 1997). Successful programs in both Latin America and South Asia demonstrate how it is possible for local citizens to be trained as technical professionals to overcome deficits in access to funds and technical support from higher levels of government.

Specifically, a program originating in the US and successfully piloted in Honduras called 'Circuit Riders' has had great success in training people to travel around to assist in operation and maintenance of rural public water sources. In Honduras, these Circuit Riders provide assistance in both technical and financial management. An NGO provides training for the Circuit Riders and also organizes general assemblies for the communities involved with the program (Mikelonis, 2008).

The example illustrates the potential for interested citizens in Capiz to become involved in water management at a municipal scale. In every *barangay* visited during fieldwork in January 2010, there was at least one person with experience and technical know-how in repairing water supplies. Moreover, there were people who were willing to contribute to the upkeep and maintenance of supplies. If there was an opportunity for a person(s) to gain a paid position by the PHO to 'ride the

circuit' and provide technical assistance for *barangay* water sources, this could enable significant improvements to the current water safety situation around the province. It is recommended that the PHO explores funding routes for creating these municipal-level positions, and concurrently seeks the technical advisors it would require to provide training for these technicians through the Local Water Utility Administration or Water District.

Funding

Funding will be one of the limiting factors in the pace at which Capiz Province is able to improve and upgrade the drinking water supply infrastructure. However, Capiz can make a strong case with presentation of the water quality results, the focused strategic plans for meeting regulatory requirements and demonstration of the clear initiatives already undertaken at the PHO.

It is recommended that the funds be allocated specifically for water infrastructure improvement and repair, and not be allowed to disappear into a general annual budget. The PHO has to work with the provincial government and the Local Water Utility Administration to ensure that there is accountability for municipal and *barangay* level fund allocation and that clear deliverables have been decided before funds are distributed. This will require the establishment of a database management system and the ongoing collection of water quality and Sanitary Survey information to monitor the current public water sources within each municipality.

The recommended order of importance for funding infrastructure upgrades is as follows:

- Funds to monitor and improve chlorine dosing of Level 3 sources
- Funds to acquire safe storage containers (and disinfection products if required)
- Funds to train and employ technical officials to operate at a municipal level to repair and maintain supplies
- Funds for repairs/maintenance of Level 1 and Doubtful sources (public)
- Funds for increasing access to Level 2 sources
- Funds for increasing access to Level 3 sources resulting in decreased cost (economy-of-scale)

Safe storage containers present both an immediate remedial measure and also a sustainable longer term investment. Securing financing for technical support for the upkeep of public water supplies is of primary importance if long-term, sustainable improvements are to be made for the water sources in Capiz. If the infrastructure is not maintained, the money represents a wasted investment

for which all parties lose. Once the capacity at the municipal level to maintain and manage water sources has been established, funds to repair and protect Level 1 and Doubtful sources from contamination should be provided.

Increasing access to Level 2 sources represents a higher investment and these funds should be made available to different municipalities over time based on need established by current infrastructure and water quality and also by a thorough investigation regarding the new source water quality and quantity to provide a viable, long-term supply of water. Interviews suggested that there are ample, unexplored spring sources located around Capiz and that people thought highly of the quality of these sources (Patrick, 2010). Lastly, interviews with people in areas where Level 3 sources exist revealed that the fees were a heavy burden for many families in Capiz (P300 + per month) and that access was limited. Level 3 service is generally limited by household locations (i.e. only those along the main service road have access) and ultimately by their ability to pay for the service. Thus, there needs to be an effort to explore the potential for various funding routes that will enable fees to be lowered and/or systems to be expanded so that the economy-of-scale can be applied.

7.4 Recommendations for Future Microbiological Tests

Due to the limitations present in the detection limits for Quanti-Tray® and Petrifilm™, future projects utilizing the EC-Kit are recommended to use Quanti-Tray®/2000.

Based on the statistical analyses of the drinking water quality test results, we recommend the use of the EC-Kit for both improved and unimproved water sources. However, if there are limiting factors (e.g. insufficient funds, shortage of SIs, time constraints, etc.), we recommend that the 10-mL predispensed Colilert® tube alone be used for improved drinking water sources. This test could potentially be replaced by the H_2S test. In addition, for unimproved drinking water sources, we discourage the use of microbiological tests, and instead recommend that DOH assume that unimproved drinking water sources are contaminated.

One of the primary complications observed in the study was with the field usage of the EC-Kit. Trainees of the EC-Kit attended a one-day workshop, and the training at this workshop was not complete enough for field tests to commence. The chief problem may have been that the training took place in May; however, due to unavoidable delays, the test program itself could not begin until December. Moreover, the initial version of the EC-Kit instructions lacked information regarding quality control procedures, and did not sufficiently emphasize the need to maintain sterile

conditions when collecting water samples for the EC-Kit. Furthermore, there were no photos included with the instructions to help illustrate each step. Since then, the EC-Kit instructions have been modified (see Appendix VI).

Future workshops in the EC-Kit should allow users to have a "trial" field testing, and a follow-up workshop to address any questions or confusion about the methods and interpretation of results. In particular, we noticed that users of the EC-Kit were especially perplexed regarding how to properly perform the fluorescence readings for the Colilert® test and the Petrifilm™ gas-forming colony counts. We advised future users of the EC-Kit to describe the Colilert® results as "milky, blue" fluorescence, and to emphasize reading Petrifilm™ results held up to proper daylight or bright lighting, so as to visibly notice the gas bubble formations. In addition, it is highly recommended that the Petrifilm™ *E.coli*/Coliform Count Plate Interpretation Guide be utilized in analysis of Petrifilm™ results[3]. A possible method for future workshops could have trainees in pairs or small groups, and have each member individually count the blue colonies with gas bubbles, and have the group members compare their counts. This would highlight the need to only count the colonies with gas bubbles, not colonies without gas bubbles, and also introduce the concept of having a "double-check" count.

[3] Document available for download under "Instructions for Use" at the 3M website: http://solutions.3m.com/wps/portal/3M/en_US/Microbiology/FoodSafety/product-information/product-catalog/?PC_7_RJH9U523003DC023S7P92O3O87_nid=C0WJ62882Vbe29BDXSBJ7Fgl

8 Conclusions

The fieldwork in Capiz during January 2010 revealed both the challenges and the opportunities that exist within the province with respect to drinking water quality and water management. The significant proportion of sources sampled with *E.coli* contamination has and will continue to serve as an importance source of awareness for both local residents and hopefully for officials at the provincial and national level about the need to focus on water safety. Water quality and quantity are incredibly important because of the pivotal role they play in enabling healthy and productive lives. While the Philippines are generally a place of water abundance, the quality of the water largely governs the uses for which it is appropriate and safe. The Philippines has a growing population and a largely water-based economy, which emphasizes the importance of focusing on water management at this point in the development of the country.

E.coli test results showed that Doubtful and Level 1 sources had higher percentages of Intermediate and High/Very High risk levels according to the WHO. The wide range of drinking water quality results for a given water source category could be attributed to the varying source types (e.g. Level has JMP, PDW, etc.) Drinking water samples collected from Level 2 and Level 3 water sources were found to be in the Conformity to Low Risk Level. This indicates a decreased likelihood of contamination in water sources that have piped distribution or in systems that receive treatment prior to distribution. This is demonstrative of the potential health benefits of increasing the proportion of the Capiz population with access to these services.

Most of the drinking water samples tested for chlorine residual did not meet the WHO/DOH minimum chlorine residual requirements. Therefore, we recommend the following: (i) increasing the chlorine dose administered to the effluent drinking water at the water treatment plant, and (ii) testing chlorine residual at the treatment plants and throughout the distribution system to ensure that it meets WHO/DOH standards.

The Sanitary Survey site assessments generally showed that many hazards are present around public water sources, and that it is highly likely that some of these- specifically septic tanks and animal waste- are contributing significantly to poor water quality. Ongoing monitoring and hazard identification will allow the province to implement appropriate control measures to reduce this risk to acceptable levels. We noticed that significant local capacity, initiative, ideas and interest exist for improving water safety within the community. Thus, there is a strong foundation in Capiz Province upon which to build a sustainable and effective system for water services provision to all citizens.

The next steps are for the PHO to continue with regular water quality testing programs in Capiz. Field-based tests were looked at as single P/A or enumerative tests, and as a combination of tests (i.e. one P/A test and one enumerative test) to determine the best testing combination (Chuang 2010, Trottier 2010). Based on these criteria, the study recommended the use of the laboratory-made 20-mL H2S test as a single P/A test for testing improved water sources, and the use of the Colilert test as a single P/A test for testing unimproved water sources.

From the calculations of error and proportional reduction in error for unimproved and improved water sources, it possible to make better predictions with just the use of the Colilert® test, but not just the use of the Petrifilm™ test. This is due to the detection limits for Petrifilm™ being much higher than Colilert®, namely positive Petrifilm™ results fall within the High and Very High risk level categories, whereas positive Colilert® results fall within the Intermediate, High, and Very High risk level categories. Most importantly, the two test set of the EC-Kit allows for the best reduction in error, with a proportional reduction in error of 63% for unimproved water sources and 60% for improved water sources.

Additional recommendations are to improve source safety and protection through education, coordination and planned enforcement and monitoring. Training local citizens to act as technicians to repair and maintain existing infrastructure is critical for preventing continued contamination of water sources. It is also recommended that the use of safe storage for drinking water is promoted and that the PHO explores the potential use of household water treatment for users of private water sources. Longer term plans need to include strategies for aligning and developing systems within the province to existing national level regulations, the development of effective management systems both at the municipal and provincial level, and finally on securing the necessary funding to implement programs and services.

9 References

Almedom, A. M., Blumenthal, U., & Manderson, L. (1997). *Hygiene Evaluation Procedures: Approaches and Methods for Assessing Water- and Sanitation-Related Hygiene Practices.* London, UK: International Nutrition Foundation for Developing Countries (INFDC).

APHA, AWWA, WPCF. (2007). *Standard methods for the examination of water and wastewater.* Washington, DC: American Public Health Association.

Ashley, R., Blackwook, D., Butler, D., & Jowitt, P. (2004). *Sustainable water services: a procedural guide.* London, UK: IWA Publishing.

Bartram, J., Fewtrell, L., & Stenström, T.-A. (2001). Harmonised assessment of risk and risk management for water-related infectious disease: an overview. In WHO, *Water Quality: Guidelines, Standards and Health.* (pp. 1-15). Geneva: World Health Organization.

Brikké, F., & Bredero, M. (2003). Chapter 7: Storage and distribution. In *Linking technology choice with operation and maintenance in the context of community water supply and sanitation: A reference document for planners and project staff* (p. p.98). Geneva, Switzerland: World Health Organization and IRC Water and Sanitation Centre.

Cairncross, S., & Shordt, K. (2004). It does last! Some findings from a multi-country study of hygiene sustainability. *Waterlines 22 (3)* , 4-7.

CAWST. (2007). *Appendix J. How to Use and Take Care of BSF. Training Course Module.* Calgary, Alberta: Centre for Affordable Water and Sanitation Technology (CAWST) .

Chuang, P (2010). *Comparison of EC-Kit with Quanti-Tray®: Testing, Verification and Drinking Water Quality Mapping in Capiz Province, Philippines.* Massachusetts Institute of Technology.

CIA. (2009, November). *CIA The World Factbook*. Retrieved November 24, 2009, from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

Clasen, T. (2005, 10 11). *WELL .* Retrieved 03 22, 2010, from http://www.lboro.ac.uk/well/: http://www.lboro.ac.uk/well/

Crump, J., Otrieno, P., Slutsker, L., Keswick, B., Rosen, D., Hoekstra, R., et al. (2005). “Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhea in areas

with turbid source water in rural western Kenya: cluster randomized controlled trial. *BMJ doi:10.1136/bmj.38512.618681* .

Department of Health. (1995). *Implementing Rules and Regulations of Chapter II Water Supply of the Code on Sanitation of the Philippines.* Manila: UNICEF.

DOH. (2007). *Philippines National Standards for Drinking Water .* Manila: Republic of the Philippines Department of Health; Office of the Secretary .

DOH. (1995). *The Code of Sanitation of the Phililppines- Chapter II Water Supply.* Manila: Department of Health; Environmental and Occupational Health Office.

DOH. (1976). *The Code on Sanitation of the Philippines: Presidential Decree No.856.* Manila: Philippines Department of Health; UNICEF.

Doyle, M., & Erickson, M. (2006). *Closing the Door on the Fecal Coliform Assay. Microbe Vol1: No.4.*

Duke, W., Nordin, R., & Mazumber, A. *Comparative Analysis of the Filtron and Biosand Water Filters.* http://www.pottersforpeace.org/wp-content/uploads/comparative_analysis_of_the_fltron_and_biosand_water_filterseditms.pdf: University of Victoria, Canada.

Garandeau, R., Casella, D., & Bostoen, K. (2009). *Evaluating & Improving the WASH Sector:Strengthening WASH Governance, Learning about Complexity, Assessing Change.* The Hague, The Netherlands: IRC International Water and Sanitation Centre.

Gerba, C. P. (2000). Indicator Microorganisms. In R. Maier, I. Pepper, & C. Gerba, *Environmental Microbiology* (pp. 491-503). San Diego: Academic Press.

Gov.Ph. (2009). *The Official Government Portal of the Republic of the Philippines*. Retrieved November 24, 2009, from http://www.gov.ph/index.php

Grant, M., & Ziel, C. (1996). Evaluation of a simple screening test fo faecal pollution in water. *Journal of Water SRT - Aqua* , 13-18.

Hach. (2009). *Pocket Colorimeter II Analysis Systems: Instruction Manual, Chlorine (Cl2).* Retrieved May 19, 2010, from Hach: http://www.hach.com/fmmimghach?/CODE%3A5957088_ED520969|1

Howard, G. (2002). *Water Quality Surveillance- a practical guide.* Loughborough, England: Water Engineering and Development Centre, Loughborough University 88pp.

Howard, G., & Bartram, J. (2003). *Domestic Water Quantity, Service Level and Health.* Geneva, Switzerland: World Health Organization.

IDEXX. (2010a, February). *IDEXX February 2010 Newsletter*. Retrieved February 20, 2010, from IDEXX: www.idexx.com/view/xhtml/en_us/water/newsletter/201002.jsf

IDEXX. (2010b). *Quanti-Tray & Quanti-Tray/2000*. Retrieved February 21, 2010, from IDEXX: http://www.idexx.com/view/xhtml/en_us/water/quanti-tray.jsf

IDRC. (1998). *Module 7: Water Quality Control Techniques.* San Jose, Costa Rica: Fundaction Tecnologica de Costa Rica.

Koppen, B. v., Smits, S., Moriarty, P., Vries, F. P., Mikhail, M., & Boelee, E. (2009). *Climbing the Water Ladder : Multiple-use water services for poverty reduction (TP series; no. 52). 213 p.* The Hague, The Netherlands: IRC International Water and Sanitation Centre and International Water Management Institute.

Lantagne, D. (2001). *Investigation of the Potters for Peace Colloidal Silver-Impregnated Ceramic Filter: Intrinsic Effectiveness and Field Performance in Rural Nicaragua.* Allston, MA, USA 02134: Alethia Environmental.

Lee, T. (2000). *Household Water Filter Project in Nepal. Master of Engineering Thesis.* Cambridge, MA: Massachusetts Institute of Technology. Civil and Environmental Engineering Dept. .

Lockwood, H. (2004). *Scaling Up Community Management of Rural Water Supply.* IRC International Water and Sanitation Centre.

Luby, S., Agboatwalla, M., Painter, J., Altaf, A., Billhimer, W., Keswick, B., et al. (2006). Combining drinking water treatment and hand washing for diarrhea prevention, a cluster randomized controlled trial. *Tropical Medicine and International Health.Vol. 11. No. 4. doi:10.1111/j.1365-3156.2006.01592.x* , 479-489.

MacDonald, A., Davies, J., Calow, R., & Chilton, J. (2005). *Developing Groundwater: A guide for Rural Water Supply.* Rugby: Practical Action Publishing.

Manja, K., Maurya, M., & Rao, K. (1982). A simple field test for the detection of faecal pollution in drinking water. *Bull WHO* , 797-801.

Maycumber, I. (2009). *Strategies for Implementing Biosand Water Filter Projects: Case Studies from the Philippines; Master of Science in Civil Engineering.* Fort Collins, Colorado: Colorado State University; Peace Corps Masters International; http://www.peacecorpswiki.org/images/Strategies_for_Implementing_BSF_Projects.pdf.

Metcalf, R. (2006). The Portable Microbiology Laboratory Revolutionizing Point Source Water Testing in Africa. PowerPoint presentation MIT June '09. Sacramento, CA: California State University.

Micrology Laboratories. (2009, October 12). *Coliscan Easygel*. Retrieved February 21, 2010, from Micrology Laboratories: http://micrologylabs.mennonite.net/Home/Our_Methods/Coliscan_Media/Coliscan_Easygel

Micrology Laboratories. (2008). *Coliscan Easygel Guide.* Goshen, IN http://www.micrologylabs.com/Home/Our_Methods/Coliscan_Media/Coliscan_Easygel.

Mikelonis, A. (2008). *A Program to Implement a Circuit Rider Program in Honduras.* Final Paper: 1.851J MIT Water and Sanitation in Developing Countries[unpublished].

Moriarty, P., Batchelor, C., Smits, S., S.Pollard, Butterworth, J., Reddy, G., et al. (2004). *Resources, Infrastructure, Demands and Entitlements (RIDe): a framework for holistic and problem-focussed water resources assessments.* UK: WHIRL Water, Households & Rural Livelihoods.

Mudgal, A. (1997). *India Handpump Revolution: Challenge and Change.* HTN Working Paper: WP 01/97.

Nath, K., Bloomfield, S., & Jones, M. (2006). *Household water storage, handling and point-of-use treatment.* Somerset, UK: International Scientific Forum on Home Hygiene.

NSO. (2002, June 21). *Press Release - Census - 2002*. Retrieved February 27, 2010, from National Statistics Office of the Philippines: http://www.census.gov.ph/data/pressrelease/2002/pr0276tx.html

Patrick, J. (2010). *Recommendations For At-Risk Water Supplies in Capiz Province, Philippines: Using Water Source and Community Assessments.* Massachusetts Institute of Technology.

PFP. (2006). *Potters for Peace*. Retrieved April 2010, from http://s189535770.onlinehome.us/pottersforpeace/?page_id=9

Pillai, J., Mathew, K., Gibbs, R., & Ho, G. (1999). H2S paper strip method - A bacteriological test for faecal coliforms in drinking water at various temperatures. *Water Science Technology* , 85-90.

Province of Capiz, Philippines. (2009). Retrieved November 24, 2009, from Captivating Capiz: http://www.capiz.gov.ph/

Rietveld, L., Haarhoff, J., & Jagals, P. (2009). A tool for technical assessment of rural water supply systems in South Africa. *Physics and Chemistry of the Earth 34* , 43-49.

Roxas City, Philippines. (2007). Retrieved October 21, 2009, from The Official Website of Roxas City, Capiz, Philippines: http://www.roxascity.gov.ph/

Skinner, B. (2003). *Small-Scale Water Supply: A Review of Technologies.* London: ITDG Publishing.

Smet, J., & Wijk, C. v. (2003). *Small Community Water Supplies: Technology, people and partnership TP40-E.* Netherlands: IRC International Water and Sanitation Centre.

Sobsey, M. (2002). *Managing Water in the Home: Accelerated Health Gains from Improved Water Supply.* Geneva, Switzerland: WHO/SDE/WSH/02.07.

Sobsey, M., & Pfaender, F. (2002). Evaluation of the H2S method for detection of fecal contamination of drinking water. *WHO* .

Thermalindo. (2007). *Online Catalog: Microbiology .* Retrieved December 2009, from Thermalindo Sarana Laboratoria: http://www.thermalindo.com/online_catalog_detail.asp?categoryid=118&productid=441

Trottier, S. (2010). *Study of Four New, Field-Based Microbiological Tests: Verification of the Hydrogen Sulfide (H2S), Easygel®, Colilert, and Petrifilm™.* Massachusetts Institute of Technology.

U.S. Department of State. (2009). Retrieved November 24, 2009, from The Office of Electronic Information, Bureau of Public Affairs: http://www.state.gov/r/pa/ei/bgn/2794.htm

UNICEF. (2009). *Women hand pump mechanics on the move*. Retrieved April 2010, from UNICEF India: http://www.unicef.org/india/wes_5438.htm

Venkobachar, C., Kumar, D., Talreja, K., Kumar, A., & Iyengar, L. (1994). Assessment of bacteriological water quality using a modified H2S strip test. *Journal of Water SRT - Aqua* , 311-314.

WaterAID. (2010). *Keeping the water flowing*. Retrieved April 2010, from WaterAID: http://www.wateraid.org/international/what_we_do/where_we_work/india/3918.asp

WHO. (1997i). 3.Surveys. In WHO, *Guidelines for Drinking Water Quality- Volume 3 Surveillance and control of community supplies* (pp. 42-50). Geneva: World Health Organization ISBN 92 4 154503 8.

WHO. (2003ii). 4.Water Safety Plans. In WHO, *WHO Drinking Water Quality Guidelines- Vol.3 2nd addition* (pp. 48-82). Geneva: World Health Organization.

WHO. (1997ii). 6.Technical Interventions. In WHO, *Guidelines for Drinking Water Quality 2nd Edition- Volume 3 - Surveillance and control of community supplies* (pp. 84-128). Geneva: World Health Organization ISBN 92 4 154503 8.

WHO. (2008). *Guidelines for Drinking Water Quality* (3rd Edition ed.).

WHO. (2003i). *WHO Drinking Water Quality Guidelines Volume 3- 2nd edition.* Geneva: World Health Organization.

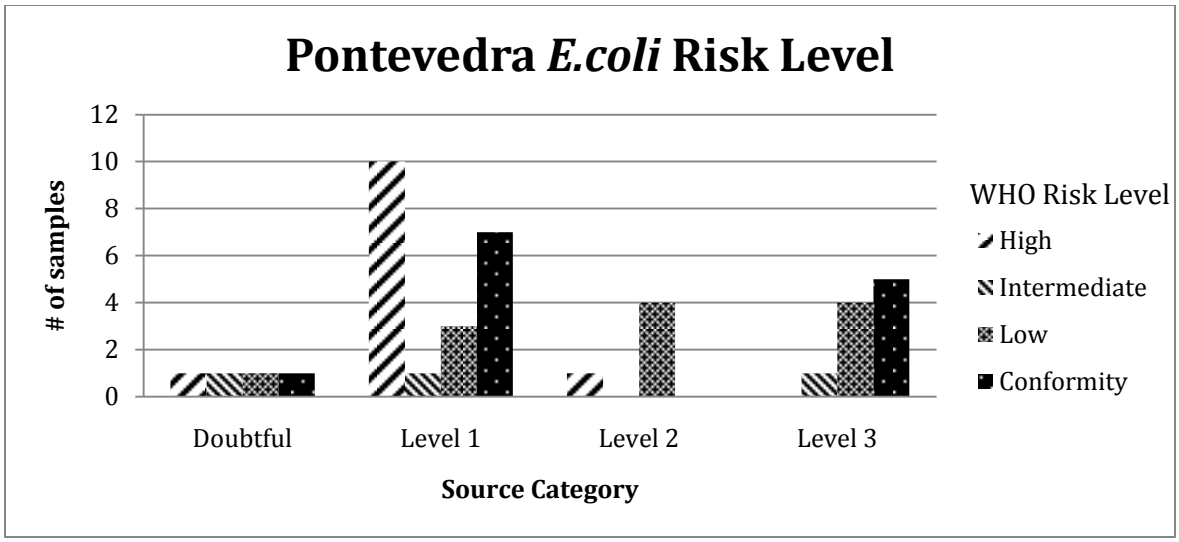
Wijk-Sijbesma, C. v. (2001). *The best of two worlds?: methodology for participatory assessment of community water services (Technical paper series, no.38).* Delft, The Netherlands: IRC International Water and Sanitation Centre.

WorldBank. (2004). *Lessons Learned from Rural Water Supply Projects in the Philippines: Identifying Elements of Sustainability Field Note 46426.* World Bank Water and Sanitation Program (WSP).

WorldBank. (2003). *Management Models for Small Towns Water Supply:Lessons learned from case studies in The Philippines.* World Bank Water and Sanitation Program.

WWICS. (2006). *Water Stories: Expanding Opportunities in Small-Scale Water and Sanitation Projects.* USA: Environmental Change and Security Program Woodrow Wilson International Center for Scholars.

Appendix I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4
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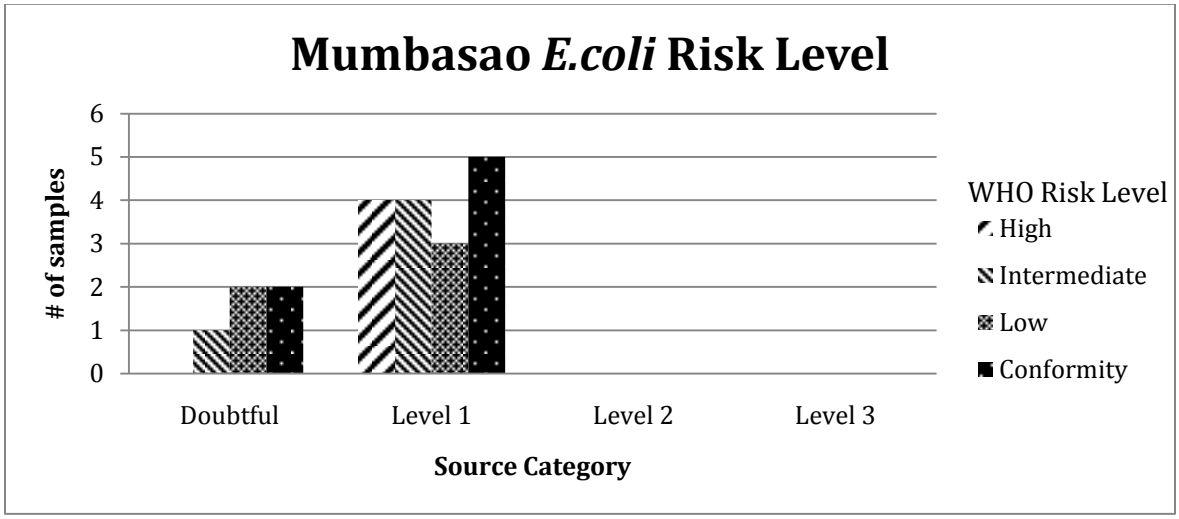
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity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Level 1
Level 2
Level 3
Source Category
WHO Risk Level
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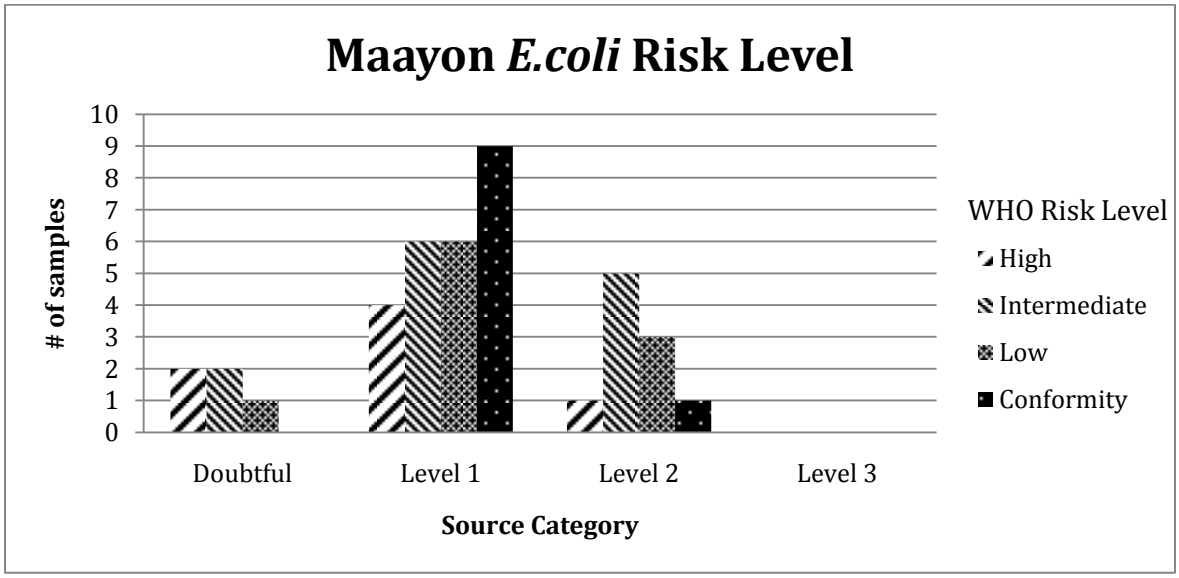
Intermediate
Low
Conformity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Level 2
Level 3
Source Category
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Intermediate
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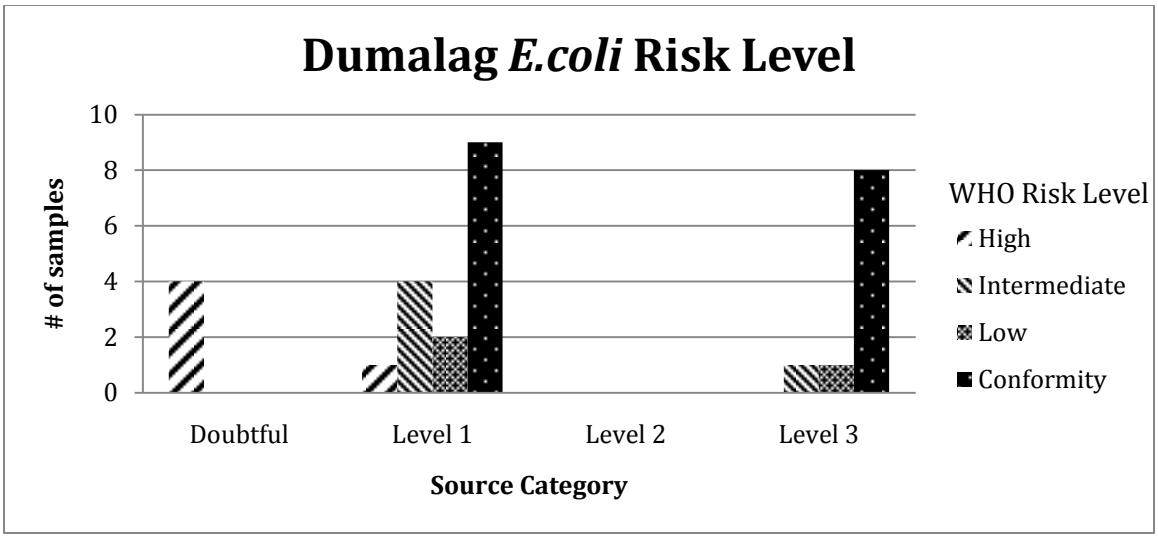
Conformity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4
2
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Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
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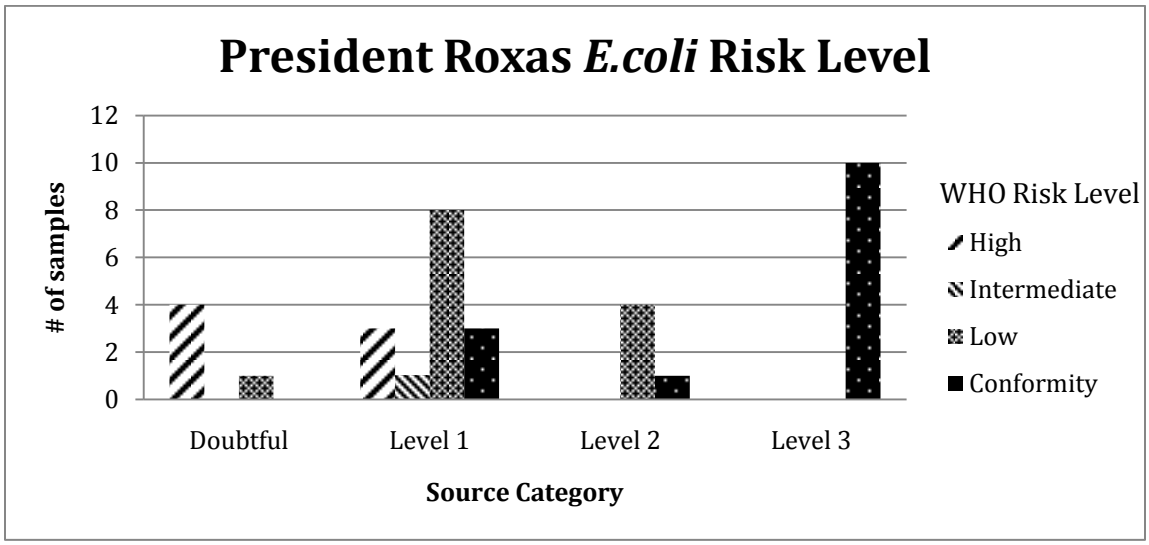
Intermediate
Low
Conformity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Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
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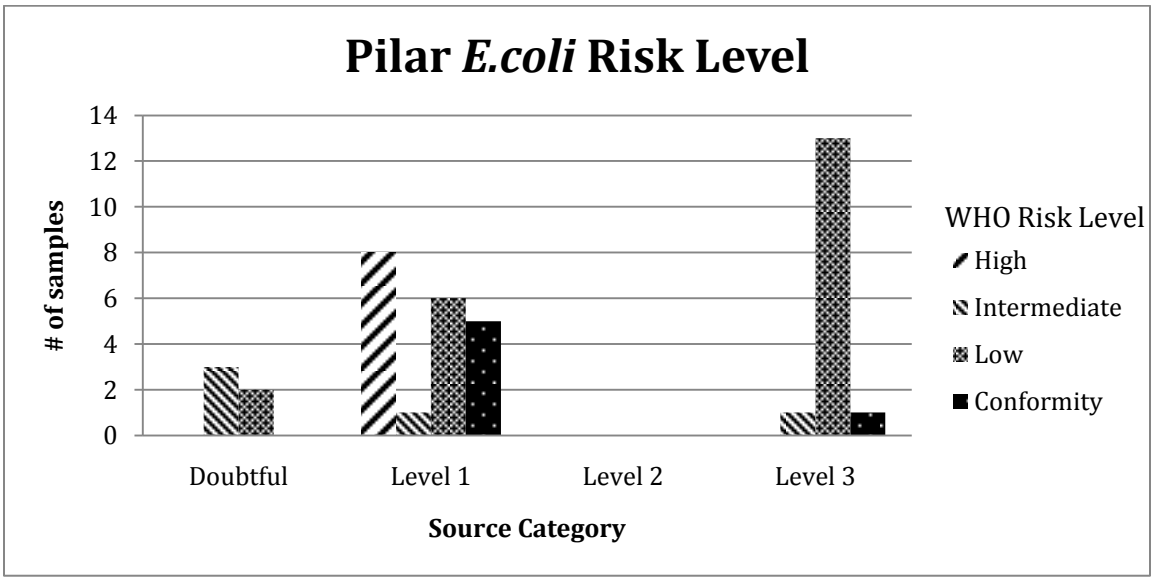
Intermediate
Low
Conformity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Level 2
Level 3
Source Category
WHO Risk Level
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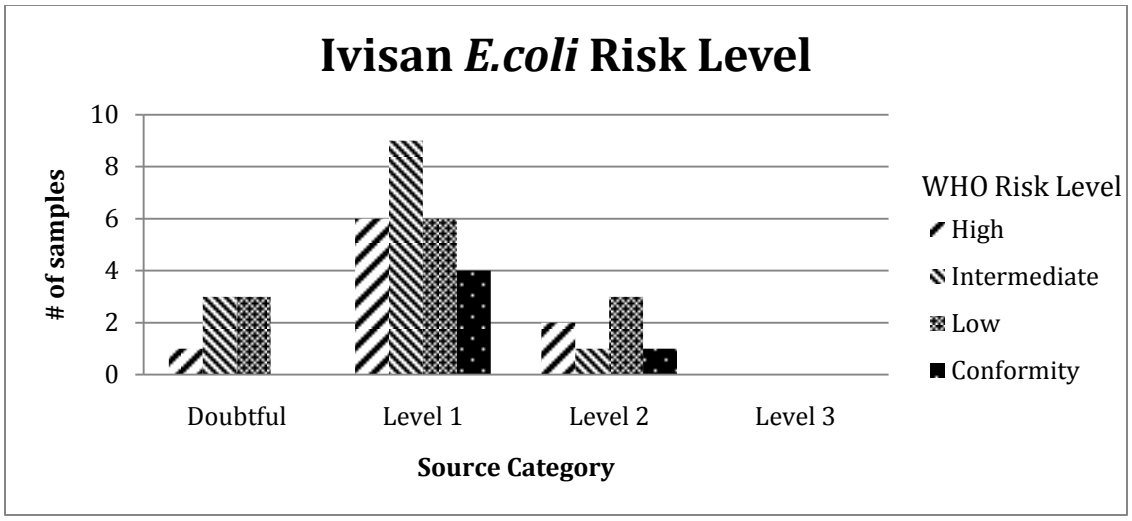
Intermediate
Low
Conformity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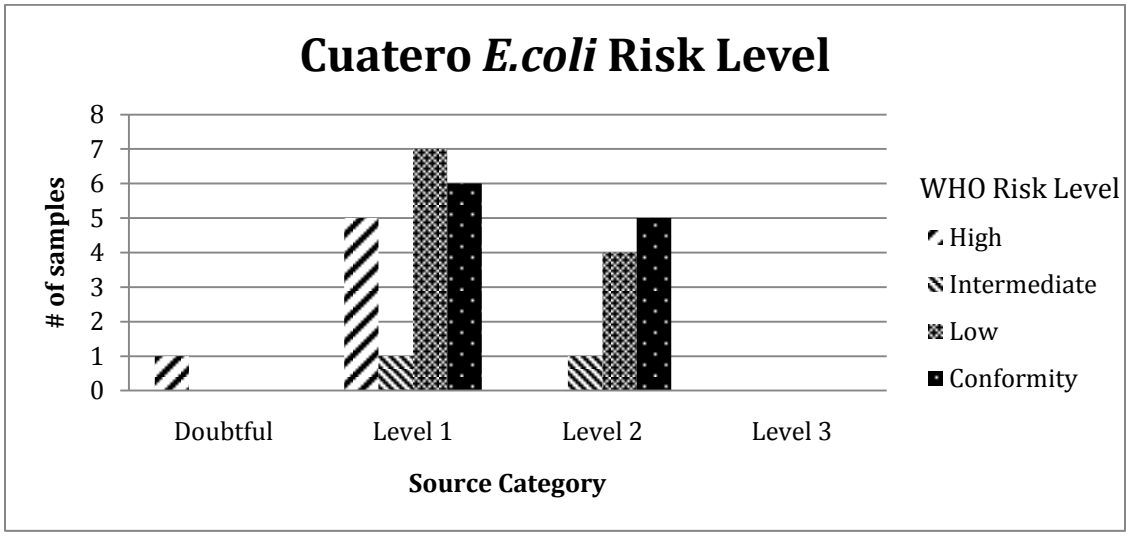
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity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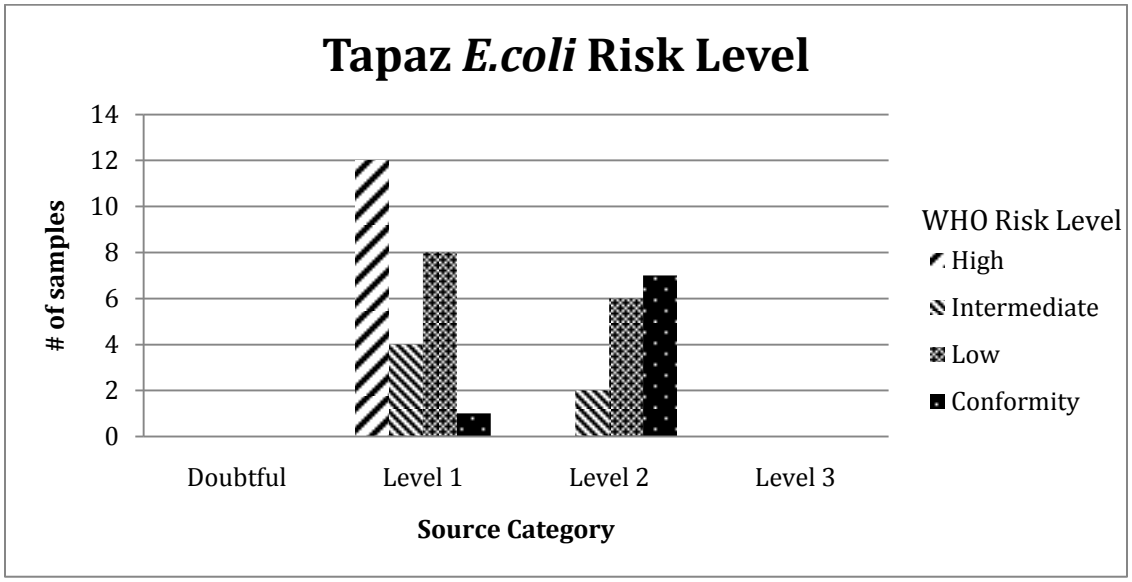
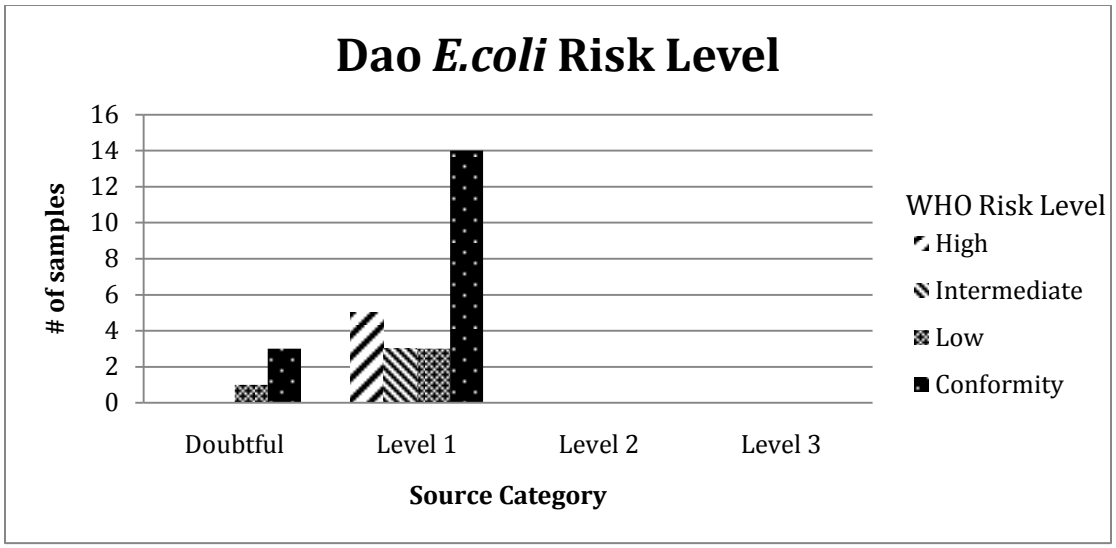
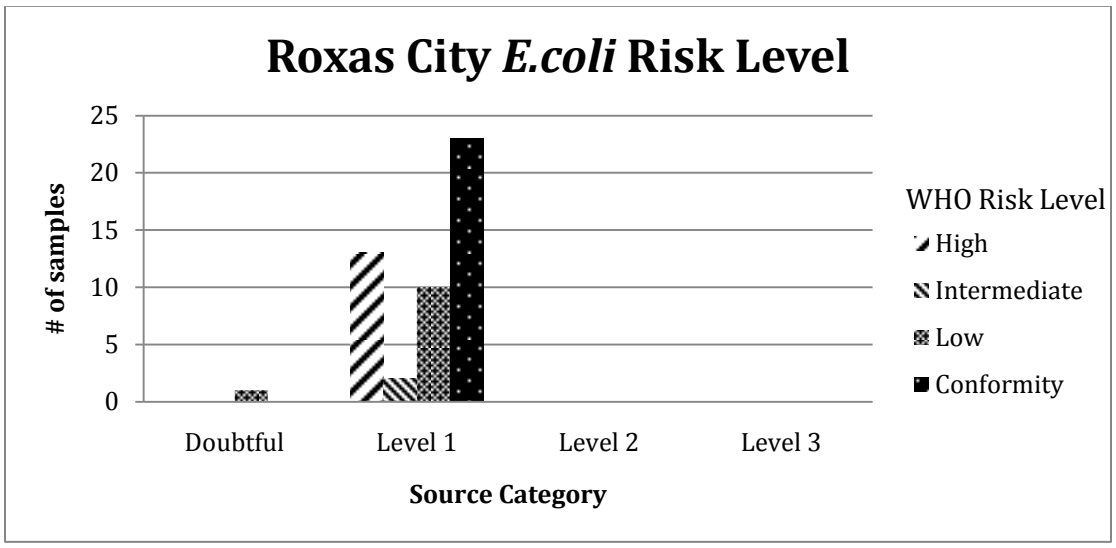
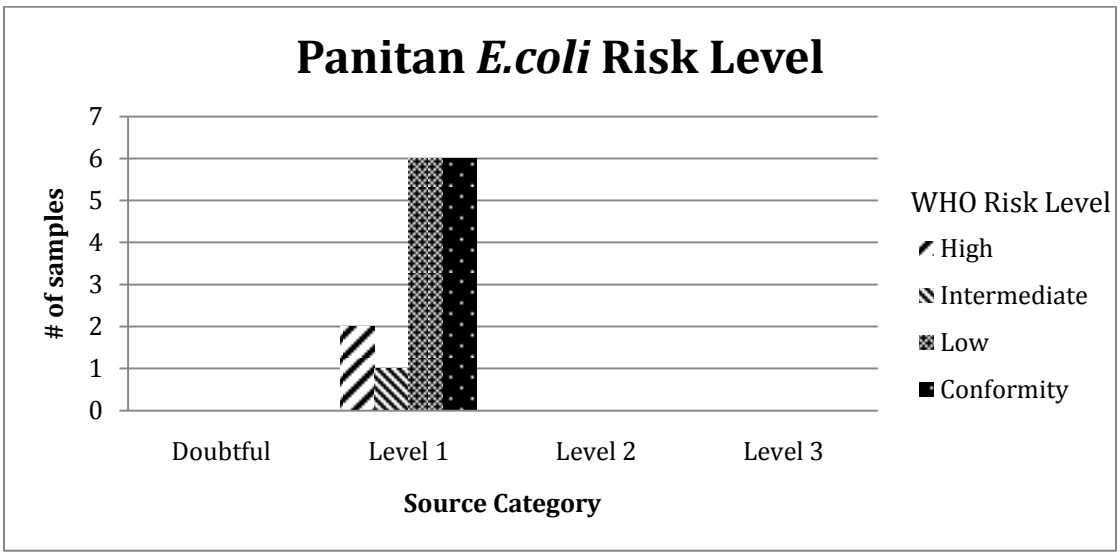
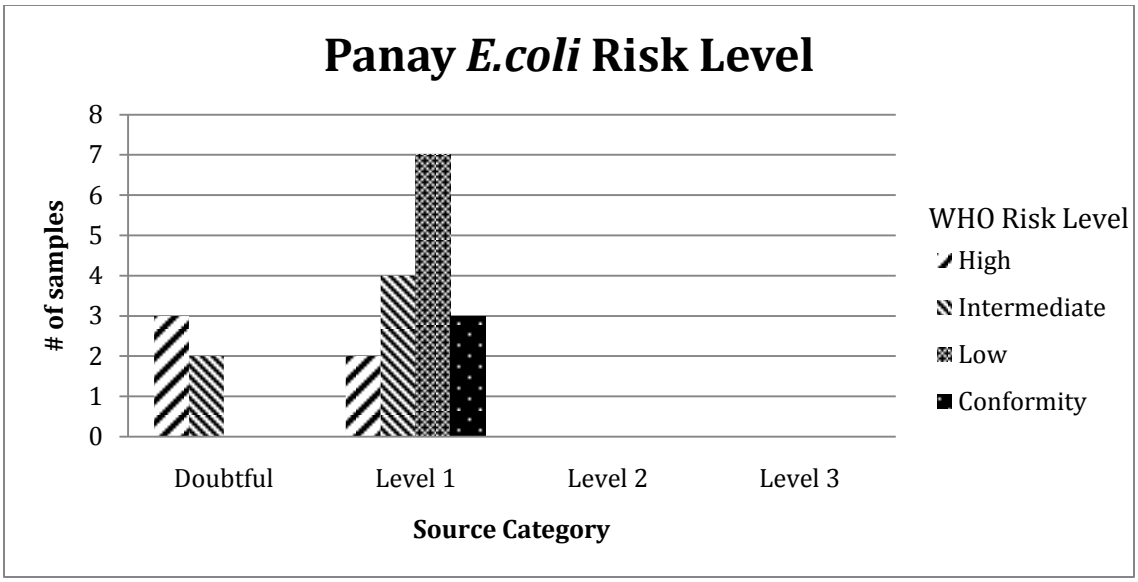
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

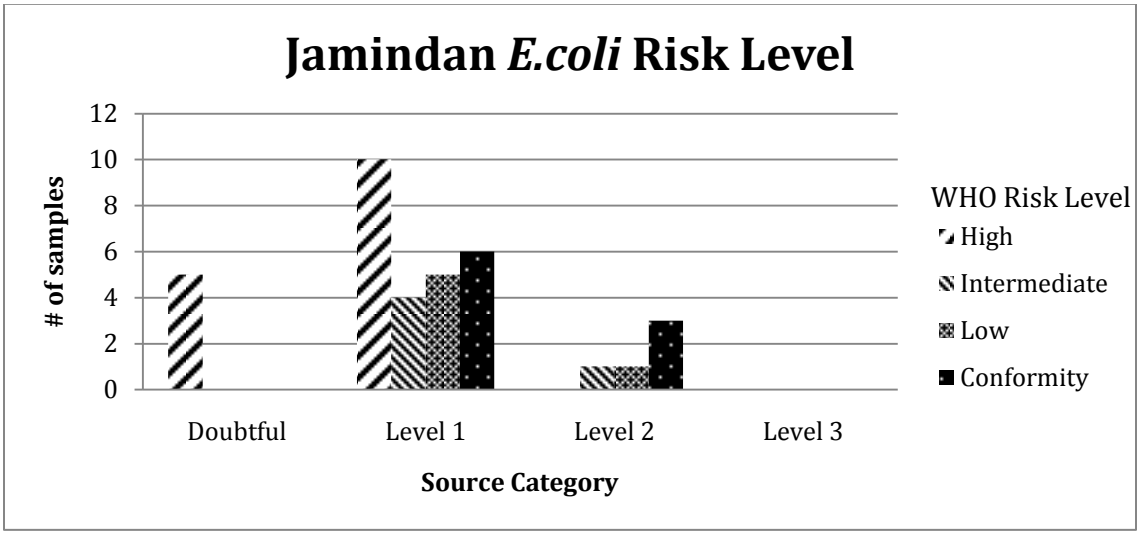

Tapaz *E.coli* Risk Level
# of samples
14
12
10
8
6
4
2
0
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

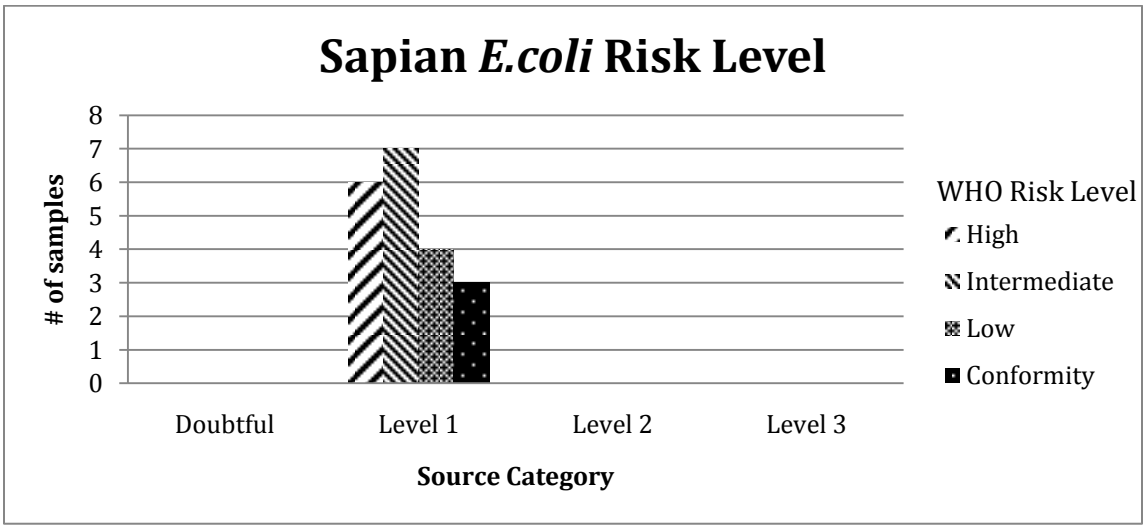

Dao E.coli Risk Level
16
14
12
10
8
6
4
2
0
# of samples
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

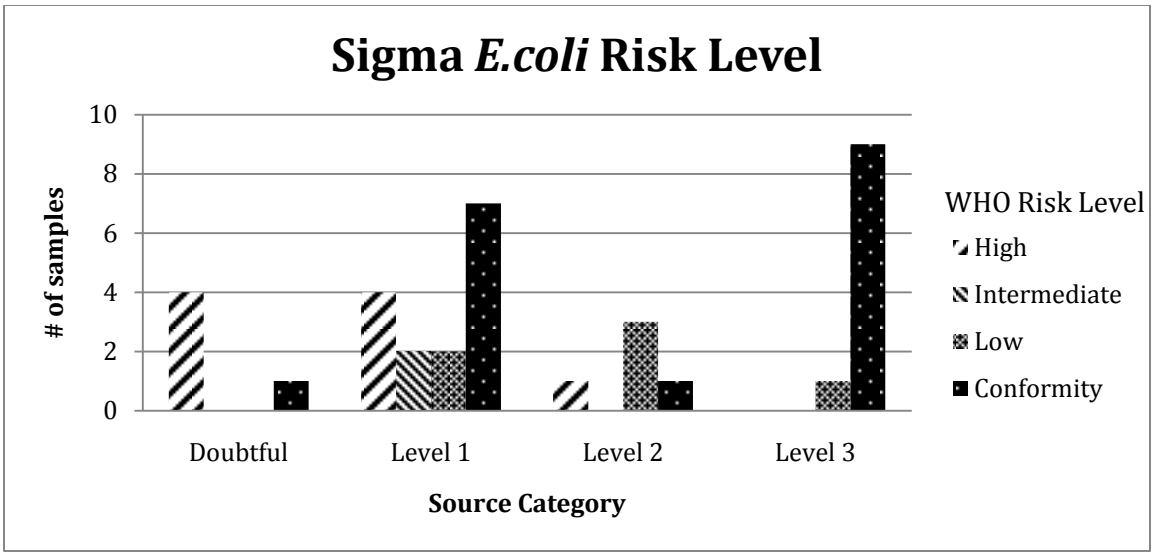

Roxas City E.coli Risk Level
25
20
15
10
5
0
# of samples
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

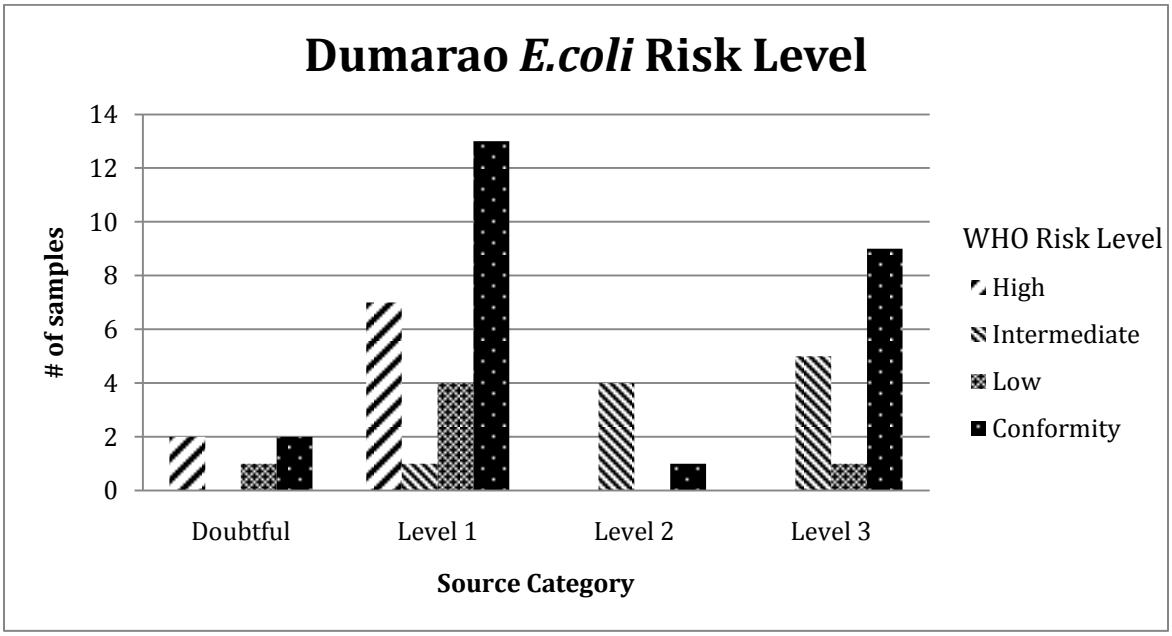

Panitan E.coli Risk Level
7
6
5
4
3
2
1
0
# of samples
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity


Panay *E.coli* Risk Level
# of samples
8
7
6
5
4
3
2
1
0
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

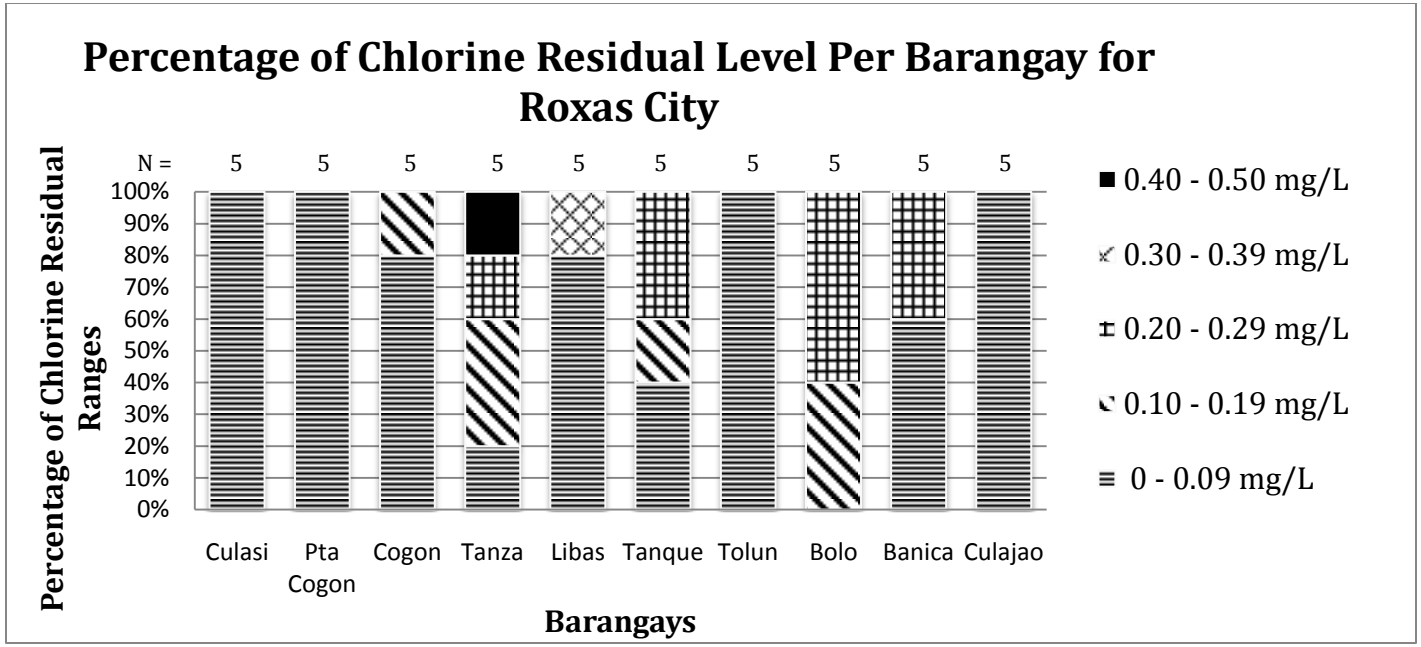

Jamindan *E.coli* Risk Level
# of samples
12
10
8
6
4
2
0
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

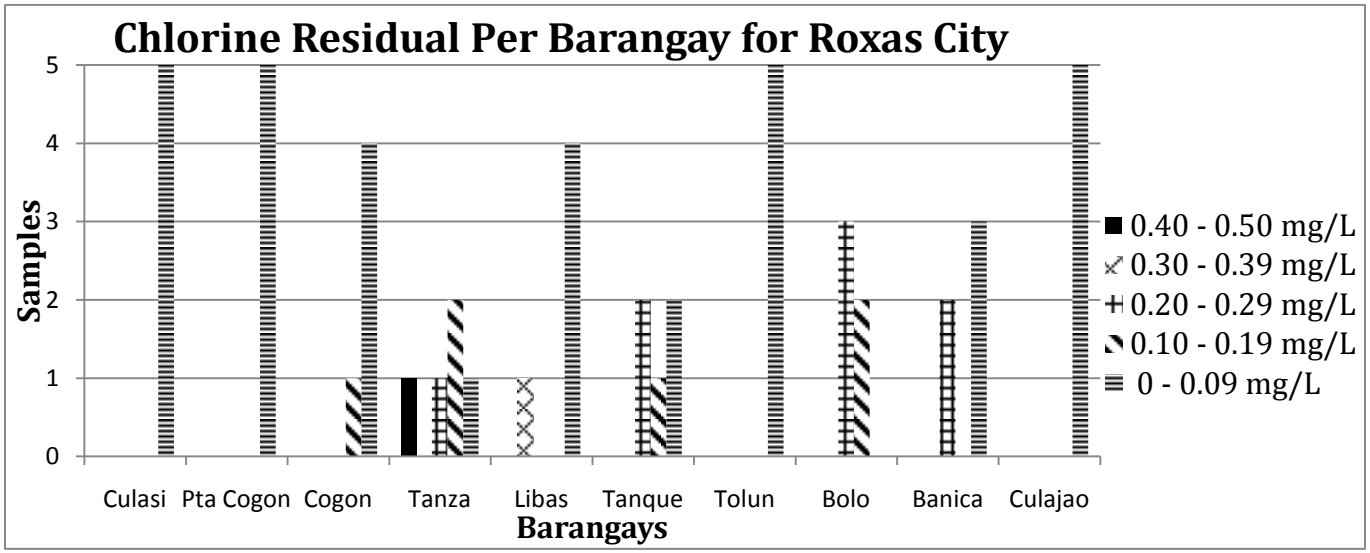

Sapian *E.coli* Risk Level
# of samples
8
7
6
5
4
3
2
1
0
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

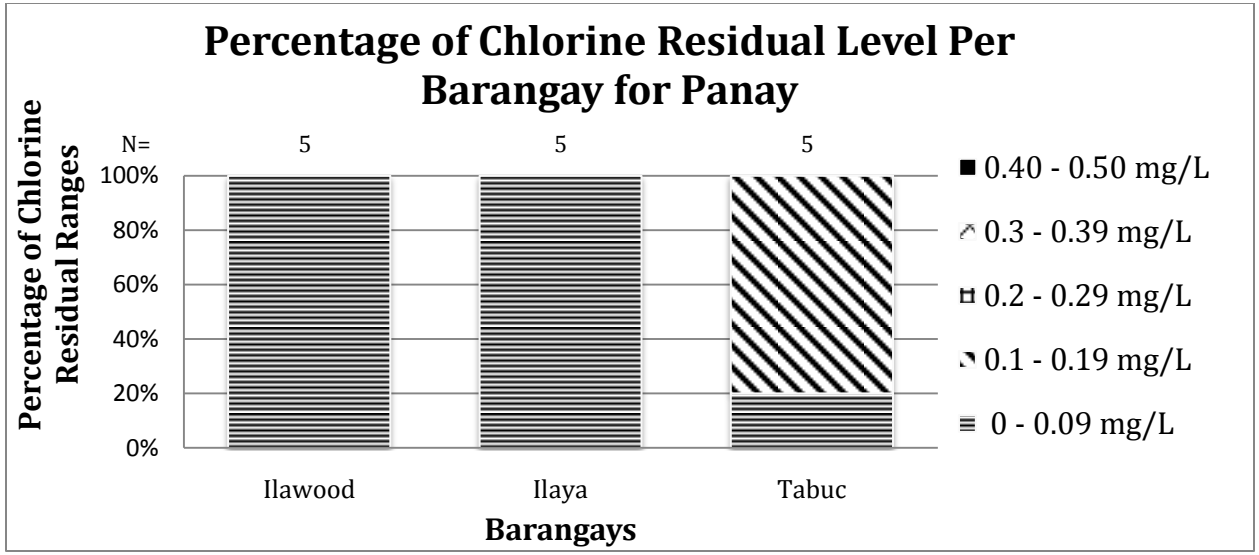

Sigma *E.coli* Risk Level
10
8
6
4
2
0
# of samples
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

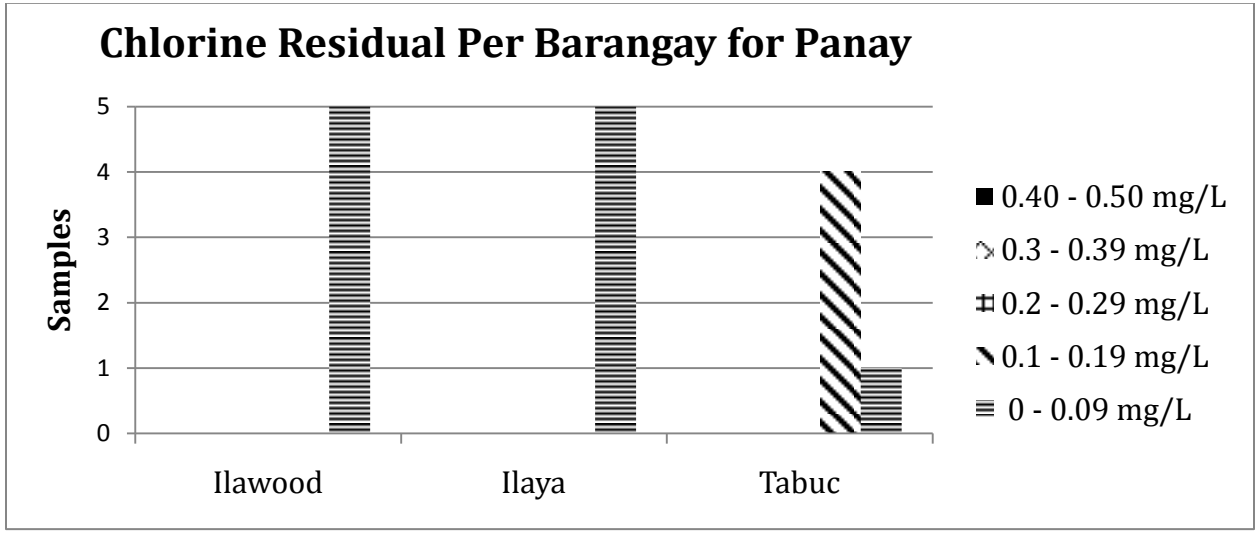

Dumarao *E.coli* Risk Level
14
12
10
8
6
4
2
0
# of samples
Doubtful
Level 1
Level 2
Level 3
Source Category
WHO Risk Level
High
Intermediate
Low
Conformity

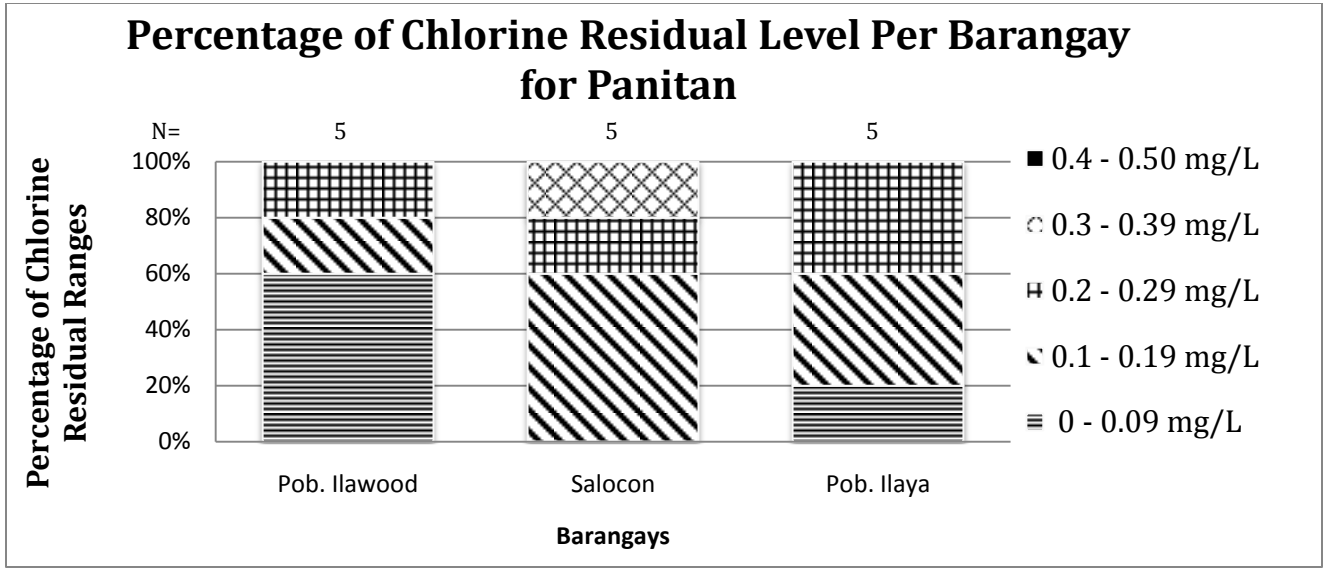
Appendix II

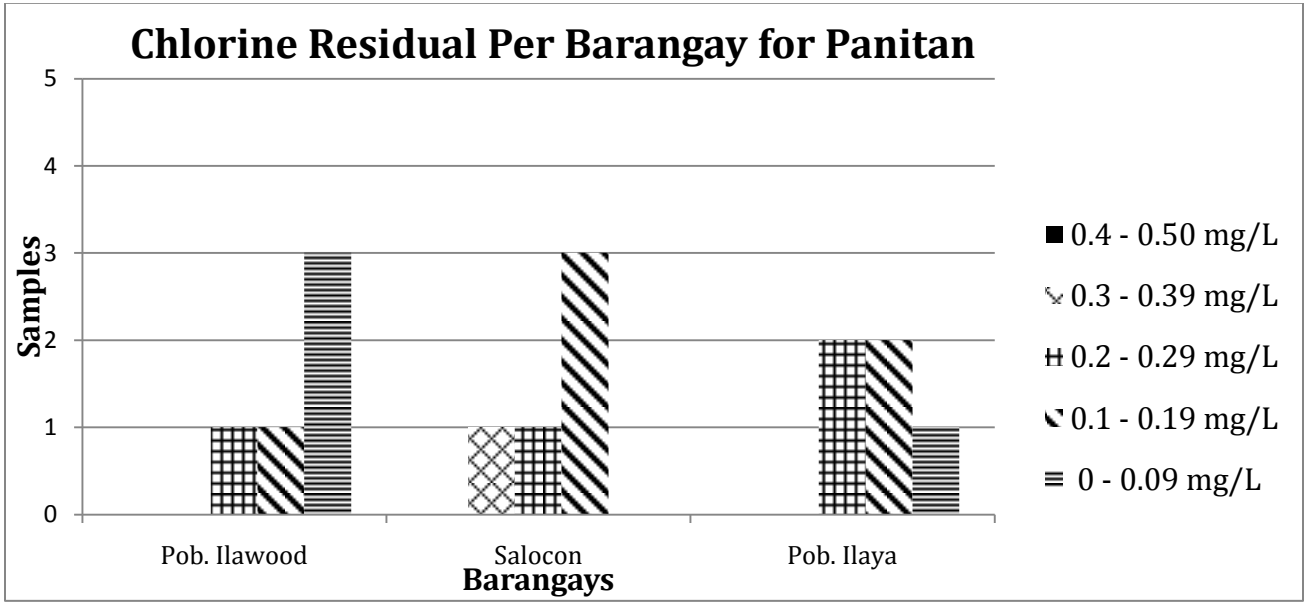

Percentage of Chlorine Residual Level Per Barangay for Roxas City
Percentage of Chlorine Residual Ranges
N = 5 5 5 5 5 5 5 5 5 5
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Culasi
Pta Cogon
Cogon
Tanza
Libas
Tanque
Tolun
Bolo
Banica
Culajao
Barangays
0.40 - 0.50 mg/L
0.30 - 0.39 mg/L
0.20 - 0.29 mg/L
0.10 - 0.19 mg/L
0 - 0.09 mg/L

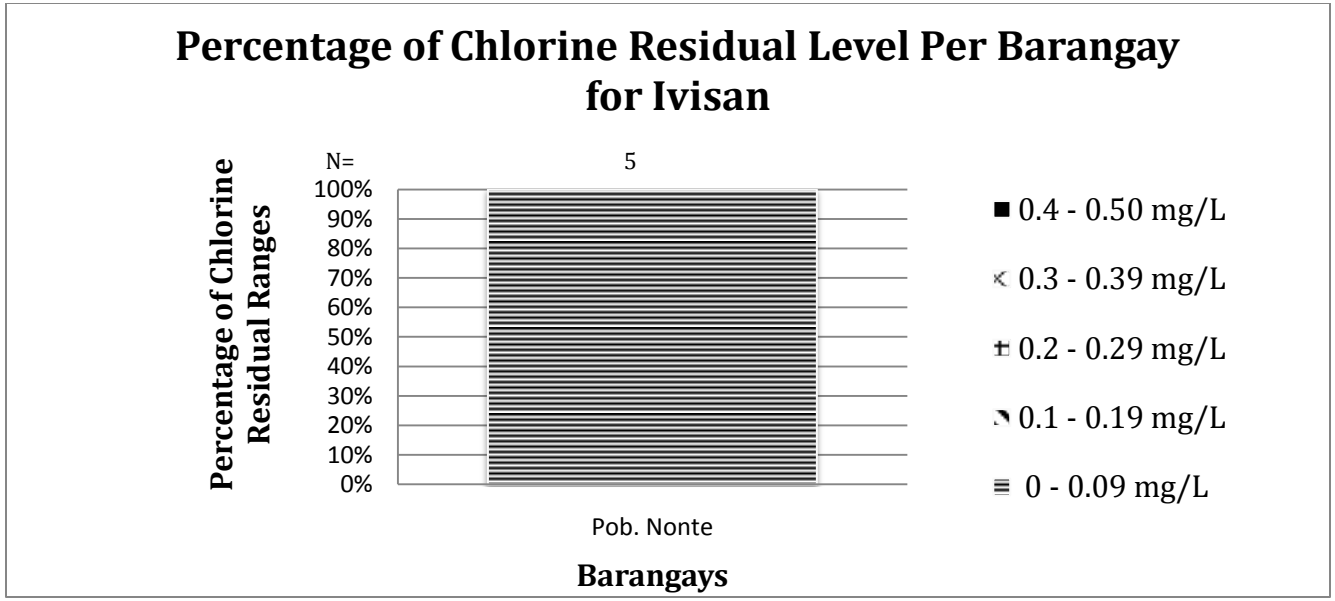

Chlorine Residual Per Barangay for Roxas City
Samples
5
4
3
2
1
0
Culasi
Pta Cogon
Cogon
Tanza
Libas
Tanque
Tolun
Bolo
Banica
Culajao
Barangays
0.40 - 0.50 mg/L
0.30 - 0.39 mg/L
0.20 - 0.29 mg/L
0.10 - 0.19 mg/L
0 - 0.09 mg/L

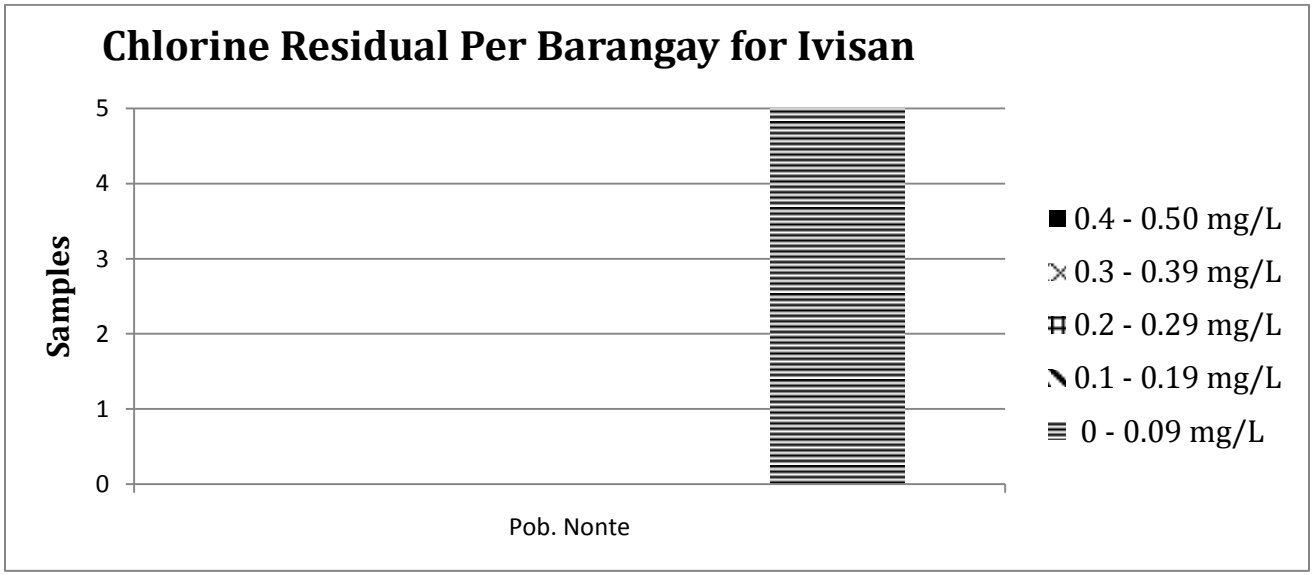

Percentage of Chlorine Residual Level Per Barangay for Panay
Percentage of Chlorine Residual Ranges
N=
5
5
5
100%
80%
60%
40%
20%
0%
Ilawood
Ilaya
Tabuc
Barangays
0.40 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L


Chlorine Residual Per Barangay for Panay
Samples
5
4
3
2
1
0
Ilawood
Ilaya
Tabuc
0.40 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L


Percentage of Chlorine Residual Level Per Barangay for Panitan
N=
5
5
5
100%
80%
60%
40%
20%
0%
Percentage of Chlorine Residual Ranges
0.4 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L
Pob. Ilawood
Salocon
Pob. Ilaya
Barangays

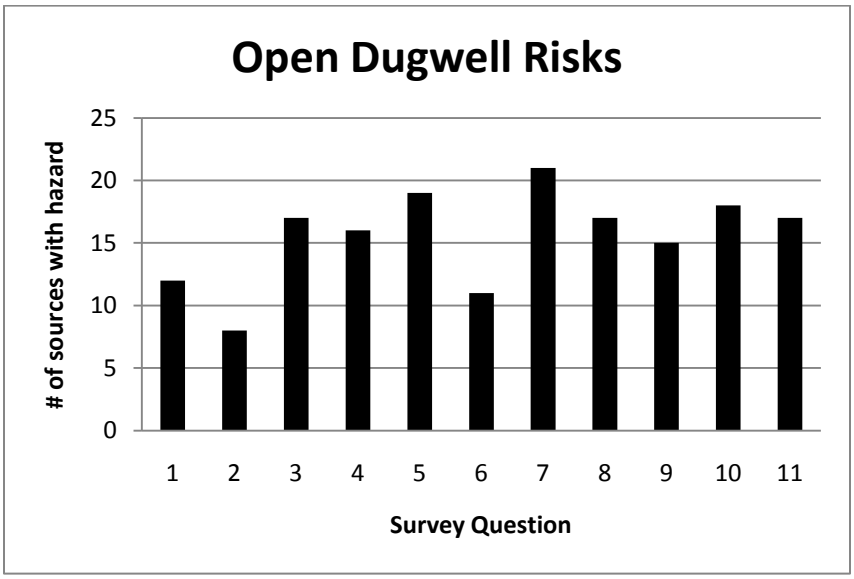

Chlorine Residual Per Barangay for Panitan
5
4
3
2
1
0
Samples
0.4 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L
Pob. Ilawood
Salocon
Pob. Ilaya
Barangays


Percentage of Chlorine Residual Level Per Barangay for Ivisan
N=
5
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Chlorine Residual Ranges
0.4 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L
Pob. Nonte
Barangays


Chlorine Residual Per Barangay for Ivisan
5
4
3
2
1
0
Samples
0.4 - 0.50 mg/L
0.3 - 0.39 mg/L
0.2 - 0.29 mg/L
0.1 - 0.19 mg/L
0 - 0.09 mg/L
Pob. Nonte

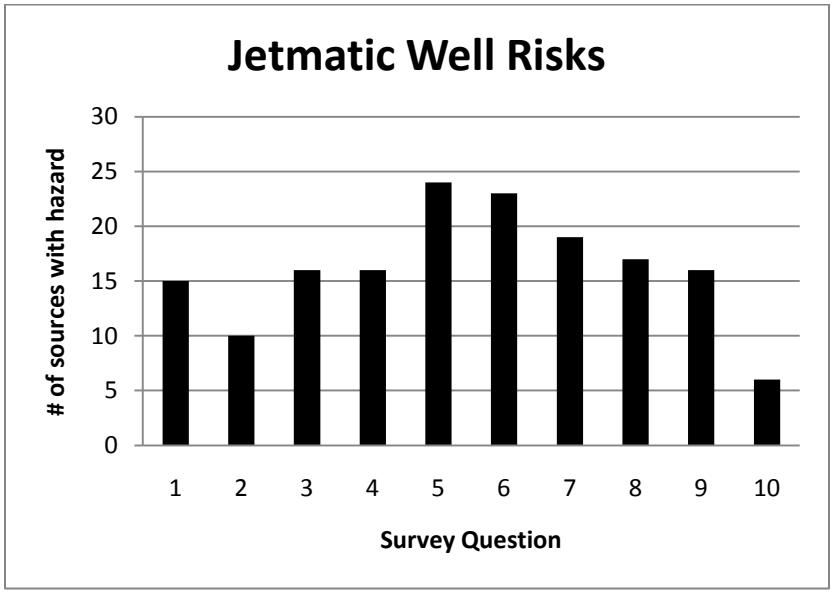
Appendix III

1	latrine within 10m
2	latrine on higher ground than handpump
3	other sources of pollution (animal excreta, rubbish)
4	poor drainage, stagnant water with 2m of handpump
5	faulty, non-existent, dirty drainage channel
6	inadequate parapet around wellhead
7	concrete floor less than 1m wide around well
8	inadequate wall seal for 3m below ground level
9	crack in concrete floor around handpump or well
10	rope and bucket left open to contamination
11	no wall or fencing around handpump or well (permitting animals)

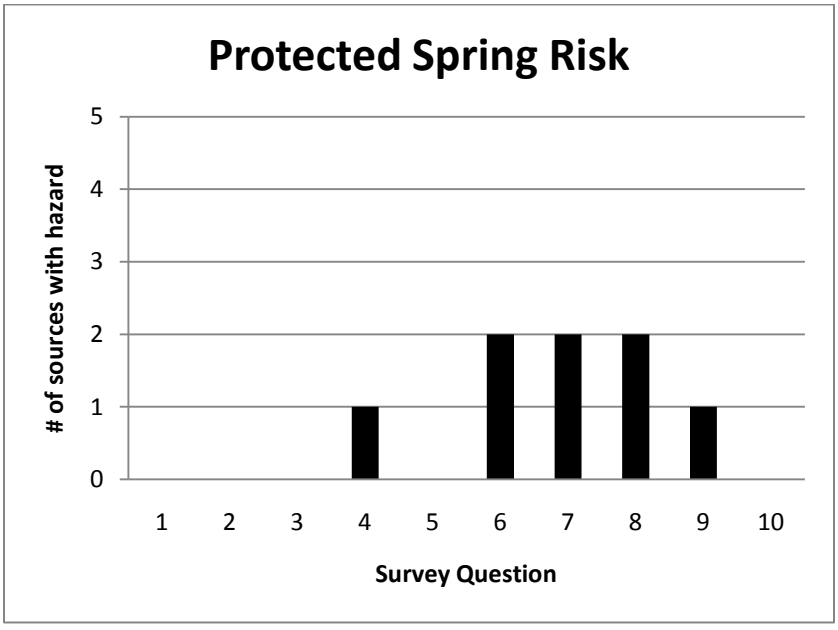


Tubewell with Handpump (Jetmatic)

1	latrine within 10m
2	latrine on higher ground than handpump
3	other sources of pollution (animal excreta, rubbish)
4	poor drainage, stagnant water with 2m of handpump
5	faulty, non-existent, dirty drainage channel
6	no wall or fencing around handpump or well (permitting animals)
7	concrete floor less than 1m wide around handpump
8	ponding on concrete floor around handpump
9	crack in concrete floor around handpump or well
10	loose handpump at point of attachment to base

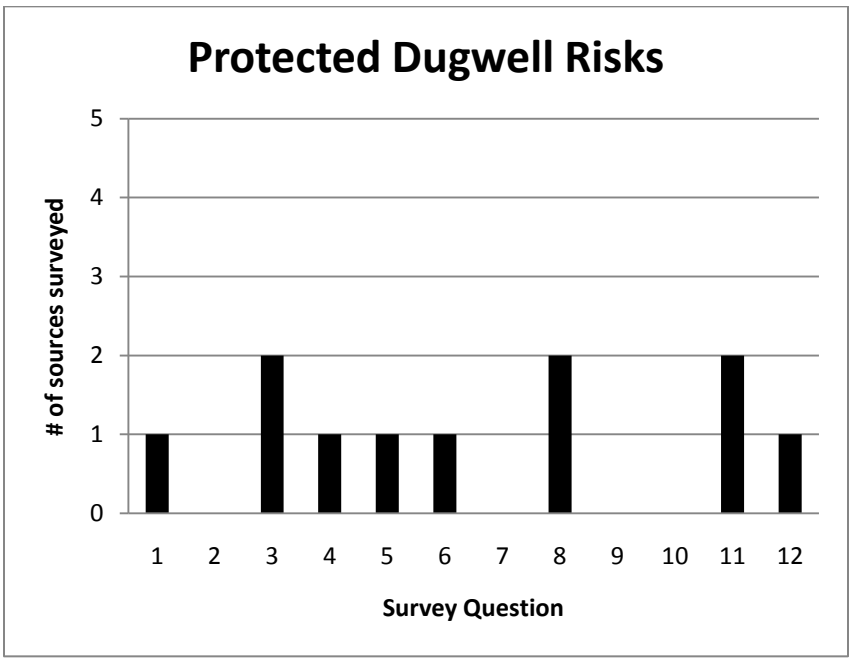


1	spring source unprotected by masonry or spring box (and thus open to surface contamination)
2	faultry masonry protecting spring source
3	unsanitary inspection cover in the masonry
4	silt or animals in spring box
5	unsanitary air vent in masonry
6	unsanitary overflow pipe
7	unfenced area around spring
8	possible animal access within 10m of spring source
9	lack of surface water diversion ditch above spring
10	uphill latrines



Protected Dugwell

1	latrine within 10m
2	latrine on higher ground than handpump/source
3	other sources of pollution (animal excreta, rubbish)
4	poor drainage, stagnant water with 2m of handpump
5	faulty, non-existent, dirty drainage channel
6	no wall or fencing around handpump or well (permitting animals)
7	concrete floor less than 1m wide around pump
8	ponding on concrete floor around handpump
9	crack in concrete floor around handpump or well
10	loose handpump at point of attachment to base
11	unsanitary well cover
12	inadequate wall seal for 3m below ground level



Appendix IV

Infrastructure Control Measures

Following a sanitary inspection, it is typical that a number of infrastructure control measures are introduced, in order to bring risk to an acceptable level and to increase the safety of the water source. The following are specific infrastructure control measures for some types of water sources typically found in rural areas in the Philippines.

Dugwells are often much more subject to contamination than other point sources, such as boreholes and protected springs, because the lining of the well is often permeable and the means of withdrawing water can often introduce contamination (Howard, Water Quality Surveillance- a practical guide, 2002). They should be covered with a locking sanitary lid and water should be withdrawn with the use of a handpump, as opposed to individuals using their own buckets to collect the water. The use of a windlass in an open dugwell is also an improvement; however where a community well has a windlass, only one bucket should be used and left suspended over the opening. A concrete plinth should be constructed around the well, which should then be surrounded by a concrete apron with a drainage channel to prevent water from pooling around the source. The top of the well should be at least 30cm above the apron. It has been found that the most common sources of contamination to dugwells are from cracks or other damage to the concrete plinth or drainage channel (WHO, 1997ii).

Tubewells and Boreholes with handpumps or mechanically operated pumps and a sanitary cover are an improvement to open dugwells. A concrete ring should be built around the top of the pipe and then a plinth for the handpump to rest on; the pipe should extend into the base of the pump to create a seal. The concrete apron surrounding the plinth should be at least 2m in diameter and sloped towards the drainage channel (Howard, Water Quality Surveillance- a practical guide, 2002). A *communal faucet system* where water is piped from the source to various outlet taps can be improved by ensuring that the pipe remains buried and that the tap is supported with the use of a plinth or metal support (see Figure below). The joints of the pipes are easily damaged when the tap riser is not supported and is moved around during use.

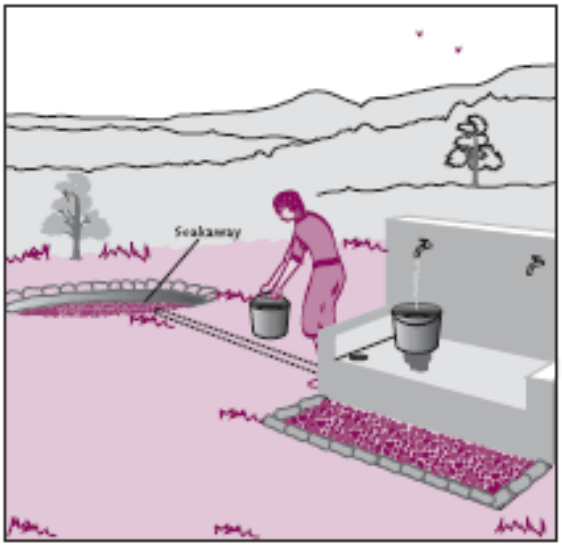


Figure 1. Communal standpost (Brikké & Bredero, 2003)

Springs require encasements with the following features to minimize hazards:

- A watertight spring box with a lockable inspection box: which intercepts the source and extends down to an impermeable layer OR a number of pipes which collect the water and lead to a storage tank;
- A protective cover;
- A protected overflow outlet;
- A connection to a distribution system or another supply;
- An impermeable layer above the spring box and the eye of the spring to prevent the entrance of contaminants. This should be concrete or clay, and should be underlain by graded gravel to act as a filter for water entering the collection system;
- A drainage channel to prevent pooling water and lead surface water from above the spring away from the source (MacDonald, Davies, Calow, & Chilton, 2005).

Rainwater collection systems should be protected by regularly cleaning the roof and gutters, and by ensuring the roof, gutter and tank are thoroughly cleaned at the beginning of the wet season (Skinner, 2003). Additionally, for the first 5-10 minutes of rains occurring after extended dry periods, it is recommended that the water be diverted to allow contamination and debris to wash away. This water can be used for purposes other than drinking. A screen or mesh can also be installed at the end of the gutter length to prevent large debris from entering, however this has to be checked regularly (WHO, 1997ii).

Adapted from (WHO, 4.Water Safety Plans, 2003ii)

Control Measure	*Recommended*
Dugwell/Tubewells	
Install locking sanitary lid	
Use dedicated bucket for withdrawing water	
Install windlass + dedicated bucket for water withdrawal	
Recommended handpump installation	
Build concrete plinth around well	
Build concrete apron around plinth (2m diameter)	
Fix cracks/faults in concrete lining around well	
Build drainage channel	
Ensure no faults in drainage channel and that is draining away from well	
Communal Faucet	
Bury piping	
Build tap riser support with metal or concrete plinth	
Spring	
Build watertight spring box with a lockable inspection box: which intercepts the source and extends down to an impermeable layer OR a number of pipes which collect the water and lead to a storage tank	
Build a protective cover	
Protect overflow outlet	
Construct a connection to a distribution system or another supply	
Build an impermeable layer above the spring box and the eye of the spring to prevent the entrance of contaminants. (should be concrete or clay, and should be underlain by graded gravel to act as a filter for water entering the collection system)	
Build drainage channel to prevent pooling water and lead surface water from above the spring away from the source	
Rainwater Systems	
Clean tank thoroughly	
Clean roof	
Build diverter for first 5-10 minutes of rainfall	
Install a screen/mesh to keep large particulates out of tank	
Site Protection	
Build protective fence around source (locked fence)	
If possible, move animal watering, latrines to 30m (10m minimum)	
Move waste collection facilities to 30m from source	

Appendix V

Aquatabs

Technology Description (based on manufacturer's claims)

- Aquatabs are a product used to chemically disinfect water
- Aquatabs are effervescent (self-dissolving) tablets which, when added to unsafe drinking water, make the water safe to drink
- Aquatabs rapidly release a measured quantity of chlorine in a safe and effective manner
- They are used to self-disinfect water at the point-of-use at the household level
- Aquatabs utilize the active ingredient sodium dichloroisocyanurate (NaDCC), also known as sodium troclosene and sodium dichloro-s-triazine trione
- The NaDCC used in Aquatabs is approved by the US EPA and NSF International for routine treatment of drinking water for human consumption
- The Joint FAO/WHO Expert Committee on Food Additives (JECFA) have approved NaDCC for routine use for drinking water
- The European Union has produced a specification for the use of NaDCC in treating drinking water.
- Aquatabs only use pharmaceutical or food grade ingredients for the effervescent base. Sources of NaDCC are available that do not conform to the above standards and specifications and may not be safe for the treatment of drinking water
- Aquatabs do not use these unsuitable sources
- Aquatabs are exclusively manufactured by Medentech Ltd to pharmaceutical standards. Medentech holds a Certificate of Good Manufacturing Practice for the manufacture of Medicines and is an ISO9001:2000 Quality Assured Company

What contaminants does it remove (based on manufacturer's claims)?

They are used to kill microorganisms in water, to avoid diseases such as cholera, typhoid, dysentery and other waterborne diseases. They are not used for chemical pollution

How does it remove contaminants?

Chlorine disinfection

Capacity (flow rate and/or batch volume)

- Aquatabs are available in a range of sizes to suit the different circumstances found at the household level
- Where water is collected from outside the home, the typical vessel size is approximately 20 liters
- A free available chlorine (FAC) level of 0.5 mg/L is recommended 30 minutes after adding the 67 mg Aquatabs tablet to the water. At 24 hours after the addition, a minimum FAC level of 0.2 mg/L is recommended
- From a series of field evaluations in a wide range of polluted water sources and from household storage vessels, the following Aquatabs dose is recommended:
    - For clear water, for example from municipality supplies and groundwater, add one 67 mg Aquatab in 20 liters of clear water
    - For dirty-looking water (turbid water), for example surface waters, the water should be filtered through a cloth before adding the Aquatabs. Add two 67 mg Aquatabs in 20 liters of turbid water
- Each 67mg Aquatab contains 40 mg free available chlorine (FAC)

Cost of technology (per single unit)

The 67 mg strength Aquatabs is available in boxes of 100's at P600.00 ($13.33USD) per box (retail price to the household) or P6.00 ($0.13USD) per tablet (email on 04/10 from Aileen Puzon) (contact info at the end of description)

Effective Household Water Management with this Product

Operation

From manufacturers label instructions:

1. Use one 67 mg Aquatab to treat 20 liters of clear water in a jerry can.

2. If water is dirty, filter it first with cloth, then treat with two Aquatabs.

3. Close the jerry can and wait 30 minutes before use.

4. No stirring or shaking is necessary.

5. Do not swallow the tablet.

- Aquatabs are non-hazardous for transportation. They can be shipped by land, sea or air without any special conditions
- Being in tablet form, they are easier and safer to handle than liquids or powders
- The tablets are individually strip-packed (in strips of 10 individual tablets) protecting access by children

Maintenance/Cleaning

It is recommended that Aquatabs are stored in cool, dry conditions, away from direct heat and sunlight.

Replacement period

Aquatabs are a recurrent use product, which means that each time the 20 liter treated volume is used up, another 20 liter volume needs to be treated with a new tablet.

Aquatabs have a shelf-life of 5 years, including tropical conditions.

Table 1. Advantages/disadvantage of Aquatabs

Aquatabs**Advantages**	**Disadvantages**
Convenient	Users may not accept the taste or odor of chlorine
Reduction in most bacteria and viruses	Low protection against protozoa, such as cryptosporidium or giardia
Provides a chlorine residual that is easily monitored to indicate successful use	Low efficacy in waters with high turbidity or high organic content
	Potential for carcinogenic effects of disinfection by-products over long-time periods of use

Name of Implementing Organization

Manufacturer: Medentech
Distributor in the Philippines: Chiral Pharma Corporation

Location and Extent of Implementation / Sales

All over the Philippines

Contact

Medentech Ltd.

Michael Gately

Head of Sales & Marketing

Clonard Road, Wexford, Ireland.
+353-53-9117900 Switch
+353-53-9117927 Direct
e-mail: mgately@medentech.com

Chiral Pharma Corporation

Aileen D. Puzon
Group Product Manager

2291 Don Chino Roces Ave., Makati City

Tel. No. (632) 836-5898 to 99

Fax No. (632) 976-9053

email: adpuzon@chiral.com

website: www.medentech.com; www.aquatabs.com

PuR

Technology Description (based on manufacturer's claims)
PuR® is a flocculation/disinfection product. Proctor and Gamble (P&G), as part of a collaborative effort with the U.S. Centers for Disease Control (CDC), has developed a sachet registered under the brand name PuR®, comprised principally of ferrous sulfate and calcium hypochlorite.

What contaminants does it remove?
Colloidal and suspended particles, microbes, some metal (arsenic, lead, other), pesticides such as DDT and other organic chemicals

How does it remove contaminants?
PuR® cleans turbid water by coagulation/flocculation, precipitation of metals and chlorine disinfection.

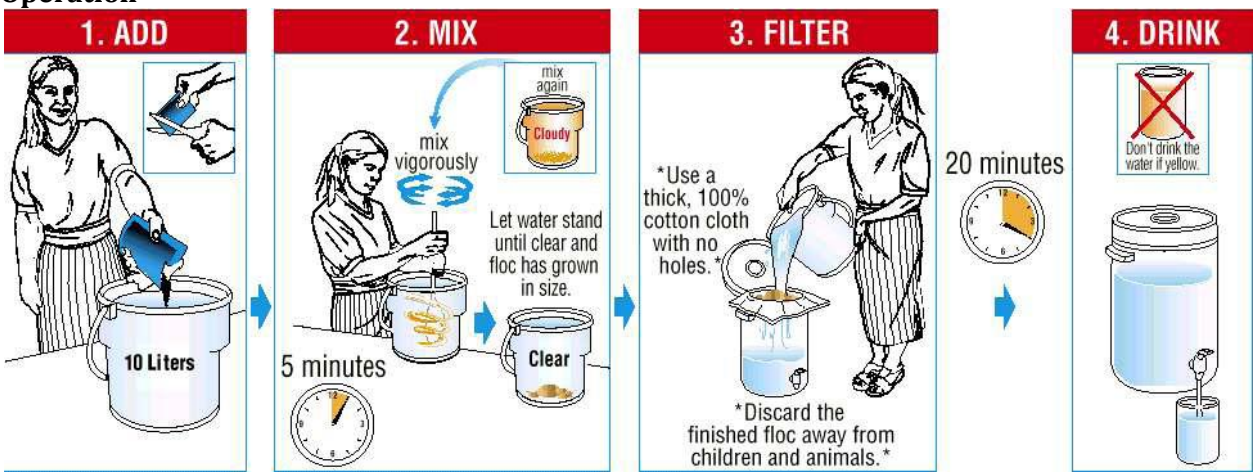
Capacity (flow rate and/or batch volume)
A single sachet of PuR® purifies 10 liters of drinking water.

Cost of technology per unit
Capital: Cost of the two 10-liter buckets, one bucket for mixing and one for treated water storage.

O&M: The consumer cost is about $0.07-0.10USD per packet depending on the local duties & import taxes when PUR is brought into the country (based on 03/10 email with Allison Tummon and Greg Allgood (contact info at end of description).

Effective Household Water Management with this Product

Operation



The sachet is cut open and the contents are poured into a bucket filled with 10 liters of water. Jerry cans are not appropriate mixing vessels for use with PuR®, as water cannot be stirred properly. The contents are manually mixed rapidly with a large, clean spoon, and then allowed to precipitate and settle for 5 minutes. Next, the 10 liters of water is decanted by pouring into a second safe storage container covered by a piece of clean cotton material. After 20 minutes, the water is safe to drink. The sludge that has collected in the bottom of the first bucket can be discarded into a latrine.

Maintenance/Cleaning
The mixing and the storage buckets should be cleaned with soap and clean water on a daily basis.

Replacement period
PuR® is a recurrent use product, which means that after the 10 liters of treated water is consumed, a new 10 liter volume must be treated. The replacement period therefore likely occurs on a regular, daily basis.

Table 2. Advantages/disadvantages of PuR

Advantages	Disadvantages
Clinically proven. About equal health protection as chlorine disinfection alone	Comparatively expensive
Locally available through the distribution network	Requires behavior change in usual water handling practices
Combines turbidity removal with microbial disinfection	Requires well-established distribution channels
Can precipitate metals and remove some organic chemicals	Some users find the process of stirring, pouring and waiting tedious
Visually impressive improvement in water clarity. This can be convincing to users of the efficacy of the product	Taste is also a potential issues- there will be a chlorine taste in water treated
Measurable chlorine residual allows an easy way to monitor use	Customers use it sporadically as 'medicine' and/or only for young children
Simple to use	Issues with user acceptance
Residual protection to prevent recontamination	Available in limited number of countries

Name of Implementing Organization
Proctor and Gamble (P&G)
Type of Implementing Organization
For profit multi-national corporation
Location and Extent of Implementation / Sales

P&G is selling PuR® to large relief organizations, such as UNICEF, Americare, and
CARE – where it is being distributed in disaster areas. PUR is currently being marketed in Kenya, Uganda, Haiti, Pakistan, Philippines, Guatemala, Morocco, and Ethiopia. P&G has introduced the product at a loss in Uganda and also Haiti as well.

There is experience with PUR in the Philippines already as PUR has been used in previous typhoons (including Ondoy & Parma in October 2009) by P&G global emergency relief partners including AmeriCares & their local NGO partner Asia America Initiative. These organizations worked with the local Department of Social Welfare & Development and also Global Medic (a Toronto based relief organization) & their partner UMCOR (United Methodist Committee on Relief) (03/10 email with Allison Tummon).

Contact

Organization Name: Proctor and Gamble (P&G)
Contact Person: Greg Algood
Telephone(s): 1-800-PUR-LINE
Email: Greg Allgood <allgood.gs@pg.com>

Boiling

Technology Description

Boiling is a form of thermal disinfection. It is among the oldest forms of household water treatment and is effective in destroying all classes of waterborne pathogens (including viruses, fungi, protozoans, helminthes, bacteria and bacterial spores) (Sobsey M. , 2002). Additionally, it can be used on all waters, including those that have high turbidity.

What contaminants does it remove (based on manufacturer's claims)?

All classes of waterborne pathogens (including viruses, fungi, protozoans, helminthes, bacteria and bacterial spores).

How does it remove contaminants?

Thermal destruction and inactivation of pathogens.

Cost of technology

Depends on local fuel prices and practices.

Effective Household Water Management

It used to be recommended that water be brought to a rolling boil and held for 1-5 minutes; however the lower end of this range is usually sufficient for destroying all pathogens according to the latest WHO recommendations. The water should ideally be stored in the same container in which it was boiled, however transfer to a safe storage container with a lid and a tap is also beneficial as this prevents the possibility of recontamination. Water should be consumed within the same day, once it has cooled.

Maintenance/Cleaning

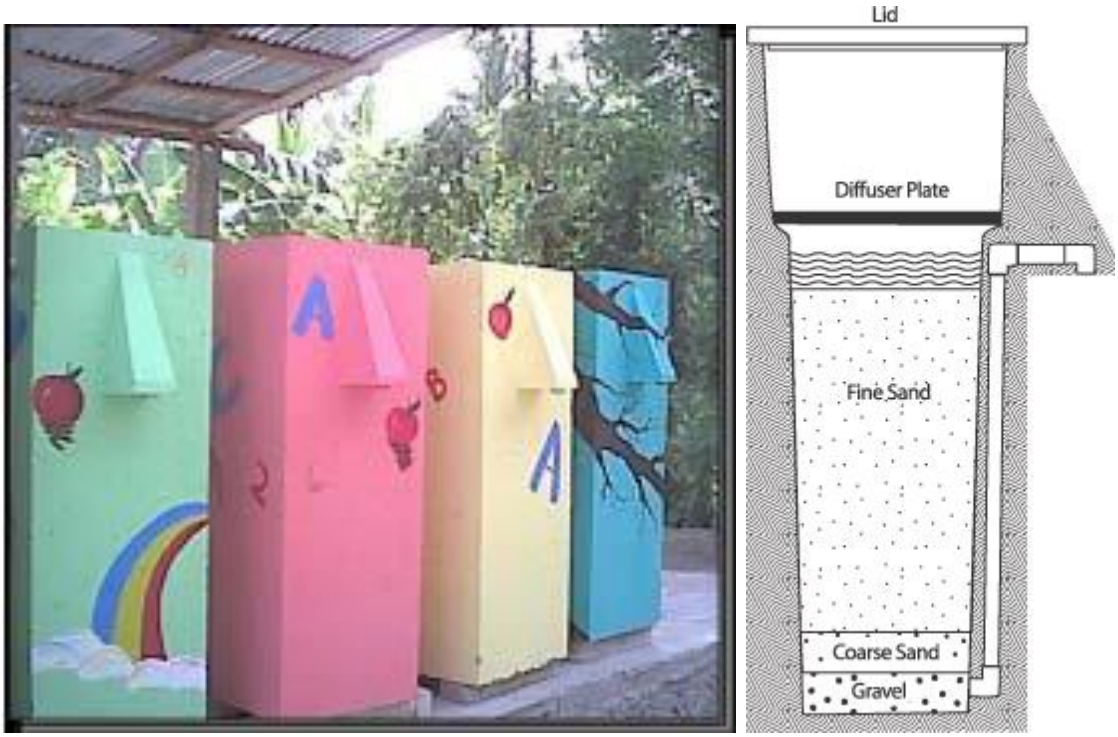
Vessels used to collect and boil the water should be cleaned with soap and clean water on a daily basis.

Table 3. Advantages/disadvantages of boiling

Advantages	Disadvantages
Convenient- most households can practice this method without capital investment	Affects the taste of water
Little or no training required	Wood fuel consumption causes deforestation
Widely known and practiced	Dirty cooking fuels affect indoor air quality and can cause respiratory illnesses
Effective against all microbial pathogens	Post-boiling storage issues can lead to

	recontamination; no residual protection
Scientifically proven	Handling large boiled water volumes can be hazardous

Biosand Filter



Technology Description

The Biosand filter (BSF) is an intermittent, household-scale, slow sand filter. This water filtration system is comprised of precisely measured and arranged layers of gravel, coarse sand, fine sand and a standing layer of water housed in a concrete (or plastic) container. Water is poured into an upper diffuser basin which contains small holes enabling the water to gently rain down on the sand filter. The BSF operates according to the same principles as traditional slow sand water filters, which were invented in Great Britain and France several centuries ago. The difference is that the BSF is designed for the household, as opposed to a larger, community scale, and water can be added intermittently – it does not need to flow through the filter continuously. The filter can be constructed almost anywhere in the world, because it is built using materials that are universally available. The concrete BSF is made using a steel mold. There are several sizes and shapes of concrete BSFs. Production is always done locally, due the weight of the product.

What contaminants does it remove (based on manufacturer's claims)?

Bacteria, worms, including guinea worm, protozoa cysts, some viruses. Biosand filters have been shown to remove:

- More than 90% of *E.coli* bacteria
- 100% of protozoa and helminthes (worms)
- 50-90% of organic and inorganic toxicants
- up to 67% of iron and manganese
- most suspended sediments

How does it remove contaminants?

As with all slow sand filters, the removal of microorganisms happens in the filter through a combination of mechanical, biological and electro-chemical processes. When water is poured into the top of the filter, the dirt, organic material and microscopic organisms contained in the water are trapped at the surface of the sand, forming a biological layer called a *schmutzdecke* (in German) or "dirty layer". Over a period of several days to weeks, depending on a variety of factors such as temperature, quality of the source water and volume fed to the filter, microbes colonize the biological layer, where they find organic material (food) and oxygen supplied by the water, which in turn, supports their growth and reproduction. Four processes remove pathogens and other contaminants in this filter:

- **Mechanical straining**- Sediments, cysts and worms are removed from the water by becoming trapped in the spaces between the sand grains. The filter can also remove some inorganic compounds and metals from the water when they are precipitated in solid form and get trapped by the sand.
- **Predation**- The *schmutzdecke* microorganisms ingest bacteria and other pathogens found in the water.
- **Natural death**- Pathogens naturally die because there is not enough food and oxygen.
- **Adsorption**- Viruses are adsorbed (become attached) to the sand grains. Once attached, they are metabolized by the cells or are inactivated by antiviral chemicals produced by the organisms in the filter. Certain organic compounds are also adsorbed to the sand and therefore removed from the water.

Capacity (flow rate and/or batch volume)

45 – 60 liters/hour

Cost of Technology per Unit

Capital: $29-$33/ concrete system (full cost) (P1,300-P1,500) (Maycumber, 2009)

O&M: After multiple years use, sand may need replacement if regular cleaning does not succeed in removing accumulated debris. Estimated investment in equipment: $333 (P15,000) per single steel mold for concrete filters (Maycumber, 2009).

Effective Household Water Management with this Product

Operation

1. Use the filter daily - this will maintain the water level 5 cm above the sand (measured during the pause period) and keep the bio- layer alive.

2. Ensure water quality is from the best possible source. Always use the same source if possible. If water is very dirty, allow the water to settle for 24 hours, and then pour the clear water through a fine woven-cloth (folded many times).

3. Use two separate containers; one container should be used as a receiving container to properly store and disinfect water from the filter, a second container should be used as a source container to collect the water from the water source. *Ensure both containers are kept clean.*

4. Typically, add between 1 to 5 drops of bleach for each liter (or up to 1 teaspoon per gallon) to the empty receiving container - for example, if the container is 20 liters then add at least 20 drops of bleach.

5. Remove the filter lid and slowly pour contents of the source container into the filter, without letting the sediments enter the filter, and then replace the lid. As the water fills the receiving container, it mixes and reacts with the chlorine to treat any remaining bacteria.

6. When filtration is complete, cover receiving container.

7. Feed the filter with source water by repeating this process at least once a day.

8. Clean the filter spout daily.

9. Do not store food on the diffuser plate.

10. Keeps animals away from the spout and filtered water (CAWST, 2007)

Maintenance/Cleaning

- **Location**- Protected from the weather (dust & wind), birds, animal, mosquitoes and insects. Placing the filter indoors is preferred.
- **Level**- Filter placed on a level spot- even floor, not slanted, no bumps.
- **Leaks or Cracks**- Drips of water or wet spots under the filter will indicate a leak in the concrete box.
- **Lid**- Clean on the outside and inside; no rotting wood parts; tight fitting but not sealed.

- **Diffuser**- Clean regularly; sand under diffuser should be level and smooth; rotten wood should be replaced; diffuser should rest securely on the lip. This should be approximately 5 cm (2") above water level.
- **Sand Level**- The surface of the sand should be 5 cm (2") below the water level. Contact your technician to add (or remove) sand if this dimension is not correct; the sand should be smooth and level.
- **Spout**- Clean daily; eliminate any direct human and animal contact with spout and filtered water.
- **Receiving Container**- 5-10 cm (2" - 4") – a small opening will prevent contaminants from entering the container that now hold treated water. Sanitize the container frequently (every second day) by washing it with soap and water or with a chlorine cleaning solution. Ensure the container has a lid. Do not scoop water out of receiving container. It is best to pour the water out.
- **Flow Rate**- Measure the outlet flow rate from the spout when filter reservoir has just been filled with water; 0.6 liter/minute (100 seconds per liter) is the design rate for the standard concrete filter; if the flow rate is less than about 0.3 liter/minute (1/3 quart/min), clean the sand in the filter by using the "swirl and dump" technique (CAWST, 2007).

Replacement period

Concrete Biosand filters are durable and robust and are expected to last 5-20 + years.

Water Quality – Independent Testing

Membrane filtration tests carried out in the MIT laboratory indicated that the Biosand technology effectively removes an average of 99.5% of total coli form from river water (Lee, 2000).

Table 4. Advantages/disadvantages of Biosand Filter

Advantages	**Disadvantages**
Used properly, the biosand filter removes bacteria (about 90-99), parasites (100%), and certain contaminants and toxins such as turbidity, iron, and manganese	Biological layer takes 1-2 weeks to develop to maturity
Water tastes and looks good	High turbidity (>10-25NTU) causes filters to clog and should not be applied to biosand filter without pretreatment
Simple to operate and maintain	Filter must be used regularly to maintain its efficacy
High flow rate: concrete biosand filter provide	There is a lag time after start-up and after

flow rates ranging from 30-60L/h depending on unit size	disturbance or removal of the sand during cleaning, before the filter attains its best level of bacterial removal
Visually, one can see the water become cleaner after treatment. This can be convincing to users by showing the visual effect of the process	Biosand filters removes viruses only partially and do not remove color or dissolved compounds
Needs few replaceable parts	There is no residual protection with the biosand filter and safe storage is necessary after filtration to prevent recontamination
Concrete biosand version is high durable and robust- may last 5-20+ years	Biosand filters cannot be easily moved once they are put in place, because each unit is extremely heavy. Moreover, moving the filter may disrupt the carefully leveled sand and gravel beds and may crack the container
May be constructed from locally available materials, including sand, gravel	
No chemicals need to be added to the filter to make it work effectively	
Opportunity exists for local businesses to produce and market this product	

Name of Implementing Organization

- Center for Affordable Water and Sanitation Technology (CAWST) – Calgary, Canada
- A Single Drop for Safe Water (ASDSW)- Philippines

Most training by this NGO has been focused in Mindanao as well; however there are Peace Corps Volunteers that have worked as close as Iloilo to introduce the technology. Kevin Lee heads the BSF program for ASDSW and has been trained by CAWST directly.

Type of Organization

Concrete Biosand filters have typically been implemented by NGOs

Implementation Approach

Partial cost recovery and charitable donation are typical approaches used by NGOs implementing the concrete Biosand filter. In the Philippines, 80% of the filters disseminated through ASDSW (approximately 1000 filters) have been sold through aid or development organizations such as Rotary, LGSPA, LGU and others (email with Kevin Lee, 05/10).

Location and Extent of Implementation / Sales

Worldwide, 270,000 filters have been installed reaching more than 2.5 million people. As of 2008 in the Philippines, approximately 1,300 filters have been installed. ASD currently has active BSF projects in Mindanao, Palawan and Camarines Sur (email wth Gemma Bulos 04/10).

Contact

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Megafresh Filter (commercially available)

Various models and sizes of Megafresh Water Purifiers or X-Green Filters, manufactured in Korea, are currently commercially available in the Philippines. While the price point may be high for many people in Capiz, they are still a viable option for some households.

Technology Description

The filter uses a variety of media to purify water; there are 6-stages of media through which water flows when poured into the top of the filter unit. The main component is a 0.9micron ceramic filter, which is followed by an activated carbon filter, a bio-ceramic mineral ball, a zeolite component, a mineral sand component and finally a mineral stone component.

What contaminants does it remove (based on manufacturer's claims)?

Sediments, solid impurities, bacteria (typhoid, cholera, amoeba), chlorine, THM, pesticides, organic chemicals and odor/color causing impurities, heavy metals (such as lead, mercury, arsenic, chromium).

How does it remove contaminants?

The 0.9micron diatomaceous ceramic component filters out bacteria and particles greater than 0.9microns. The activated carbon stage is said to remove chlorine, trihalomethanes (THM), organic chemicals and odor/coloring-causing materials. This is followed by the 'bio-ceramic mineral ball' which is said to enrich the water with minerals. The zeolite component helps eliminate heavy metals, and finally the mineral sand component re-mineralizes the water and restores the pH to mildly alkaline levels. The final 'mineral stone' stage is comprised of stones which contain germanium- which is said to absorb heavy metals, toxins, odors and other impurities, while releasing minerals and aiding in oxygenation of the water before it enters the storage component.

Cost of Technology per Unit

Capital: In Roxas City, filter units available at prices ranging from P750-P5,000 ($16.67-$110.00USD).

O&M: Regular replacement of both ceramic and activated carbon components means recurring costs every 3-6 months. A replacement component for a larger filter unit was observed to be P380 ($8.45USD).

Effective Household Water Management with this Product

Maintenance/Cleaning

It is recommended that when discoloration occurs, the ceramic cartridge should be taken out of the unit and the surface scrubbed with a nylon pad.

Cleaning: Scrub cartridge until cartridge becomes clean again. It is suggested that the cartridge is cleaned after 15 to 30 days.

Any detergent, chemicals or an oily pad should NOT be used for cleaning the cartridge.

Replacement period

The manufacturer states that the ceramic water filter should perform for 6 to 12 months. ('Depending on your water's level of total dissolved solids (TDS)'). The activated carbon component is said to require replacement every 3 to 6 months.

Water Quality – Independent Testing

One test was conducted in January 2010 using a Megafresh filter to treat a sample from an open dugwell. Two test methods were used to analyze the results, given as follows:

Sample	Test Method	Total coliform result (CFU/1mL)	*E.coli* result (CFU/1mL)
Raw water	Petrifilm™	2	TNTC[4]
Treated water	Petrifilm™	0	0

Table 5. Advantages/disadvantages of Megafresh household filters

Advantages	Disadvantages
Proven to remove bacteria, particles, organic chemicals Includes safe storage Presently available in Capiz Province	Requires regular cleaning Requires replacement parts (3-6months) No residual disinfection Expensive

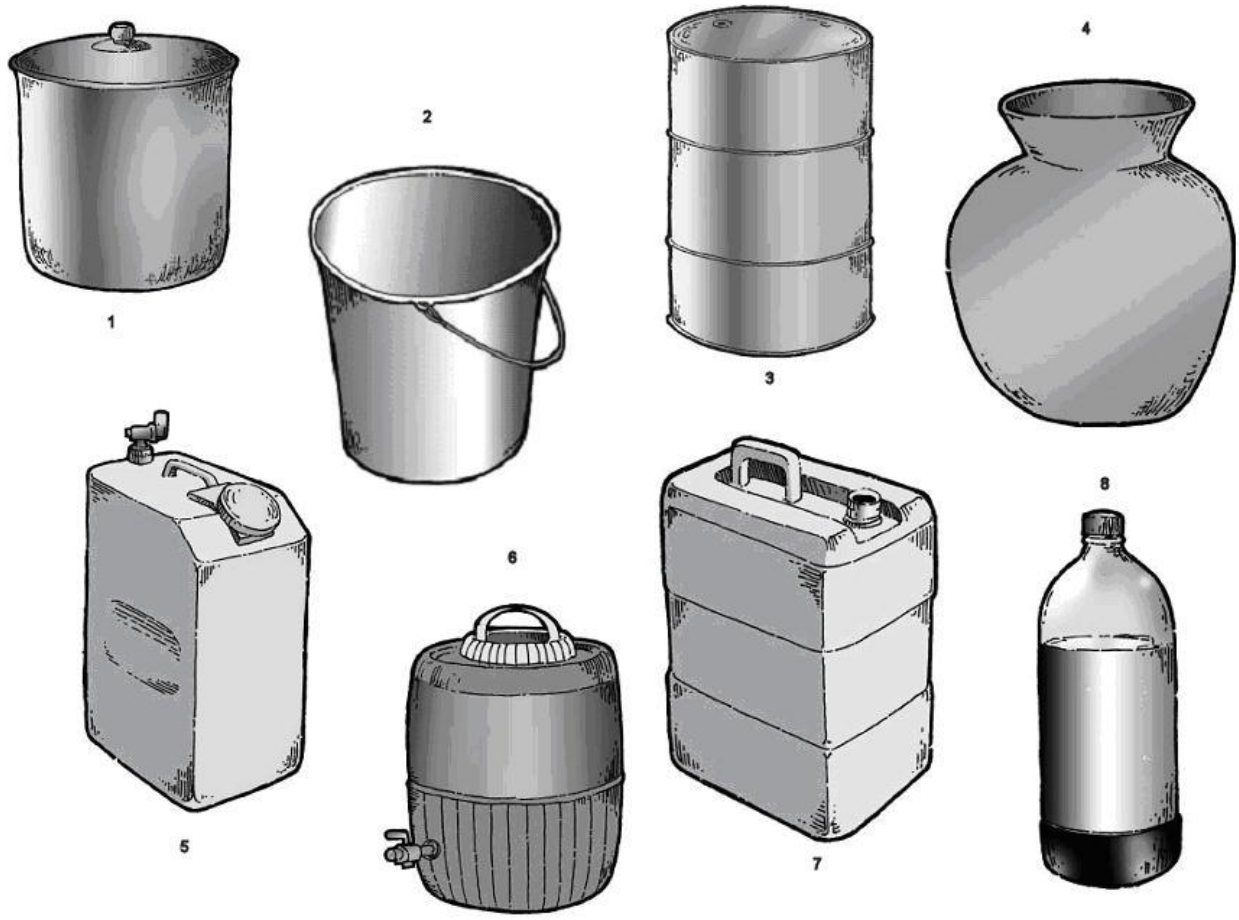
Contact

Website: http://www.x-green.com/english/products_1.html

Safe Storage

[4] TNTC = too numerous to count

Technology Description



By the simplest definition, "safe storage" is a hygienically clean and covered drinking water storage container. According to this definition, vessels #1, 3, 5, 6, 7 and 8 are all potentially "safe storage" containers. A cloth cover or lid could be added to vessels #2 and #4 which would satisfy this simple definition of "safe storage."

A more rigorous definition of a "safe storage" container is:

- A dedicated container **not** used for water collection or any other purpose but only for water storage
- Made of durable, easy to clean material
- Volume between 10 and 30 liters, with handle(s)
- Inlet diameter between 6 and 9 cm
- Durable spout or spigot allowing a discharge rate of 1 liter per 15 seconds as outlet
- Instructions for use, cleaning container and disinfection of its contents permanently attached to vessel

"Safe storage" as defined by the U.S. Centers for Disease Control (CDC) is the use of a dedicated container for drinking water storage that includes (1) a narrow mouth to prevent the dipping hands or cups into the vessel; (2) a lid to keep the container closed and (3) a spigot or small opening to pour out the water. In many countries, the CDC has promoted safe storage in high density polyethylene (HDPE) plastic vessels. The CDC HDPE vessel is as #5 in the above figure.

In the Philippines, evidence was seen about the use of safe storage in a few households (though this was not the focus of village visits so the extent of the use is unknown) and interviews revealed that drinking water is commonly stored separately from water used for other purposes. Thus, this is promising for promoting the use of these containers, as people will likely already be familiar with the concept and potentially with the containers. Figure 6-2 beside shows an example of the use of a safe storage vessel in one of the village visits.

What contaminants does it remove (based on manufacturer's claims)?

Safe storage can remove large particles, which can be organic or inorganic.

How does it remove contaminants?

Gravity sedimentation

Capacity (flow rate and/or batch volume)

Variable volumes – a dedicated volume between 10 – 30 liters is recommended, but other volumes, such as 1 to 2 liter PET bottles or 200 liter (50 gallon) drums could also qualify.

Cost of technology per unit

Capital: * will vary in Capiz Province, depending on container choice

O&M: N/A

Effective Household Water Management with this Product

Operation: N/A. **Maintenance/Cleaning**: N/A.

Figure 1. Safe storage vessel use in Cuartero

Replacement period

Varies with the different types of containers and also depends on patterns of handling and use. Some safe storage containers may last for 5- 10 years if handled properly.

Table 6. Advantages/disadvantages of safe storage

Advantages	Disadvantages
Integrates well with other household drinking water management and treatment practices, such as traditional methods of storage, as well as coagulation, filtration or chlorination	Safe storage containers may be more expensive than traditional clay pots or jerry cans. For low-income households, possession of a dedicated safe storage container may be a burden
Potential beneficial health effects	

Type of Implementing Organization

Government agencies, NGOs, commercial

Implementation Approach

Various for-profit, partial cost recovery and charitable approaches

Contact

Centers for Disease Control
Contact Person: Rob Quick, M.D.
Address: 1600 Clifton Road, MS-A38, Atlanta, GA
Telephone(s): 404-639-0231
Fax: N.A.
Email: safewater@cdc.gov
Website: www.cdc.gov/safewater

Appendix VI

EC-Kit Instructions

Materials (provided in kit)

Petrifilm *E.coli* / Total Coliform Plates
WhirlPak bags
Cooler Bag + Ice Pack
Colilert 10 milliliter pre-dispensed tubes
Incubator Belt
Cardboard + Rubberbands
3.5 ml sterile plastic pipette
Blacklight + 4AA batteries
Laminated Instructions

Setup and Quality Control Procedures

- Materials obtained locally: isopropyl (rubbing alcohol- available in pharmacies), paper towels or tissues, permanent black marker, garbage bag/masking tape or ceramic/plastic tile, soap, liquid bleach, field notebook.
- Wash hands with soap and water.
- Locate a clean, level surface. Cover surface with a large plastic garbage bag, taped down with masking tape. Or, use a square ceramic or plastic tile as a work surface. Wipe down work surface with isopropyl
- Run blanks and duplicates – minimum of 5% of total samples tested - using boiled, cooled water, or bottled water.
- Record all your test results in a lab notebook. Be sure to include date, each test result and observations.

Procedure for Colilert Test

- Using the black-marked 10 milliliter (mL) guide test tube provided (the one tube with colored tape in the package), mark <u>all</u> the other test tubes in your kit with a permanent black marker at the same 10 mL level.
- Label each tube with the sample name, time, and date of sample collection, initials of person sampling.
- Remove cap, without touching the inside of the cap with fingers or hand. Then fill the Colilert test tube with 10mL of sample water to the black mark 10 mL level in one of two ways.
    - *Using Tap other water supply delivered via a spout or on/off spigot (e.g. hand pump, public standpipe, treatment unit spout)*: Fill Colilert tube to the 10 mL mark by adding water directly. Do not exceed the 10 mL black-marked level on the tube. Replace cap & invert tube several times to mix.
    - *Using Sterile Plastic Bag*: Collect water sample in a sterile plastic bag that has been provided in the kit, then pour directly from bag into the Colilert tube. Or, use the sterile pipette provided in kit (graduated at 1 mL) to transfer sample water from the plastic bag to the test tube 10 times. Take care not to touch the sides of the tube or the water in the tube with the pipette. Then, replace the cap and mix the water in the test tube by inverting it several times to dissolve the nutrients.

- Put Colilert tube in top pocket of incubator belt. Tie the incubator belt around your waist and wear it non-stop for 24 hours +/- 2 hrs. This will incubate the water sample using your body heat.

Interpreting Colilert Results

After 24 hours, if samples are clear, no coliform bacteria are present (see top tube in Figure 1). If samples are slightly yellow or yellow, coliform bacteria are present (see middle and bottom tubes in Figure 1). Record as clear (absent) or yellow (present) on data sheets. If the samples fluoresce to form a milky-blue color under UV/black light, then E. coli are present (see bottom tube in Figure 2). Otherwise, if the sample does not fluoresce, then *E.coli* are not present (see top 2 tubes in Figure 2.

NOTE: 2 tubes in Figure 2 show UV/black light reflecting off the Colilert tube glass. THIS IS NOT FLUORESCING!) If *E.coli* are present, a Petrifilm test should also be performed in order to quantify (If sample risk is unknown, perform both tests).

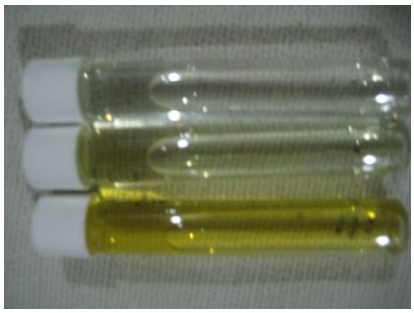


Figure 2

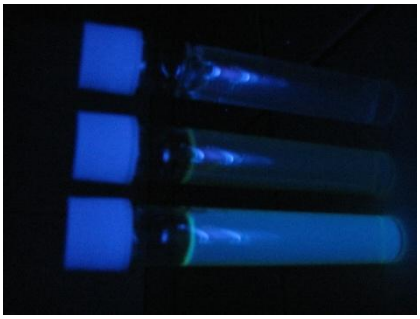


Figure 3

Procedure for Petrifilm Test

- Place the Petrifilm on a flat surface that has been wiped down with isopropyl alcohol.
- Fill sterile pipette with 1mL of sample water (1 mL= top graduated line just below top of pipette bulb)
- Lift the top film. With pipette perpendicular to Petrifilm plate, carefully dispense the 1 mL of sample from the pipette on to the center of the pink circle.
- Gently roll the top film onto the Petrifilm plate. Take care not to trap air bubbles under the top film.
- Allow the water to naturally spread out to fill the entire pink circle and allow gel to set for 1-2 minutes.
- Place the Petrifilm between two pieces of cardboard. Secure the Petrifilm between the cardboard using rubber bands.
- Place Petrifilm samples in bottom pocket of incubator belt. Up to five Petrifilms can be stacked between one set of cardboard squares. Incubate at body temperature non-stop for 24 hours +/- 2 hours at body temperature..

Interpreting Petrifilm Results

E.coli are blue colonies with gas bubbles. Total coliform are the sum of red plus blue colonies with gas bubbles. If the total number of blue colonies with gas bubbles is less then 1, then the water may still have an intermediate risk level that is below the detection limit of the Petrifilm test (See Table 1 below). If the total number of blue colonies with gas bubbles counted is between 1 and 10, this represents a high risk level. If the total number of blue colonies with gas bubbles counted is above 10, this is a very high risk level.

Recommendations on Reading Colilert and Petrifilm Results

Colilert:

The UV/black light test to determine fluoresce MUST BE PERFORMED IN THE DARK (a dark room, a closet, a bathroom, or outdoors at night). Otherwise, fluoresce will not be able to be seen clearly.

Petrifilm

Must be read in bright daylight. Hold the Petrifilm up to natural light.

Must be counted SYSTEMATICALLY. (Figure 3)

Be sure to count every colony – blue with gas bubbles, red with gas bubbles, then add blue + red with gas bubbles including even very small colonies with gas bubbles.

Use the grid system on the Petrifilm plate. Begin at the top right square and proceed sequentially from square to square following the curved "S" path on the figure below. Colonies on the horizontal grid lines are "pushed down into the square below." Colonies on the vertical grid lines are pulled forward into the next square. See Figure 3.

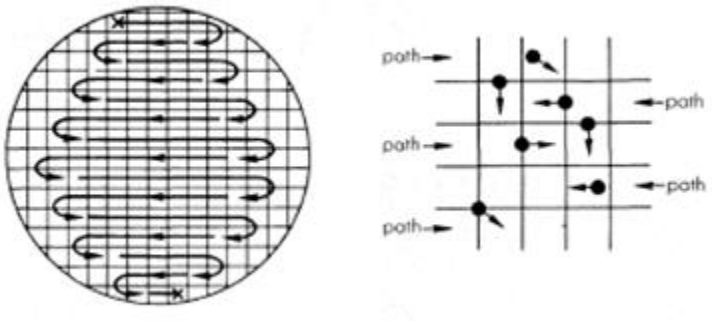


Figure 3: System for counting coliform colonies

Bubble patterns may vary. Gas may disrupt the colony so that the colony "outlines" the bubble (circles 1 and 2 in Figure 4). Artifact bubbles may result from improper inoculation or from trapped air within the sample. They are irregularly shaped and are not associated with a colony (circle 3 in Figure 4). Figure 5 shows various bubble patterns associated with gas producing colonies. All should be enumerated.

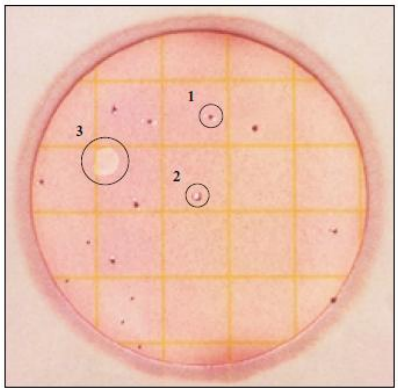


Figure 4: Sample Total Coliform Count Plate. Circles 1 and 2 are associated with colonies with gas bubbles, circle 3 is not associated with a colony.

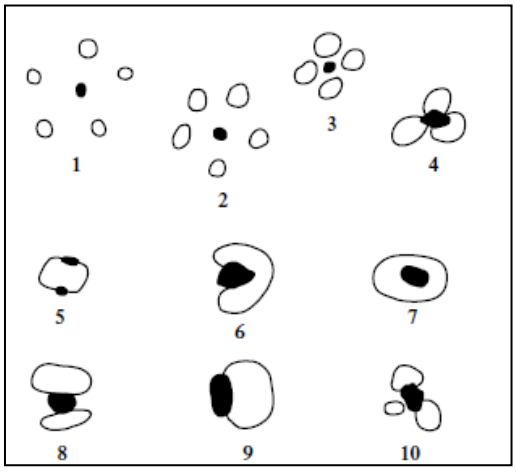


Figure 5: Various Bubble Patterns for Gas Producing Colonies.

Interpretation of EC-Kit Results for *E.coli*

The EC-Kit - Colilert and Petrifilm – provides results for both *E.coli* and total coliform. First, *E.coli* is discussed:

Q: Why do we care about *E.coli*?

A*: E.coli* is used to determine the safety of drinking water.

Q: What level of *E.coli* is safe to drink?

A: World Health Organization guideline for *E.coli*: *"E.coli* or thermotolerant coliform bacteria must not be detected in any 100 milliliter sample for all water directly intended for drinking, treated water entering the distribution system or treated water in the distribution system." (WHO, 2004)

Q: What if a water quality test shows higher *E.coli* values than the WHO guideline value of 0 *E.coli*/100 milliliter sample?

A: Refer to a risk table (see Table 1 below).

Interpretation of EC-Kit Results *for E.coli* using a Risk Table

The two right-hand columns of Table 1 show the World Health Organization's risk rankings for *E.coli* (WHO, 1997). At less than 1 (<1) *E.coli* colony forming units (CFU) per 100 milliliter of sample, WHO quantifies risk as "conformity" meaning that it meets the WHO Guideline value of non-detection of any *E.coli* in 100 milliliter of sample (see above). At 1-10 *E.coli* colony forming units (CFU) per 100 mL sample, WHO quantifies risk as "low," 10-100 as "intermediate," 100-1000 as "high," and greater than 1000 as "very high." Looking at the "Colilert" far left (1st) column, an "absent" result (clear, no fluorescence) is equivalent to either a WHO risk category of "conformity" or "low" risk. A test result for Colilert that comes out "present" i.e. yellow, showing total coliform and showing blue fluorescence means that the Colilert tube contains at least 1 *E.coli* per 10mL of sample added. This can be equivalent to one of three risk levels, depending on the corresponding Petrifilm result. If Petrifilm counts of blue colonies with gas bubbles are zero, the present/yellow/fluorescent Colilert + the Petrifilm, shows intermediate risk (equivalent to WHO risk categories of between 10 – 100 colony counts /100 mL). High and very high risk waters are identified by present/yellow/blue fluorescent Colilert results and *E.coli* counts of blue colonies with gas bubbles on the Petrifilm test at either the 1-10 count (equivalent to WHO "high" risk level) or 10 – 100 count (equivalent to WHO "very high" risk level).

Table 7: Risk Levels from *E.coli*

EC-Kit Results – *E.coli* (Metcalf, 2006)		**Risk Level Categories** (World Health Organization, 1997)	
Colilert® *E. coli* Result	Petrifilm™ *E. coli* Result	Risk Level	*E.coli* in sample (cfu/100 mL)
Absent (no fluorescence)	0	Conformity	< 1
Absent (no fluorescence)	0	Low	1-10
Present (blue fluorescence)	0	Intermediate	10-100
Present (blue fluorescence)	1-10 (blue with gas bubbles count)	High	100-1000
Present (blue fluorescence)	> 10 (blue with gas bubbles count)	Very High	> 1000

The EC-Kit for Total Coliform

The coliform group is the most common indicator group used worldwide. The most frequently used coliform indicator tests are:

- Total Coliform
- Thermotolerant coliform (sometimes referred to as "fecal" coliform)
- *E.coli*

Q: Why do we care about total coliform?

A: While it is strongly desirable not to detect total coliform in drinking water, total coliform is not necessarily from the feces of humans and mammals (in contrast, *E.coli* and most thermotolerant coliform are). Some coliform can occur naturally in the environment. Therefore, *E.coli* is the most widely use test to determine whether there is human or animal feces in drinking water and total coliform is used to measure treatment performance.

Q: How is treatment performance measured?

A: Treatment performance is measured by sampling and running EC-Kit tests on at least two samples from a treatment system. The treatment system can be of any scale: large centralized treatment, community treatment or household treatment. The first sample one should collect is of the influent water – the water that supplies the treatment system. The second sample is of the treated water. By comparing the before treatment and after treatment samples, one can determine a percentage removal efficiency of the treatment system. This helps determine if the treatment system is performing effectively or not.

Interpretation of EC-Kit Results for Total Coliform

Total coliform are the sum of red colonies with gas bubbles plus blue colonies with gas bubbles in the Petrifilm test. Interpret the total coliform counts using Table 2.

Table 2: Interpreting Total Coliform Counts

	EC-Kit Results – Total Coliform		**Total Coliform Interpretation**	
	A	B	C	D
1	Colilert® Total Coliform Result	Petrifilm™ Total Coliform Result	Combined Colilert and Petrifilm result as a total coliform count (WHO, 1997)	Standardized Unit Equivalent (for comparison, assuming a 100 milliliter sample size (which is the widely used standard)
2	Absent (clear, no fluorescence)	0	0	<10 total coliform / 100 ml
3	Absent (clear, no fluorescence)	0	0	<10 total coliform / 100 ml
4	Present (yellow)	0	at least 1 total coliform per 10 ml	At least 10 total coliform /100 ml

			of sample in Colilert test	
5	Present (yellow)	1-10 (red with gas bubbles + blue with gas bubbles count)	1 – 10 total coliforms per 1 mL for the Petrifilm test	100-1000 total coliform/100 mL (standardized by multiplying C5 result by 100)
6	Present (yellow)	> 10 (red with gas bubbles + blue with gas bubbles count)	10 – 100 total coliforms per 1 mL for the Petrifilm test	1000 – 10,000 total coliform/100 mL (standardized by multiplying C6 result by 100)

Disposal of Tests

Colilert and Petrifilm tests can be safely stored for periods of days, weeks or even months, in order to be used as training tools, or to refer back to them. However, interpretation of results should only be done after 24 hours of body heat incubation.

Once you are ready to dispose of the tests, a simple, safe method is to add a few drops of household bleach (typically about 6% chlorine concentration). Add bleach to both to the Colilert tubes and to the Petfilm, by lifting the film and dispensing the drops. Allow to sit for 30 minutes, then the Colilert can be disposed down a drain, a latrine, or a dug hole. The Petrifilm can be disposed of as waste.

Appendix VII

The H_2S test

The procedure used to prepare the H_2S culture media (M1 and M2), process the samples and interpret the results were taken from (Manja, Maurya, & Rao, 1982); (Grant & Ziel, 1996); (Pillai, Mathew, Gibbs, & Ho, 1999), (IDRC, 1998), and (Venkobachar, Kumar, Talreja, Kumar, & Iyengar, 1994). Furthermore, the originial medium established by (Manja, Maurya, & Rao, 1982)) used 1 mL of Teepol. However, since Teepol is not widely available, (Grant & Ziel, 1996)) used lauryl sulfate salts (or sodium lauryl sulfate) instead. Also, the H_2S test reagent includes sodium thiosulfate, which neutralizes chlorine present in a water sample. This means that the H_2S test is a suitable microbiological test for chlorinated water supplies

H_2S medium

Bacteriological peptone	40.0 g
Dipotassium hydrogen phosphate	3.00 g
Ferric ammonium citrate	1.50 g
Sodium thiosulphate	2.00 g
Teepol 601/Sodium lauryl sulfate	0.20 g
L-cystine (for M2 medium only)	0.25 g
Water, distilled or boiled tap	100.0 mL

Preparation of the H_2S-test reagent

1. Weigh the above listed dry ingredients on a well-calibrated scale.
2. Prepare the 100-mL distilled or boiled water in a 200-mL beaker.
3. Carefully add the dry reagents to the beaker of water, stirring constantly until mixture seems homogeneous.

Preparation of the test tubes and bottles (20-mL samples)

1. Any kind of 50- to 200-mL sterilized glass bottles with heat resistant caps, or 4-oz Whirl-Pak bags can be used.
2. Taking Kleenex type paper, or non toxic paper, place a sufficient amount in each container so as to allow the paper to readily absorb 1 mL of the culture medium. The absorbant paper will be approximately 2 cm x 3 cm to 5 x 5 cm in size.

3. Place the bottles (loosely capped) in an autoclave at 115˚C for 15 minutes. Then place the bottles in a dry hot air oven at 55˚C for 60 minutes to sterilize and dry. Alternatively, the bottes can be placed in a hot air oven at 70˚C for 60 minutes. Cool the bottles until they reach ambient temperature. The media can be stored for up to 6 months in a cool, dry and dark place. The bottles must be opened only immediately before collecting the water sample.
4. If Whirl-Pak bags are used, dry the paper strip media in a hot air oven at 55˚C for 60 minutes. Place the strips in a plastic bag and store in a cool, dry and dark place for up to 6 months. The paper strip should be placed into the Whirl-Pak bag immediately before collecting the water sample.

Labeling of tubes and bottles

Appendix F provides detailed information on the labeling system developed by the Capiz Province PHO and during the laboratory studies at MIT.

Preservation and incubation of samples

When the samples are collected directly into bottles, sterile sampling bags, or test tubes (with paper strips), these samples must be processed and incubated as soon as possible. In tropical regions, the samples can be incubated at room temperature. Incubation should continue for a maximum of 48 hours and should be interpretated within 24 to 48 hours of incubation.

In Capiz, incubation occurred in Roxas City Memorial Hospital's Water Quality Laboratory, at ambient temperature, which ranged from 25˚C to 30˚C. At MIT, incubation occurred in the MIT M.Eng Environmental Engineering Laboratory, at ambient temperature which ranged from 20˚C to 26˚C.

Interpretation of results

Samples should be checked after 1 hour of incubation to avoid false positives, after which they should be inspected after 24 hours. The test is considered positive if it shows any blackening of the indicator paper strip inside the bottle, bag or test tube.

A negative control should also be prepared for each new source of distilled water used and for each batch of the culture medium prepared. The negative control is prepared in order to determine that the distilled water and lab-prepared reagent used are adequate for sampling purposes.

The following Table 8 presents a rough interpretation results for the H_2S test. However, throughout this study, the H_2S test results were not assigned numerical value such as >10/100 mL, >50/100 mL or >100/100 mL (such as the table presented here suggests), but rather were considered as qualitative, P/A results.

Table 8. Interpretation results for the H_2S test. (Adapted from (IDRC, 1998).

Volume of sample with a positive result	Amount of bacteria per 100 mL	Observations
20 mL	5 or more indicator bacteria	Probably more than 50 bacteria/100 mL if the blackening takes place very fast and very intensively (less than 24 hours)

Disposing of used H_2S tests

Once H_2S samples have been interpreted, the samples can be disposed of by adding a few drops of household bleach (typically about 6% chlorine concentration). The samples must be allowed to sit for 30 minutes. The sample can be disposed down a drain, a latrine, or a dug hole, and the H_2S paper strip reagent can be disposed of as waste.