Effectiveness of Ceramic Filter for Safe Drinking Water Supply in the Coastal Areas of Bangladesh

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Bachelor of Science Degree in Civil Engineering

By

Ijaj Mahmud Chowdhury (Student ID: 095413)
Md. Maksud-Ur-Rahman (Student ID: 085412)

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Islamic University of Technology (IUT)
A Subsidiary Organ of OIC.
Dhaka, Bangladesh

APPROVAL

This is to certify that the thesis submitted by Ijaj Mahmud Chowdhury and Md. Maksud-Ur-Rahman entitled as "EFFECTIVENESS OF CERAMIC FILTER FOR SAFE DRINKING WATER SUPPLY IN THE COASTAL AREAS OF BANGLADESH" has been approved by the supervisor for the partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering, Islamic University of Technology (IUT), Gazipur, Bangladesh in October 2013.

SUPERVISOR

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PROF. DR. REZAUL KARIM
Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
Gazipur, Bangladesh

DECLARATION

We hereby declare that the undergraduate project work reported in this thesis has been performed by us and this work has not been submitted elsewhere for any purpose (except for publication).

October, 2013

Ijaj Mahmud Chowdhury (Student Id: 095413)

Md. Maksud-Ur-Rahman (Student Id: 085412)

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ABSTRACT

Every year 1.5 million children die from diarrheal diseases (WHO 2009), and many of these deaths can be attributed to unsafe drinking water. Lack of access to drinking water and exposure to waterborne diseases from unsafe drinking water are problems faced by many people in the developing world. The WHO (2010) estimates that 884 million people worldwide lack access to improved sources of drinking water. Persons obtaining water from unimproved sources are at risk of drinking water contaminated with pathogens that may cause diseases such as cholera, enteric fever, dysentery, and hepatitis. Even people with access to so-called improved sources may not have microbiologically safe water and are at risk for developing the same diseases caused by drinking from unimproved sources. Now, in developing countries it has really become important to find out an affordable and effective way to produce safe drinking water that is free from any microbiological contamination. The point-of-use (POU) technology that uses conventional ceramic filters might be an effective way to reduce microbiological contamination. The use of ceramic filter in the developing countries like Bangladesh might be a good secondary source of fresh water where it is very difficult to have fresh drinking water for sustaining life. The southern coastal part of Bangladesh that is Khulna is greatly suffering from fresh surface drinking water sources. This study focuses on the two site of Khulna, which are Mongla and Dacope. A total of 142 water samples were collected in each cycle and three complete cycles were carried out. These samples were analyzed in the laboratory to identify the microbiological characteristics of water before and after filtration. The sample water have been tested for various indicator organism i.e. Total Coliform, Fecal Coliform, E. Coli, Heterotrophic Plate Count (HPC), through the process of membrane filtration and droplet technique. In conclusion, through the analysis of the results obtained, clear comparison can be made about the water quality in terms of ceramic filtration, hence the effectiveness of the ceramic filter can be determined. The microbial count for baseline of pond and PSF water source satisfied 0% water sample for all the parameters whereas RWH water supply shows a better result satisfying 44% water sample for safe drinking. Percent of samples satisfying WHO guideline were also evaluated and it has been seen that 21%, 20%, 40% samples satisfied guideline on an average for three cycles for TC, FC, *E.coli* respectively. A Quantitative Health Risk Assessment (QHRA) is done using the QHRA model. From the analysis it is seen that

the disease burden reduces after treatment of water. For treated PSF, pond and RWH water viral disease burden for median decreases 55%, 55%, 0% respectively with respect to untreated water. The findings of the present study suggests that drinking water supply options available in the southwest coastal zone pose a significant risk to public health and alternative water supply system is required.

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CHAPTER ONE

INTRODUCTION

1.1 GENERAL:

A huge improvement has been made in the past decade demonstrating that household water treatment and safe storage (HWTS) improve the microbiological quality of water stored in the home and reduce the risk of waterborne diseases in people using these technologies in developing countries. The conventional piped water system that is available in the developing countries mostly give access to the medium to high earning people, meaning that many of the poorest people must collect or manage water outside from their home. To minimize the situation several recognized organizations practice various options which include: ceramic filtration, chlorination, solar disinfection, flocculation, biosand filtration etc. About 1 billion people worldwide lack access to improve drinking water sources and many more lack of safe water sources as defined by the WHO risk-based Guidelines for Drinking-water quality (WHO 2004, 2006). Ceramic water filters provide affordable high quality drinking water, at a household or classroom level, for communities who are otherwise without access to safe drinking water. Sobsey et. al (2) suggest an approach for evaluating and ranking HWTS options and conclude: “Ceramic and biosand household water filters are identified as most effective according to the evaluation criteria applied and as having the greatest potential to become widely used and sustainable for improving household water quality to reduce waterborne disease and death.”

In response to the persistent problems associated with waterborne diseases our research topic focuses on the effectiveness of locally produced or available ceramic water filter. This study will conduct different bacteriological quality of water pre and post filtration through ceramic filter. Point of use water quality interventions have the potential to fill the service gap where piped water systems are not possible or do not deliver safe water. In the coastal areas of Bangladesh, due to salinity problem and absence of conventional piped water system low income people use water from various natural sources e.g. ponds, rivers, lakes etc which are highly contaminated with waterborne pathogens, though many of them also use water from rainwater harvesting.

Our study area is Mongla and Dacope upazila. This site has been selected because the transportation route is easy from Khulna city and the people of those regions suffer greatly due to lack of safe drinking water system. The southwest coastal region though have some source of water (Pond Sand filter, Rain Water Harvesting, Rain feed pond water) have been found contaminated microbiologically. Water sample from mentioned sources have been collected from Mongla and Dacope upazila of Khulna and tested on the laboratory and it has been seen that these sources contain waterborne bacteria and pathogens.

To overcome this situation in the southwest coastal area in house water supply system is required. It may be done through ceramic filter or solar disinfection process. The ceramic water filter which is locally produced and low cost is going to be implemented by WHO to provide safe drinking water to the deprived people of coastal areas of Bangladesh. Our research focuses on the efficiency of those ceramic filters. The purpose of this study is to check the presence of microbiological parameters (Total Coliform (TC), Fecal Coliform (FC), *E.coli*, Heterotrophic Plate Count (HPC) in the sample water (filtrated) and identify the overall efficiency of distributed ceramic filters.

1.2 OBJECTIVE:

The objective of this study is to assess the effectiveness of locally available ceramic filter in terms of microbiological bacteria removal and also to assess the health risk using QHRA model. The microbiological parameter which will be tested to evaluate the effectiveness are TC, FC, HPC, *E.coli* .

1.3 SCOPE OF THE STUDY:

The sample water collected from Mongla and Dacope include source water (surface) and filtered water through ceramic filter. Several tests were run at different cycles for determining the presence of selected microbiological parameter (TC, FC, HPC). The experiment carried out in the laboratory will help to determine the following.

- Microbiological contamination behavior of available surface drinking water source.

- Water quality in terms of selected parameter before the filtration.
- Water quality in terms of selected parameter after the filtration.
- Determination of the effectiveness of ceramic filter through comparison of before and after filtration.
- Health risk assessment

1.4 LIMITATIONS:

This study only considers the surface water source and the filters were provided only to some specific family. Though it is assumed that, after filtration maximum microbiological parameter will be reduced, but due to the using capability or ignorance of normal people, it sometime provides an undesired result. Another imitation of this study was that, samples had to carry out from Khulna to Dhaka, which may affect the results.

1.5 OUTLINE OF THESIS:

There has been many work carried out about the effectiveness of ceramic filter for safe drinking water supply system. The related works that have been carried out is discussed in the chapter two. Different findings from previous works related to microbial water quality and ceramic filter has also been discussed in the chapter of literature review. The introduction of parameters that are related with the study is given on the chapter three. Chapter four includes the study area, sampling, testing procedure and overall methodology of the study carried out. The result that has been found after different test has been discussed in the chapter five. Results are analyzed through percent reduction and based on source variation. Chapter five also includes the quantitative health risk assessment that has been done through QHRA model. Lastly, at chapter six the conclusions and recommendations has been made.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL:

An estimated 1.8 million people die every year from diarrheal diseases, less than AIDS (2.8 million) but more than tuberculosis (1.6 million) and malaria (1.3 million) (WHO 2004). The majority of deaths are associated with diarrhea among children under five years of age in developing countries, who are more susceptible to malnutrition, dehydration, or other secondary effects associated with these infections (WHO 2004). Taken together, diarrheal diseases are the third highest cause of illness worldwide and the third highest cause of death in children worldwide (WHO 2004). Most diarrheal illness is associated with unsafe water, sanitation, and hygiene (Prüss-Üstün et al. 2004). Prüss et al. (2002) estimated that 4.0% of all deaths and 5.7% of the global disease burden are attributable to inadequate water, sanitation, and hygiene, including diarrheal diseases and other water-related diseases such as ascariasis and schistosomiasis, claiming 4.2% of disability-adjusted-life years (61.9 million) worldwide (WHO 2004).

Safe drinking water is water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality. Billions of people have no access to improve safe drinking water which consequences the following

- Over four billion cases of diarrhea occur worldwide each year, which result in about 2.2 million deaths. Approximately 1.9 million of those deaths occur among children under the age of five years.

The coastal regions of Bangladesh comprise an area of 47,211 km^2, which is about 32% if the country's geographical area. In addition 35+ million people or 30% of the country's total population, live in coastal areas (BBS 2001). Mongla and Dacope, the study area of this study, is limited to the safe drinking water source as salinity is a great problem there. In many areas, rainwater is preserved in natural reservoir ponds and collection of rain water is the only source of drinking water (Islam et al. 2011). People use pond sand filters for drinking water and the proportion of rain-fed pond water and other alternative options for drinking purposes used in these coastal areas.

One of the most economic ways to reverse the safe drinking water condition is to introduce ceramic filter. Ceramic water filters are an inexpensive and effective type of water filter, that rely on the small pore size of ceramic material to filter dirt, debris, and bacteria out of water. Ceramic water filters provide affordable high quality drinking water, at a household or classroom level, for communities who are otherwise without access to safe drinking water.

2.2 WATERBORNE DISEASE:

Unsafe water, sanitation, and hygiene are associated with a wide range of infectious diseases. Water-related infections may be broadly classified into four categories by environmental transmission route: water-borne, water-washed, water-based, and water-related. This typology is commonly used by engineers and public health workers in identifying appropriate measures in interventions (Bradley 1977; Cairncross and Feachem 1993). Water-borne infections are directly transferred to an individual from ingested food or drink that is contaminated by human or animal waste carrying pathogens. This classification includes typhoid fever, cholera, hepatitis A virus (HAV), hepatitis E virus (HEV), and infections of Shigella spp and E. coli 0157:H7, among others (WHO 2006). Water-borne diseases are best prevented by improvements in microbiological water quality and prevention of casual use of unimproved sources (Bradley 1977). Waterborne infectious diseases are caused by pathogenic bacteria, viruses, protozoa, or other parasites in water. Traditionally, among the most serious waterborne threats to public health in temperate regions have been *Shigella* (causing bacterial dysentery), *Vibrio cholerae* (cholera), and *Salmonella* (typhoid, paratyphoid). Although these have mostly been eliminated from the more developed world through appropriate water, sanitation, and hygiene improvements, these and other bacterial pathogens continue to compromise water quality and public health in the less developed countries (Gleeson and Gray 1997). Viral pathogens are also increasingly recognized as important agents of diarrheal illness worldwide.

Although most bacteria in the coliform group do not cause disease, but the greater their number the greater the likelihood that disease-causing bacteria may be present. Since coliform bacteria usually persist in water longer than most disease causing organisms, the absence of coliform bacteria leads to the assumption that the water supply is microbiologically safe to drink. Therefore, the drinking water standard requires that no coliform bacteria be present in drinking water. Fecal coliform and E. coli bacteria should also be totally absent from drinking water.

2.3 EXISTING STANDARDS FOR MICROBIOLOGICAL EFFECTIVENESS:

Water treatment technology verification protocols for microbiological performance, often referred to as ETVs after the US EPA's *Environmental Technology Verification* program, exist in the United States and some other countries. Current standards for point-of-use water treatment for the United States specify a minimum 6 $\log_{10}$ (99.9999%) reduction in bacteria, 4 $\log_{10}$ (99.99%) reduction in viruses, and 3 $\log_{10}$ (99.9%) reduction in protozoan parasites demonstrated over a range of conditions and for prescribed volumes of water treated using specific test microbes (USEPA 1987; NSF 2003). All developed country protocols are highly prescriptive and are often intended to independently verify performance claims made by a manufacturer that may be linked to country-specific standards, not necessarily derived from health-based targets as articulated in the WHO *Guidelines for Drinking Water Quality* (WHO 2006). They typically specify the test pathogens or chemicals, test (challenge) water quality, frequency and duration of challenging the technology with contaminant-laden water, minimum contaminant reduction requirements, and other procedural and performance specifications. No international standards yet exist for the verification of household water treatment technologies, although WHO-led efforts to establish performance and testing guidelines based on the risk-based framework articulated in the Guidelines for Drinking Water Quality (WHO 2006) are underway. Such guidelines will need to be flexible because of varying laboratory capabilities, resources, and implementation contexts; emerging and evolving technologies; and the goal of encouraging incremental improvements in performance. The availability of new or modified protocols, material and methods for laboratory verification will enable manufacturers, regulators and implementers to ensure effectiveness of candidate POU technologies while providing flexibility and consideration of local conditions and needs.

2.4 USE OF CERAMIC FILTER IN DEVELOPING COUNTRIES:

As the issue of global safe water has gained momentum over the past twenty years, and as HWTS interventions have been further developed, ceramic filtration has been the focus of a number of laboratory studies, field studies and masters theses. Six randomized control studies have investigated the effectiveness of ceramic filters at improving microbiological quality of drinking water among users in the field (Brown *et al.* 2008, Clasen & Boisson 2006, Clasen *et al.* 2005, Clasen *et al.* 2004, Clasen *et al.* 2006, du Preez *et al.* 2008). Five of these trials went on to assess reductions in diarrhea incidence among users (Brown J 2008, Clasen et al. 2005, Clasen et al. 2004, Clasen et al. 2006, du Preez M 2008). In addition, user acceptance surveys and evaluations of adoption were components of these studies, as well as topics that were assessed in a number of master's theses and additional reports (Caens 2005, Lantagne 2001b, Palmer 2005). Factors such as the implementation setting, operation and maintenance requirements, cost, and life span have all been shown to influence successful user adoption of ceramic filters. Laboratory studies have investigated issues such as flow rate, mechanisms of filtration, and different silver application methods to better understand how the filter functions in the field (Oyanedel-Craver & Smith 2008, van Halen 2006, Franz 2005, Campbell 2005).

To combat the lack of safe drinking water in Northern Ghana, Susan Murcott, Senior Lecturer at the Massachusetts Institute of Technology (MIT) founded the non-profit organization Pure Home Water (PHW) in cooperation with local Ghanaian partners in 2005. PHW has two stated goals:

- Provide safe water via household drinking water treatment and safe storage products to 0Ghanaians in need of safe drinking water, with special emphasis on the region of Northern Ghana.
- Become locally self-sufficient and financially self-supporting.

During its first five years, PHW focused on distribution, training, and monitoring of Ceramic Pot Filters (CPFs) – a demonstrably effective method of home water treatment and safe storage. In order to more efficiently meet its stated goals, PHW has decided to pursue the local manufacture of CPFs as well. The purpose of this manual is to document a manufacturing process that will produce filters of sufficient durability, flow rate, and removal efficiency to suit PHW's customers' need for safe drinking water.

Many organizations are currently working to give people access to safe drinking water and Potters for Peace is one of them. Potters for Peace is a nonprofit organization which primarily works in Central America and has headquarters in Bisbee, Arizona. PFP is best known for their work in water treatment, which has influenced water treatment systems worldwide. The treatment strategy follows a Point-of-Use (POU) water treatment design that uses ceramic water filters to remove pathogens and other contaminants from the water. This is generally a very effective method to remove bacteria from water, though there are some concerns about the ease of use and maintenance of the filtration units.

A filter pilot project (2002-2006) was undertaken by Water and Sanitation Program (WSP) in Cambodia that have yielded promising results that suggest these interventions can be effective in improving drinking water quality and can contribute to significant health gains in populations using them. For the estimated 66% of Cambodians without access to improved drinking water sources (NIS, Combodia2004) and the potentially much greater percentage without consistent access to microbiologically safe water at the point of use, household-based water treatment can play a critical role in protecting users from waterborne disease. Surface water in Cambodia is plentiful but often of very poor quality, due in part to inadequate or nonexistent sanitation in rural areas. The study was intended to independently evaluate the microbiological effectiveness and health impacts of the CWP programs and to highlight successes and potential challenges to current and future implementation efforts. Key features identified by stakeholders were:

- Filters substantially to improve the quality of water.
- Filters contribution to measure health gains in users versus non-users.
- Factors changing over the useful life of the filter.
- Longevity of the filters being used by households.
- Factors contribute to successful long-term use in the target population.

Education initiatives have been taken in Nigeria near Sub-Saharan Africa under the research auspices of Potters for Peace, Princeton University and Ohio State University. UNICEF joined with a local non-governmental organization in Myanmar formed the Community Development Association to initiate water purification technology to the household level (Naing 2007). More than 3,000 ceramic water filters have been distributed in the Phyu village and schools in Myanmar. More than 80% of the households near the delta and coastal areas use these filters regularly and customer satisfaction is about 90% (Naing 2007). With this ceramic filter any particle or organisms that are larger than 1 micron are trapped in the filter.

Millions of these porous clay ceramic filters are in use in several countries in African, Asian, and South American continents (Plappally et al. 2009). Studies on performance of clay ceramic filters in Bolivia conducted under the nongovernmental organization Food for the Hungry International showed a decrease in the cases of diarrhea by around 45% (Clansen et al. 2006). In the studies conducted by Sobsey et al in 2008, ceramic filters and biosand filters were found to best fit the sustainability criteria in the field with consumers (Sobsey et al. 2008).

Another field survey was conducted regarding the effectiveness of ceramic filter to evaluate the interdisciplinary parameters influencing health of people. Ceramic filter were distributed across 52 families at Eweje Village, Odeda local government area, Ogun State, Nigeria. That specific survey contained questions related to hygiene, health, water source, treatment. After the end of the study a conclusion was made which stated “Apart from population, the duration of filter usage has been a major parameter for influencing general health at Eweje village. This confirms a considerable reduction in water borne diseases at Eweje after the introduction of ceramic water filters.”

Low-cost options for the treatment of drinking water at the household level were being explored by Cambodian government and non-governmental organizations (NGOs) working in Cambodia, where man lack access to improved drinking water sources. The ceramic water purifier (CWP), a locally produced ceramic filter, have been implemented by several NGOs, and an estimated of 100,000+ households in the country were using ceramic filter surveyed in the year 2010.

To meet the Millennium Development Goal of the WHO-UN (WHO 2010) eight hundred eighty-four million people are still without potable water with only 5 years to go and 34% of the deprived people live in Sub-Saharan Africa. In the last 18 years there has been 10% increase in total population of those who have access to potable water (WHO 2010). As per predictions by the World Bank in 2003, by 2015, 5-10% of the population of Middle East and North Africa, Latin America and the Caribbean will still be without reliable potable water. Similarly, approximately 15% of South Asia and 25% of Sub Saharan Africa will not have access to potable water resources (Hillie et al. 2009). Several water filtration technologies have been started by educational initiatives and non-governmental organization scarcity (Sobsey et al. 2008).

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION TO THE PARAMETERS:

This study only examines the microbiological parameters and the selected parameters for this study are: TC, FC, *E. coli*, and HPC. The early impetus behind the bacteriological examination of drinking water was to determine whether water was consumed as contaminated. It has since been recognized that microbial parameters can provide useful information throughout the drinking water production process, source water characterization, treatment efficiency etc. In this study, the effectiveness of ceramic filter has been determined through observation of microbial parameters. There are different methods available to determine TC, FC, *E. coli,* and HPC. Here, mFC broth , mEndo broth, bacto agar has been used to enumerate TC & FC, , *E. coli,* HPC respectively.

3.1.1 TOTAL COLIFORM (TC) AND FECAL COIFORM (FC):

- Total coliform group is made up of bacteria with defined biochemical and growth characteristics that are used to identify bacteria that are more or less related to fecal contaminants. Total coiform have long been utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water. The bacteria is capable to grow after 24 hour incubation at 37^0 celsius.
- Fecal coiforms are defined as the group of total coliforms that are able to grow after 24 hour incubation at 44^0 celsius. Their presence in water should not be ignored, as the basic assumptions that pathogens may be present and may cause many dreadful diseases. The presence of fecal coliform in aquatic environments may indicate that the water has been contaminated with the fecal material of humans or other animals. Fecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage. Different waterborne pathogenic diseases that may coincide with fecal coliform contamination include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively.

3.1.2 ESCHERICHIA COLI (E. COLI):

E. coli is a type of fecal coliform bacteria commonly found in the intestines of animals and humans. E. coli is short for Escherichia coli. The presence of E. coli in water is a strong indication of recent sewage or animal waste contamination. Sewage may contain many types of disease-causing organisms. Infection often causes severe bloody diarrhea and abdominal cramps; sometimes the infection causes non-bloody diarrhea. E. coli is widely preferred as an index of fecal contamination. It is also widely used as an indicator of treatment effectiveness although, as with the other coliform indicators, it is more sensitive to disinfection than many pathogens.

3.1.3 HETEROTROPHIC PLATE COUNT:

HPC measurement detects a wide spectrum of heterotrophic microorganisms, including bacteria and fungi, based on the ability of the organisms to grow on rich growth media, without inhibitory or selective agents, over a specified incubation period and at a defined temperature. The spectrum of organisms detected by HPC testing includes organisms sensitive to disinfection processes, such as coliform bacteria; organisms resistant to disinfection, such as spore formers; and organisms that rapidly proliferate in treated water in the absence of residual disinfectants. The tests detect only a small proportion of the microorganisms that are present in water. The population recovered will differ according to the method and conditions applied. Although standard methods have been developed, there is no single universal HPC measurement. A range of media is available, incubation temperatures used vary from 20°C to 37 °C and incubation periods range from a few hours to 7 days or more.

3.2 STUDY AREA AND SAMPLING:

To conduct the study of determining effectiveness of locally produced ceramic filter in the coastal region two different sites in Khulna has been selected. Water samples were collected from the Dacope and Mongla upazilas from RWHs, PSFs, pond and other sources. A total of 142 samples were collected in each cycle and a total of three cycles was done to conduct the study.

Ceramic filters were distributed to different 71 Families and this selection was random. Though different factors such as, distance from the source, income level, source variation etc was kept in mind while randomization. As salinity is a problem in the coastal region, people living there have to depend on surface water system often found contaminated. People usually collect and use rain-fed pond water and other alternative options for drinking purpose. In the study area, most of the people drink water without any effective treatment though in small scale, different treatment such as pond sand filter, solar disinfection and rain water harvesting exist but this fail to provide desired water quality in terms of microbiological parameters.

3.2.1 MONGLA:

Mongla (Town) stands on the river Pashur. It is the second biggest seaport of the country. It consists of 9 wards and 13 mahallas. It has 27192 units of house hold and total area 1461.22 km^2. Mongla has an average literacy rate of 42.8% (7+ years), and the national average of 32.4% literate. While conducting the study, 34 ceramic filters were distributed in different families in the Mongla upazila. Following table describes the samples collected from different source during 3 cycles:

Table 3.1: Sources of different samples collected from Mongla

Sample ID	1st cycle	2nd cycle	3rd cycle
M-1	Pond	R.W.H.	RWHS
M-2	RWH	Pond	Pond
M-3	RWH	R.W.H.	RWHS
M-4	RWH	R.W.H.	RWHS
M-5	RWH	R.W.H.	RWHS
M-6	Pond	R.W.H.	Pond
M-7	RWH	R.W.H.	RWHS
M-8	RWH	R.W.H.	RWHS
M-9	RWH	R.W.H.	-
M-10	RWH	R.W.H.	RWHS
M-11	RWH	R.W.H.	RWHS
M-12	RWH	R.W.H.	Pond
M-13	RWH	R.W.H.	RWHS
M-14	RWH	R.W.H.	RWHS
M-15	Pond	Pond	Pond
M-16	RWH	R.W.H.	Pond
M-18	RWH	R.W.H.	RWHS
M-19	RWH	R.W.H.	RWHS
M-20	RWH	R.W.H.	Pond
M-21	RWH	R.W.H.	-
M-22	P.S.F.	P.S.F.	Pond
M-23	P.S.F.	P.S.F.	Pond
M-24	P.S.F.	P.S.F.	RWHS
M-25	RWH	R.W.H.	RWHS
M-26	Pond	R.W.H.	RWHS
M-27	Pond	Pond	RWHS
M-28	Pond	R.W.H.	RWHS
M-29	Pond	Pond	Pond
M-30	Pond	Pond	Pond
M-31	P.S.F.	Pond	RWHS
M-32	P.S.F.	Pond	-
M-33	RWH	R.W.H.	RWHS

M-34	RWH	R.W.H.	RWHS
M-35	RWH	R.W.H.	RWHS

3.2.2 DACOPE:

Dacope Upazila (Khulna district) with an area of 99158 km^2, is bounded by batiaghata upazila on the north, Pashur River on the south, rampal and mongla upazilas on the east, paikgachha and koyra upazilas on the west. Main rivers are Pasur, Sibsa, Manki, Bhadra. The southern part of this upazila is surrounded by Sundarban (11790.13 hectors). Dacope has a population of 143131. It has 25377 units of house hold and total area 991.58 km^2. Similar to Mongla, a number of ceramic filters also distributed to the families of this upazila considering the random selection. Following table describes the samples collected from different source during 3 cycles:

Table 3.2: Sources of different samples collected from Dacope

D-1	Pond	Pond	RWHS
D-2	Pond	Pond	RWHS
D-3	Pond	Pond	Pond
D-4	Pond	Pond	RWHS
D-5	P.S.F.	Pond	RWHS
D-6	P.S.F.	R.W.H.	RWHS
D-7	Pond	R.W.H.	RWHS
D-8	RWH	R.W.H.	RWHS
D-9	Pond	Pond	Pond
D-10	RWH	R.W.H.	RWHS
D-11	Pond	Pond	RWHS
D-12	Pond	R.W.H.	RWHS
D-13	RWH	R.W.H.	RWHS
D-14	RWH	R.W.H.	RWHS
D-15	RWH	R.W.H.	RWHS
D-16	RWH	R.W.H.	RWHS
D-17	RWH	R.W.H.	RWHS
D-18	RWH	R.W.H.	RWHS
D-19	RWH	-	RWHS
D-20	RWH	R.W.H.	RWHS

D-21	P.S.F.	R.W.H.	RWHS
D-22	RWH	R.W.H.	RWHS
D-23	RWH	R.W.H.	RWHS
D-24	RWH	P.S.F.	RWHS
D-25	RWH	P.S.F.	RWHS
D-26	-	-	-
D-27	Pond	P.S.F.	RWHS
D-28	-	-	RWHS
D-29	Pond	P.S.F.	-
D-30	P.S.F.	-	River Water
D-31	P.S.F.	R.W.H.	P.S.F.
D-32	P.S.F.	-	-
D-33	P.S.F.	R.W.H.	P.S.F.
D-34	RWH	R.W.H.	RWHS
D-35	P.S.F.	P.S.F.	P.S.F.
D-36	Pond	R.W.H.	RWHS
D-37	Pond	R.W.H.	RWHS
D-38	RWH	R.W.H.	RWHS

Figure: 3.1 Coastal region of Bangladesh

3.3 SAMPLE COLLECTIONS:

Sample water is collected on autoclave able 250-500 ml sampling bottle and the bottle must be labeled properly and the cap must be air tight. The bottle is then rinsed with corresponding sample water and then filled up with sample. This has been done to create a similar environment inside the bottle so that the sample water and its constituent would find a similar atmosphere at which they originally exist. Whenever the sample is collected, the bottle neck is fastened with insulation tape and the bottle is stored in insulated box and ice cubes are placed in poly bags so that the ice water could not mix with the sample water. The temperature is tried to keep in between 2-8 Degree Celsius because pathogens could not grow in that certain temperatures.

3.4 SAMPLE PRESERVATION:

The sample should be experimented within 24 hours of collection with minimum alteration. Few changes may come due to temperature change or improper preservation procedure. To preserve the samples properly from field to lab, insulation box have been used. After sample reaches to the lab, if further preservation is required, the samples are kept in refrigerator maintaining the temperature 4^0 celsius. This is done to maintain the actual state of the collected sample and to reduce the effect of contamination. A preserved sample cannot be used for testing if the duration is more than 7-10 days. When the testing of sample took place, the samples temperature is kept on room temperature.

3.5 MEDIA PREPARATION:

PREPARATION OF M ENDO BROTH: This media is used for enumerating *E.coli* in water by membrane filtration. m Endo Broth contains peptones as sources of carbon, nitrogen, vitamins and minerals. Yeast extract supplies B-complex vitamins, which stimulate bacterial growth. For convenience and better result we add Bacto Agar with m Endo Broth to convert Broth medium into Agar medium.

The preparation of the media is done by the followings:

- 48 gm of m Endo Broth powder is dissolved in 1 liter of distilled water.
- 15.6 gm of Bacto Agar is also dissolved in that 1 liter of distilled water.
- Mixed water is heated to boiling temperature with constant shaking in every 25 seconds.
- After boiling, it is kept into the water bath to reduce the temperature.
- When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state.

PREPARATION OF MFC AGAR:

- This media is used for enumerating Total coliform and Fecal Coliform in water by membrane filtration. Suspend 43 gm. in 1 liter of distilled or de-ionized water. 10 ml of a 1 % solution of rosolic acid in 0.2 N NaOH was added. Mixed water is heated to boiling temperature with constant shaking in every 25 seconds. After boiling, it is kept into the water bath to reduce the temperature. When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state.

PREPARATION OF NUTRIENT AGAR(NA):

- This media is used for enumerating Heterotrophic plate count. 23 gm. of nutrient agar is mixed with 1000 ml of distilled water. Then the solution is boiled for 1 minute. Then the solution is put into the Autoclave machine at 121 degree celsius temperature. After autoclaving, it is kept into the water bath to reduce the temperature. When it cools down to desired temperature the mixture is then poured into the Petri Dish and wait until it transfers from liquid to a stabilized state. Pouring is done in the laminar flow because nutrient agar media very active.

3.6 MEDIA PRESERVATION:

The prepared media is preserved by freezing into the refrigerator if the samples are not available. When the samples are available the preserved media is dry heated until there is zero moisture.

3.7 TEST PROCEDURE:

There are many processes for determination of indicating organisms, here the experiment was done on membrane filtration process and droplet process.

Membrane filtration:

- In a cup, 15-20 ml normal saline have been taken and 100µL sample is also poured into the cup and then it is filtered.
- After filtration, the filter paper is placed on the media of a Petri dish.
- There should not be any bubble.
- Then the Petri dish is incubated for 24 hours at 37^0 celsius for TC, *E.coli* and 44^0 celsius for FC.

Droplet Process:

- This process is basically done for HPC determination.
- 100 µL samples are taken in the micropipette and then it is dropped into the media.
- It must be ensured that every drop must be identical.
- There must be distance between every drop so that the drop could not muddle up.

3.7.1 COUNTING OF BACTERIA AND DOCUMENTATION:

24 hours later the Petri dish is taken out from the incubator and number of available bacteria are counted and documented. The microbial of sample water will consume

the nutrient from the media and thus it will be visible to open eye. Dilution factors are multiplied if diluted sample are used. In case of the samples which shows pathogens or bacteria both in filter and droplet, in that case it is good to select from the filter paper because the sample size is greater in filter paper than droplet. It is expected that this will give comparatively accurate result.

3.8 QUANTITATIVE HEALTH RISK ASSESSMENT (QHRA):

Quantitative Health Risk Assessment (QHRA) is a technique to estimate predicted disease burden based on input data about water quality such as TTC, *E.coli*, arsenic etc. QHRA is a predictive, modeling technique and a tool to estimate what disease burden may result from specified exposures. Again QHRA is not a descriptive, empirical technique and not a tool to measure disease burden in communities. Therefore, QHRA is a scientific model whose output is only the prediction and estimation and its accuracy fully depends on the accuracy of input data and assumptions applied on the model (APSU, 2005). DALY is a metric - a new evolving approach for setting a reference level of risk. WHO has quite extensively used DALYs to evaluate public health priorities and to assess the disease burden associated with environmental exposures. The diverse hazards that may be present in water are associated with very diverse adverse health outcomes, Some outcomes are acute (diarrhea, methaemoglobinaemia), and others are delayed (cancer by years, infectious hepatitis by weeks); some are potentially severe (cancer, adverse birth outcomes, typhoid), and others are typically mild (diarrhea and dental fluorosis); some especially affect certain age ranges (skeletal fluorosis in older adults often arises from exposure in childhood; infection with hepatitis E virus [HEV] has a very high mortality rate among pregnant women), and some have very specific concern for certain vulnerable sub-populations (cryptosporidiosis is mild and self-limiting for the population at large but has a high mortality rate among those who test positive for human immuno-deficiency virus [HIV]). In addition, any one hazard may cause multiple effects (Gastroenteritis, Gullain-Barré syndrome, reactive arthritis and mortality associated with Campylobacter). In order to be able to objectively compare water-related hazards and the different outcomes with which they are associated, a common metric- DALY can take account of differing probabilities, severities and duration of effects needed.

This metric should also be applicable regardless of the type of hazard, applying to microbial, chemical and radiological hazards. The metric, DALY, is used in the Guidelines for Drinking Water Quality. WHO has quite extensively used DALYs to evaluate public health priorities and to assess the disease burden associated with environmental exposures.

The basic principle of the DALY is to weight each health effect for its severity from 0 (normal good health) to 1 (death). This weight is multiplied by the duration of the effect that is the time in which disease is apparent (when the outcome is death, the "duration" is the remaining life expectancy) – and by the number of people affected by a particular outcome. It is then possible to sum the effects of all different outcomes due to a particular agent. Thus, the DALY is the sum of years of life lost by premature mortality (YLL) and years of healthy life lost in states of less than full health, i.e., years lived with a disability (YLD), which are standardized by means of severity weights.

Thus, DALY = YLL + YLD

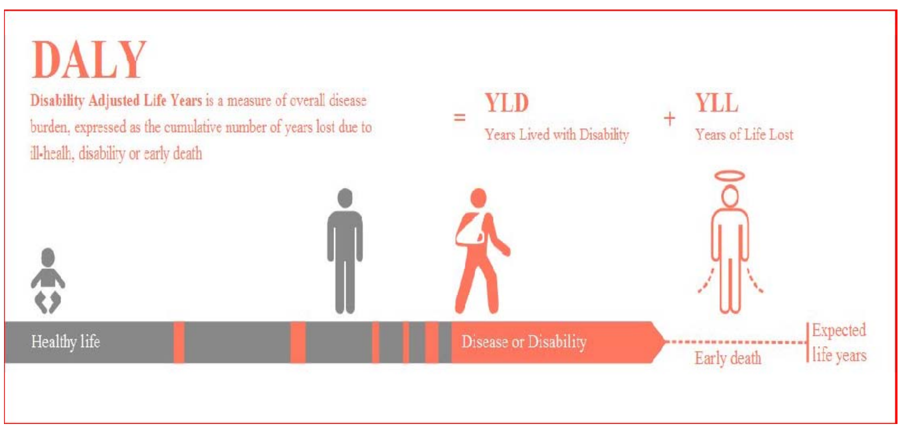

Figure 3.2: DALY interpretation

Key advantages of using DALYs are its "aggregation" of different effects and it's combining of quality and quantity of life. In addition – and because the approaches taken require explicit recognition of assumptions made – it is possible to discuss these and assess the impact of their variation. The use of an outcome metric also focuses attention on actual rather than potential hazards and thereby promotes and enables rational public health priority setting. Most of the difficulties in using DALYs relate to availability of data.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION:

In this chapter, the results from experiments are included and discussed briefly. Various comparisons have been made through analysis of the results of different cycles and sources. A total of 71 filters were distributed in the locality of Mongla and Dacope. Water from various sources are filtered through these filters and the samples are collected before and after filtration and the following analysis has been done.

- Percent reduction
- Source variation
- QHRA

4.2 TOTAL COLIFORM:

The allowable limit for Total Coliform concentration is zero in per 100 ml. The water sample collected from different sources show much higher value than the allowable one. Also the water that is unfiltered exhibit higher value than the allowable. After filtration the ratio decreased and there are many samples which satisfied the guideline. The collected samples in three cycles were tested for determination of TC. From the analysis of data from Appendix D the following graphs can be computed:

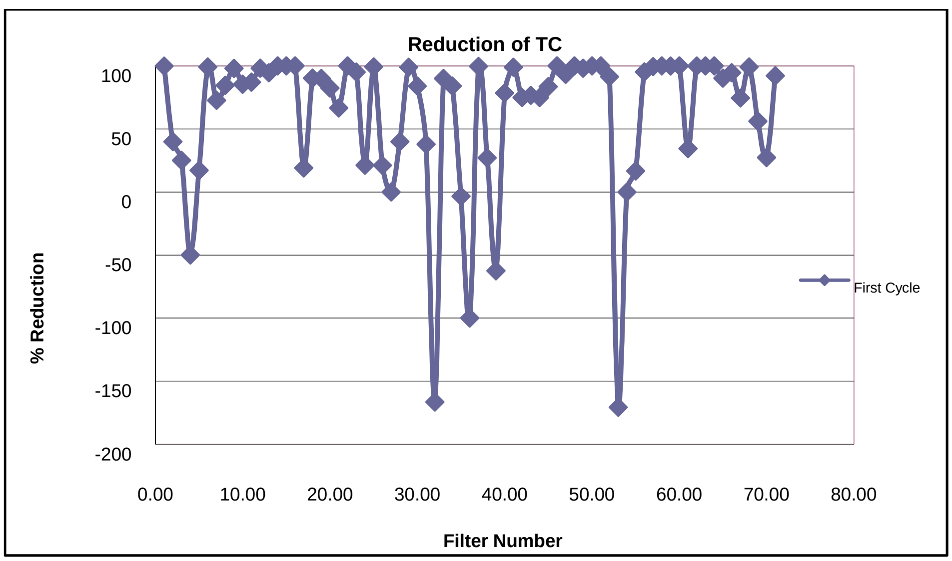

Figure 4.1: % Reduction of TC at 1st Cycle

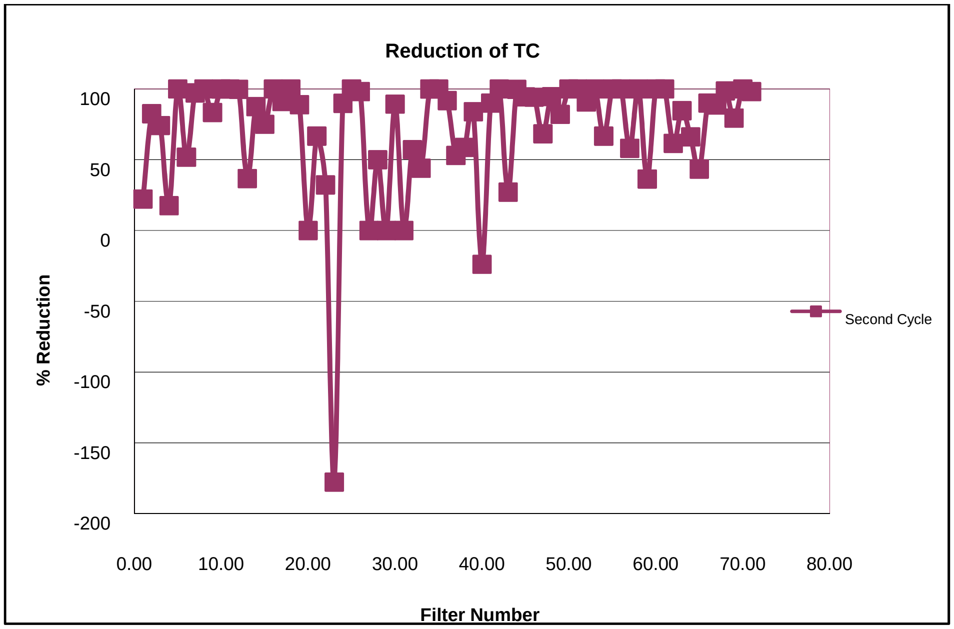

Figure 4.2: % Reduction of TC at 2nd Cycle

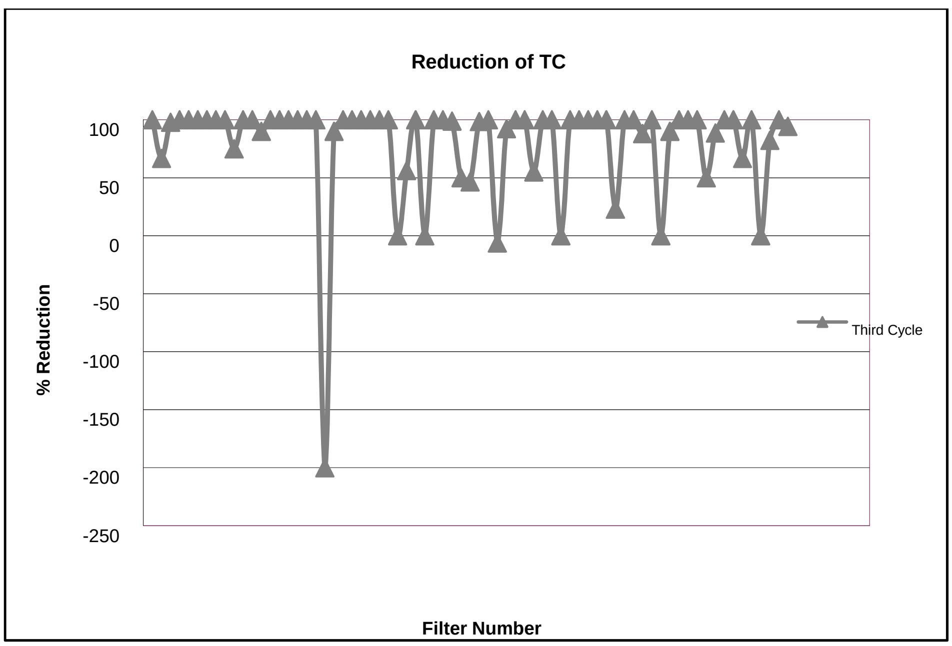

Figure 4.3: % Reduction of TC at 3rd Cycle

From the graphs it can be seen that, the reduction of TC is good, but there is few samples for which there is no reduction and increase of TC. This may happen due to other contamination in transport process or improper handling. From the graphs, maximum and minimum TC value can be obtained.

Table 4.1: Maximum, minimum & average value of TC in unit of cfu/100 ml.

	1st Cycle			2nd Cycle			3rd Cycle		
	U	F	R	U	F	R	U	F	R
Maximum	900000	272000	100	33000	17000	100	43000	2700	100
Min	0	0	-170	0	0	-23	0	0	-200
Ave	43959	8104	64	3592	608	75	3648	237	86

U= Unfiltered, F= Filtered, R= % Reduction

The samples satisfying WHO guideline before and after filtration are required to find the actual effectiveness of the ceramic filter. The following table describes number of samples in percentage that meet the requirements of guideline after filtration.

Table 4.2: Percent of samples satisfying WHO guidelines for safe drinking water supply after treatment.

1st Cycle			2nd Cycle			3rd Cycle		
Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied	Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied	Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied
6	11	7.69	4	11	10.44	13	40	46

4.3 FECAL COIFORM:

Like Total Coliform the allowable limit for FC is also zero in per 100 ml. From Appendix F the following graphs of reduction of FC can be obtained.

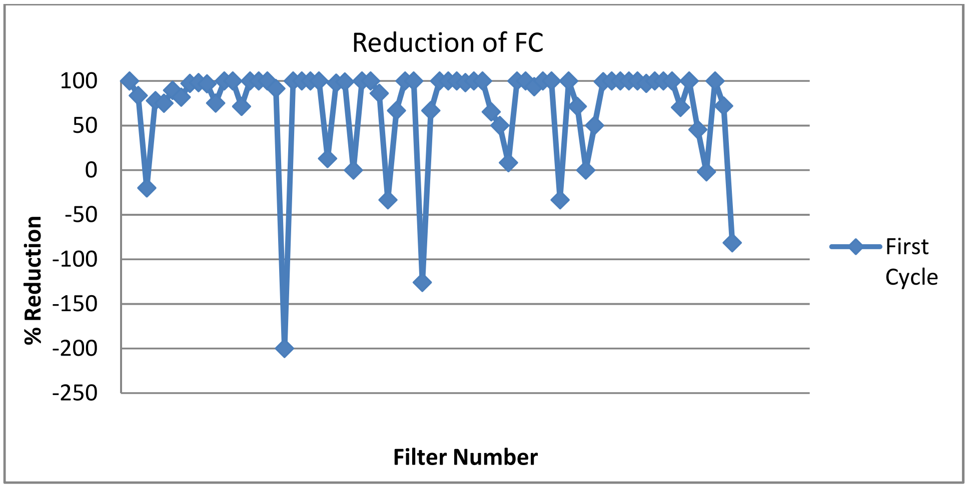

Figure 4.4: % Reduction of FC at 1st Cycle.

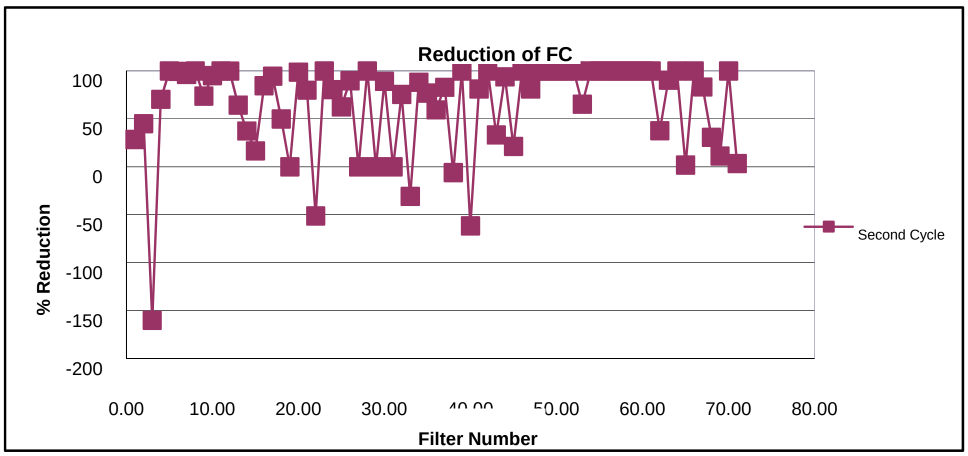

Figure 4.5: % Reduction of FC at 2nd Cycle.

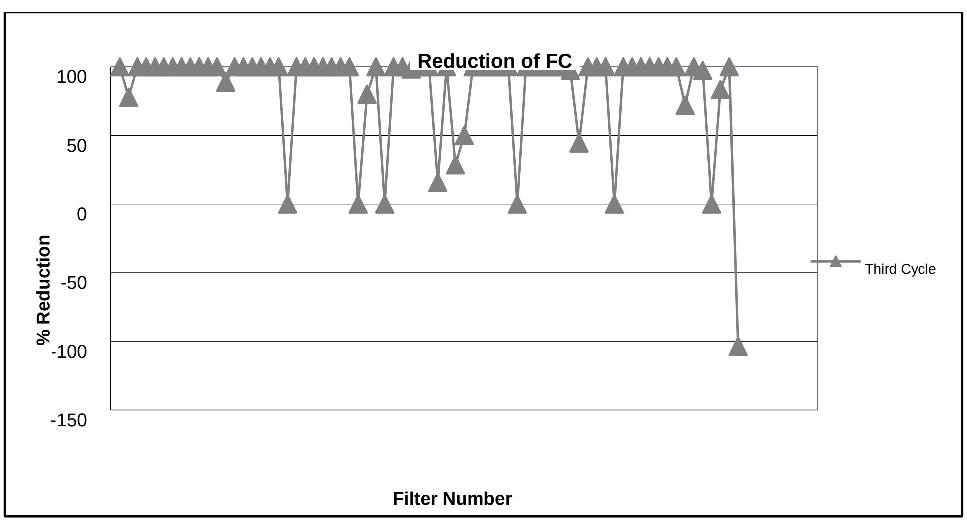

Figure 4.6: % Reduction of FC at 3rd Cycle.

Table 4.3: Maximum, minimum & average value of FC in unit of cfu/100 ml.

	1st Cycle			2nd Cycle			3rd Cycle		
	U	F	R	U	F	R	U	F	R
Max	102000	18000	100	25000	2700	100	8100	5500	100
Min	0	0	-200	0	0	-160	0	0	-103
Ave	7326	856	72	960	126	68	1165	195	90

U= Unfiltered, F= Filtered, R= % Reduction

The presence of FC indicates the presence of pathogenic bacteria. The unfiltered samples show a great deviation from the WHO guidelines. The change in maximum value after filtration is noticeable, though it is required 100% reduction to comply with WHO guidelines. From the maximum value of FC from three cycles, it can be seen that, the value of third cycle is less than the other two cycles and the reduction rate is also higher for the 3rd cycle. Percent of samples comply with the guideline is also higher for third cycle. It may be due to the seasonal variation as third cycle was conducted in the dry season. The following table describes number of samples in percentage that meet the requirements of guideline after filtration.

Table 4.4: Percent of samples satisfying WHO guidelines for safe drinking water supply after treatment.

1st Cycle			2nd Cycle			3rd Cycle		
Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied	Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied	Unfiltered sample satisfied	Filtered sample satisfied	% Satisfied
12	22	17	7	17	15	31	43	30

4.4 *E.coli*:

The major risk involved in using supply water is that of infectious disease related to fecal contamination. Hence, the microbial examination of drinking water emphasizes assessment of the hygienic quality of supply. In these two studies, *E.coli* concentration is found to exceed allowable limit for the vast majority of samples. So the supply water of both areas is mostly unacceptable for drinking and may cause adverse effects on health. From the above shown graphs we can see that, there are large numbers of E. coli bacteria or coliforms present in the water which can cause many dangerous intestinal diseases. So, these values would be used in the QHRA Model to calculate the risk associated and numbers of life in danger. The reduction in *E.coli* in percentage is shown in the following gaps for three cycles.

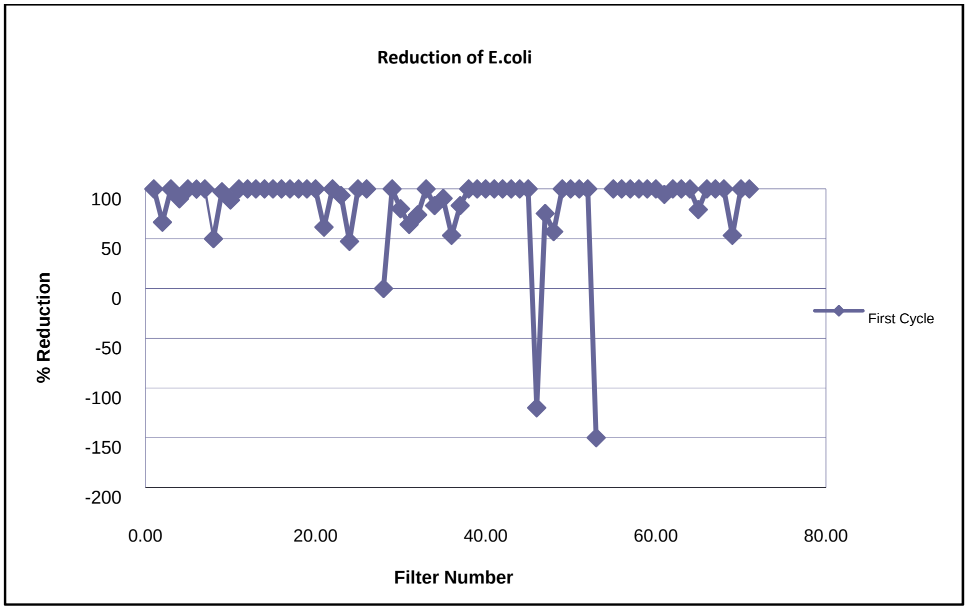

Figure 4.7: % Reduction of *E.coli* at 1st Cycle.

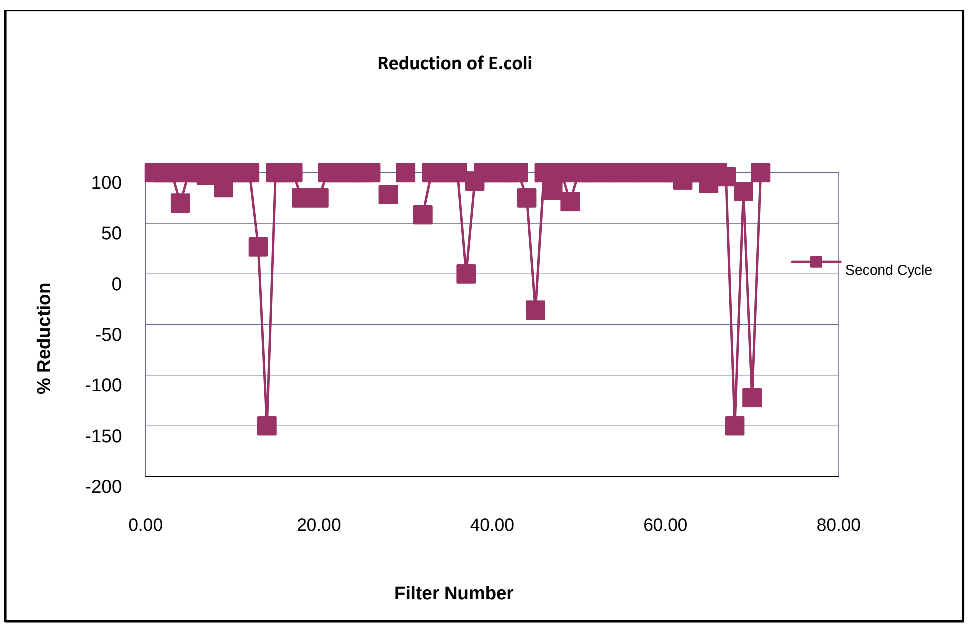

Figure 4.8: % Reduction of *E.coli* at 2nd Cycle.

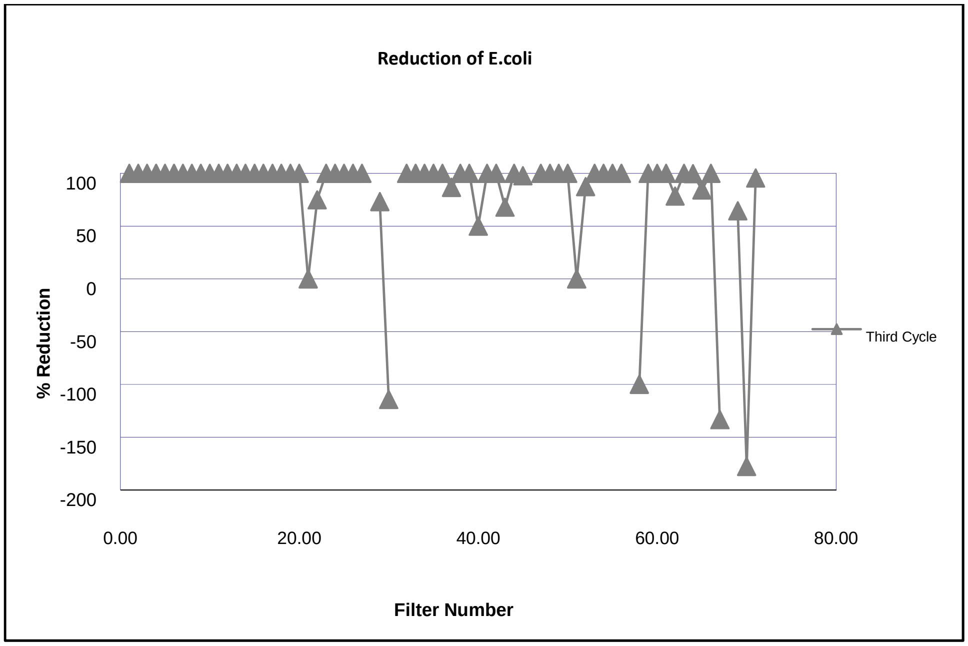

Figure 4.9: % Reduction of *E.coli* at 3rd Cycle.

Table 4.5: Maximum, minimum & average value of *E.coli* in unit of cfu/100 ml.

	1st Cycle			2nd Cycle			3rd Cycle		
	U	F	R	U	F	R	U	F	R
Max	470000	10000	100	32000	6000	100	98000	15000	100
Min	0	0	-150	0	0	-150	0	0	-177
Average	15262	752	84	2774	355	80	3261	550	79

U= Unfiltered, F= Filtered, R= % Reduction

Average reduction rate is almost 80% in all three cycles, which indicates that the effectiveness of ceramic filter in reducing *E.coli* is quite good. Few samples are showing increase of microbial, they may increase due to growth of bacteria inside the filter, or the filter itself is contaminated.

4.5 HPC:

It is the total bacterial count for the water samples. It has no such guidelines but comparative analysis can be done using the result of unfiltered and filtered samples. Following graphs of % reduction can obtained from the test results.

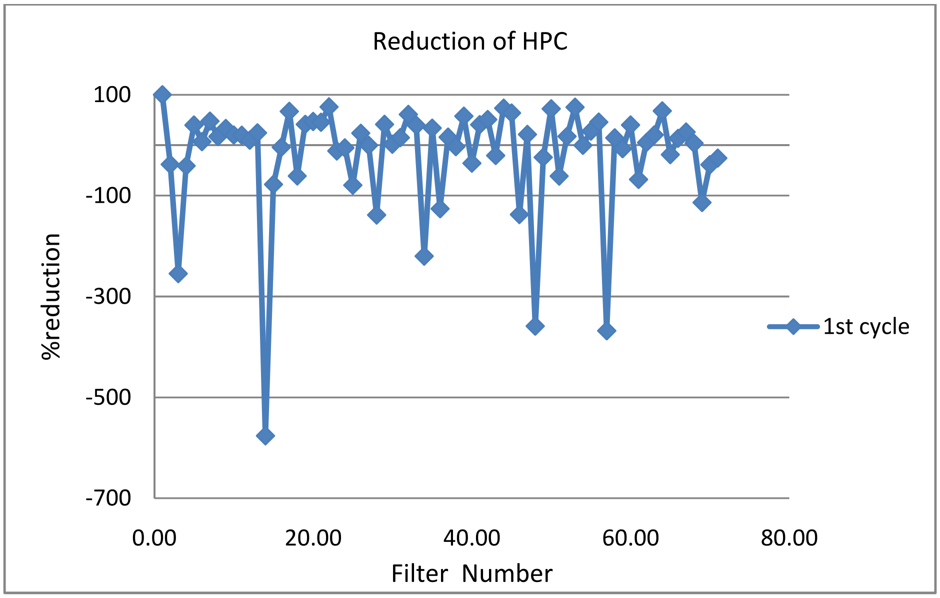

Figure 4.10: % Reduction of HPC at 1st Cycle.

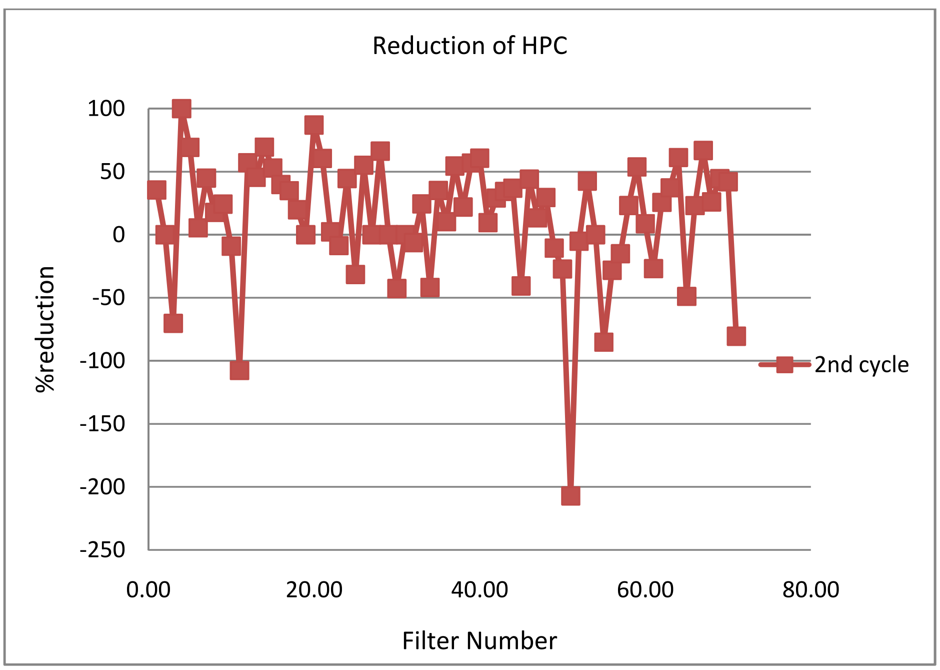

Figure 4.11: % Reduction of HPC at 2nd Cycle.

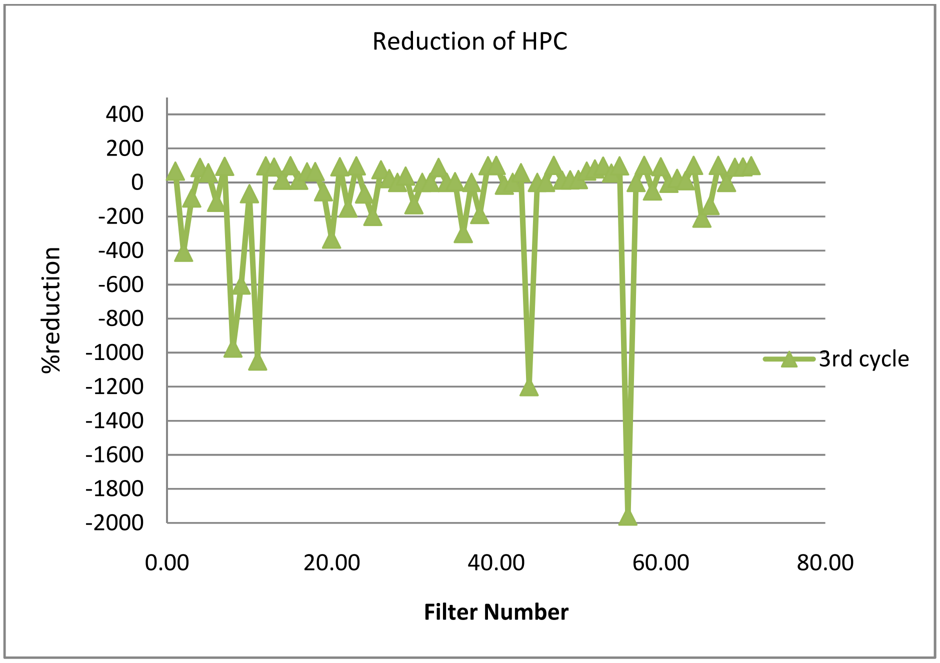

Figure 4.12: % Reduction of HPC at 3rd Cycle.

Table 4.6: Maximum, minimum & average value of HPC in unit of cfu/100 ml.

	1st Cycle			2nd Cycle			3rd Cycle		
	U	F	R	U	F	R	U	F	R
Max	714	792	100	20640	11340	100	1054	0	100
Min	11	0	-576.4	150	50	-207.1	2	1872	-972.7
Average	211.5	208.5	-19.38	2682.4	1978.7	14.6	90.59	114.7	-89.5

In HPC analysis, it has been seen that for cycle 1 and cycle 3, average reduction is in the negative axis, which indicates that the bacterial organisms increased instead of decrease. It also indicates that apart from TC, FC, *E.coli* there have been other organisms which were active after filtration and thus the count increases.

4.6 SOURCE VARIATION:

The reduction rates vary due to different sources of water. Usually rain water contains less microbiological pathogens but if the storage tank is not clean enough than bacteria may grow in the rain water. PSF and pond water is also used for drinking purposes in the study area. From table 4.1 and 4.2 it can be seen that most of the family has a tendency to collect water from RWHS as it is more pure than PSF or pond sources. Though RWHS as well as PSF and pond water has been found microbiologically contaminated at different levels. From the test results there has been seen many variations on the reduction of microbiological parameters due to use of different sources. From the results of baseline, untreated & treated water sample the following graphs can be obtained where the effect of sources in reducing microbiological parameter can be observed. The negative value means increasing of organisms after filtration instead of decreasing. It may be due to bacterial growth of any parameter in the transport period from filed to laboratory. It can also be due to improper handling. From the following figure it can be observed that, the average reduction rate for rain water is much less, it is because of few samples for which the increase of bacteria after filter is higher. If, all the three cycles for different sources and parameters are taken into consideration than it can be found that, 16.6%, 20.8%, 50% samples for PSF water satisfy the guideline for TC, FC and *E.coli* respectively. RWHS satisfy 29%, 28%, 37% water samples for TC, FC and *E.coli* respectively. In case of pond water, it shows a very little percentage for satisfying guideline after filtration. For TC, FC and *E.coli* it satisfy 0%, 11%, and 23% water sample.

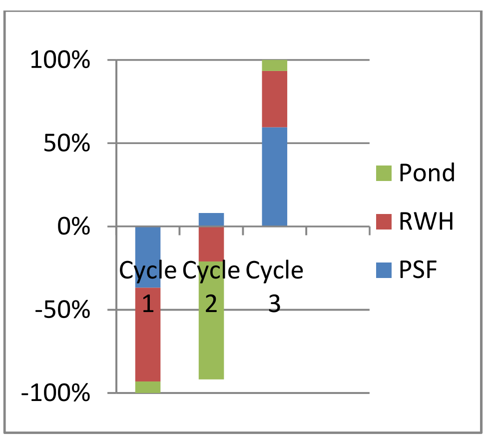

Figure 4.13: Average %Reduction of TC after filtration for different sources at different cycles.

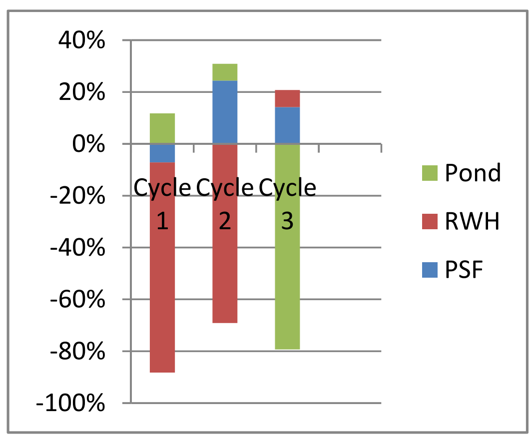

Figure 4.14: Average %Reduction of FC after filtration for different sources at different cycles.

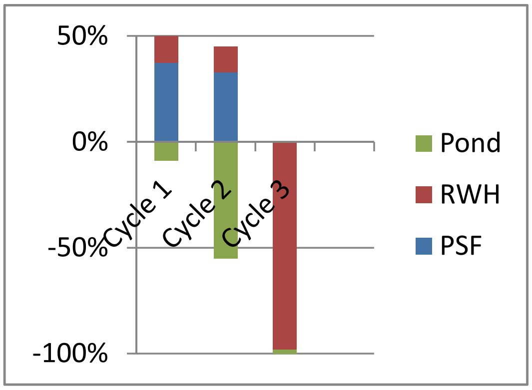

Figure 4.15: Average %Reduction of *E.coli* after filtration for different sources at different cycles.

4.7 HEALTH RISK ASSESSMENT:

The bacteriological test results of PSF, pond and RWH supplied water reveals the presence of *E.coli* in substantial numbers. These microbial indicator E. coli from test results are put into the QHRA Model (Haward et al, 2006) and hence associated disease burdens are assessed for PSF, pond and RWH water supply and compared based on their parametric concentration.

4.7.1 ASSESSMENT OF HEALTH BURDEN:

Table 4.7: Value output from QHRA Model for PSF water supply.

Compare values and results	Log additional µDALY/person•year			Additional µDALY/person•year			Comment
	95%ile	5%ile	Median	95%ile	5%ile	Median	
Scenario total burden	#NUM!	#NUM!	1.9	#NUM!	#NUM!	82.83	***Result***
Total; TTC 95% <1 GV; As 50 µg/L GV			2.4			234.43	*Compare value*
Scenario viral burden	3.4	-2.6	1.9	2,385.24	0.00	77.27	***Result***
Viral; TTC 95% <1 GV			1.7			46.99	*Compare value*
Scenario bacterial burden	4.1	-4.3	0.6	13,393.01	0.00	3.91	***Result***
Bacterial; TTC 95% <1 GV			0.4			2.27	*Compare value*
Scenario protozoal burden	2.1	-6.2	-1.7	134.38	0.00	0.02	***Result***
Protozoal; TTC 95% <1 GV			-1.9			0.01	*Compare value*
Scenario arsenical burden	#NUM!	#NUM!	0.2	#NUM!	#NUM!	1.63	***Result***
Arsenical; 10 µg/L As GV			1.5			33.46	*Compare value*
Arsenical; 50 µg/L As GV			2.3			185.17	*Compare value*
WHO 1µDPY reference GV			0.0			1.00	*Compare value*

Table 4.8: Value output from QHRA Model for pond water supply.

Compare values and results	Log additional µDALY/person•year			Additional µDALY/person•year			Comment
	95%ile	5%ile	Median	95%ile	5%ile	Median	
Scenario total burden	#NUM!	#NUM!	1.9	#NUM!	#NUM!	82.83	***Result***
Total; TTC 95% <1 GV; As 50 µg/L GV			2.4			234.43	*Compare value*
Scenario viral burden	3.4	-2.7	1.9	2,385.24	0.00	77.27	***Result***
Viral; TTC 95% <1 GV			1.7			46.99	*Compare value*
Scenario bacterial burden	4.1	-4.3	0.6	13,393.01	0.00	3.91	***Result***
Bacterial; TTC 95% <1 GV			0.4			2.27	*Compare value*
Scenario protozoal burden	2.1	-6.3	-1.7	134.72	0.00	0.02	***Result***
Protozoal; TTC 95% <1 GV			-1.9			0.01	*Compare value*
Scenario arsenical burden	#NUM!	#NUM!	0.2	#NUM!	#NUM!	1.63	***Result***
Arsenical; 10 µg/L As GV			1.5			33.46	*Compare value*
Arsenical; 50 µg/L As GV			2.3			185.17	*Compare value*
WHO 1µDPY reference GV			0.0			1.00	*Compare value*

Table 4.9: Value output from QHRA Model for RWH water supply.

Compare values and results	Log additional µDALY/person•year			Additional µDALY/person•year			Comment
	95%ile	5%ile	Median	95%ile	5%ile	Median	
Scenario total burden	#NUM!	#NUM!	1.9	#NUM!	#NUM!	82.83	***Result***
Total; TTC 95% <1 GV; As 50 µg/L GV			2.4			234.43	*Compare value*
Scenario viral burden	3.4	-2.7	1.9	2,385.24	0.00	77.27	***Result***
Viral; TTC 95% <1 GV			1.7			46.99	*Compare value*
Scenario bacterial burden	4.1	-4.3	0.6	13,393.01	0.00	3.91	***Result***
Bacterial; TTC 95% <1 GV			0.4			2.27	*Compare value*
Scenario protozoal burden	2.1	-6.3	-1.7	134.72	0.00	0.02	***Result***
Protozoal; TTC 95% <1 GV			-1.9			0.01	*Compare value*
Scenario arsenical burden	#NUM!	#NUM!	0.2	#NUM!	#NUM!	1.63	***Result***
Arsenical; 10 µg/L As GV			1.5			33.46	*Compare value*
Arsenical; 50 µg/L As GV			2.3			185.17	*Compare value*
WHO 1µDPY reference GV			0.0			1.00	*Compare value*

Table 4.10: Graphical output from QHRA Model-(PSF)

Disease Burden	Total Burden(PSF)	UCL(PSF)	MCL(PSF)	LCL(PSF)
		Log Additional µDaly/person year(DPY)		
Viral	1.9	3.4	1.9	-2.6
Bacterial		4.1	.6	-4.3
Protozoan		2.1	-1.7	-6.2

Legends: UCL- Upper confidence level, MCL- Median Confidence level,
LCL- Lower Confidence level.

The total burden due to *E.coli* is 1.9 DPY and the tolerance value is 2.4DPY. Hence the total burden due to *E.coli* in PSF water is over the tolerable range. The viral burden for *E.coli* of 95% ile with <1GV (guiding value) it varies 1.7 DPY to 3.4 DPY that is tolerable loss of healthy life per million over a year whereas the acceptable tolerance value is 1.7 DPY. Hence the viral burden due to *E.coli* in PSF water is beyond over the tolerable range. The bacterial burden for *E.coli* of 95%ile with <1GV (guiding value) is ranging from 0.4 DPY to 4.1DPY whereas the minimum tolerable limit is 0.40 DPY. Here it also appears that bacterial burden due to *E.coli* in PSF water is beyond over the tolerable range. The protozoan burden for *E.coli* of 95%ile with <1 GV (guiding value) is ranging from –1.9 DALYs to 2.1 DPY whereas the minimum tolerable limit is –1.9 DPY. Here it also appears that protozoan burden due to *E.coli* in PSF water is beyond over the tolerable range.

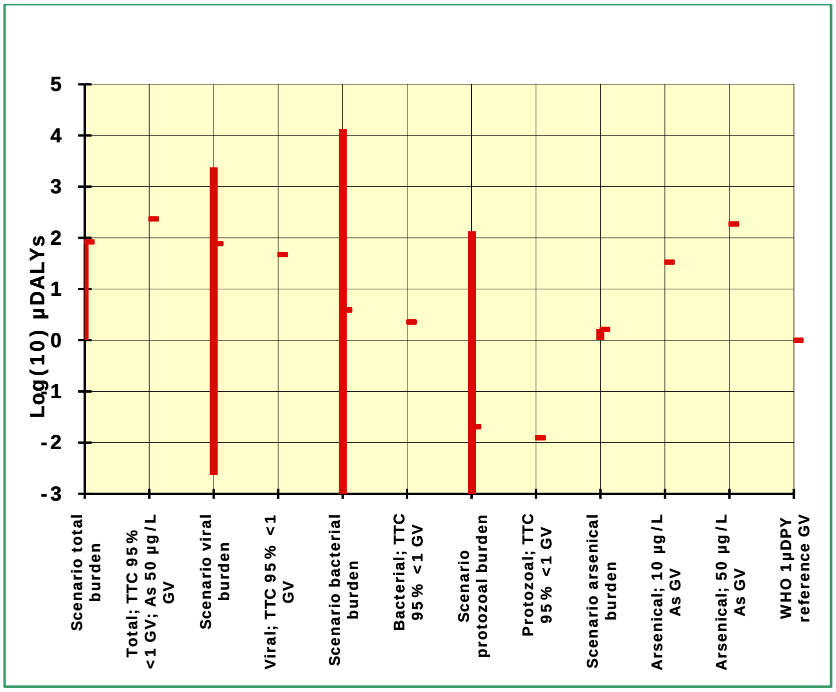

Figure 4.16: Graphical output from QHRA Model (PSF).

The total burden due to *E.coli* is 1.9 DPY and the tolerance value is 2.4DPY. Hence the total burden due to *E.coli* in pond water is over the tolerable range. The viral burden for *E.coli* of 95% ile with <1GV (guiding value) it varies 1.7 DPY to 3.4 DPY that is tolerable loss of healthy life per million over a year whereas the acceptable tolerance value is 1.7 DPY. Hence the viral burden due to *E.coli* in pond water is beyond over the tolerable range. The bacterial burden for *E.coli* of 95%ile with <1GV (guiding value) is ranging from 0.4 DPY to 4.1DPY whereas the minimum tolerable limit is 0.40 DPY. Here it also appears that bacterial burden due to *E.coli* in pond water is beyond over the tolerable range. The protozoan burden for *E.coli* of 95%ile with <1 GV (guiding value) is ranging from –1.9 DALYs to 2.1 DPY whereas the minimum tolerable limit is –1.9 DPY. Here it also appears that protozoan burden due to *E.coli* in pond water is beyond over the tolerable range.

Table 4.11: Graphical output from QHRA Model-(pond)

Disease Burden	Total Burden(pond)	UCL(pond)	MCL(pond)	LCL(pond)
		Log Additional µDaly/person year(DPY)		
Viral	1.9	3.4	1.9	-2.7
Bacterial		4.1	.6	-4.3
Protozoan		2.1	-1.7	-6.3

Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level.

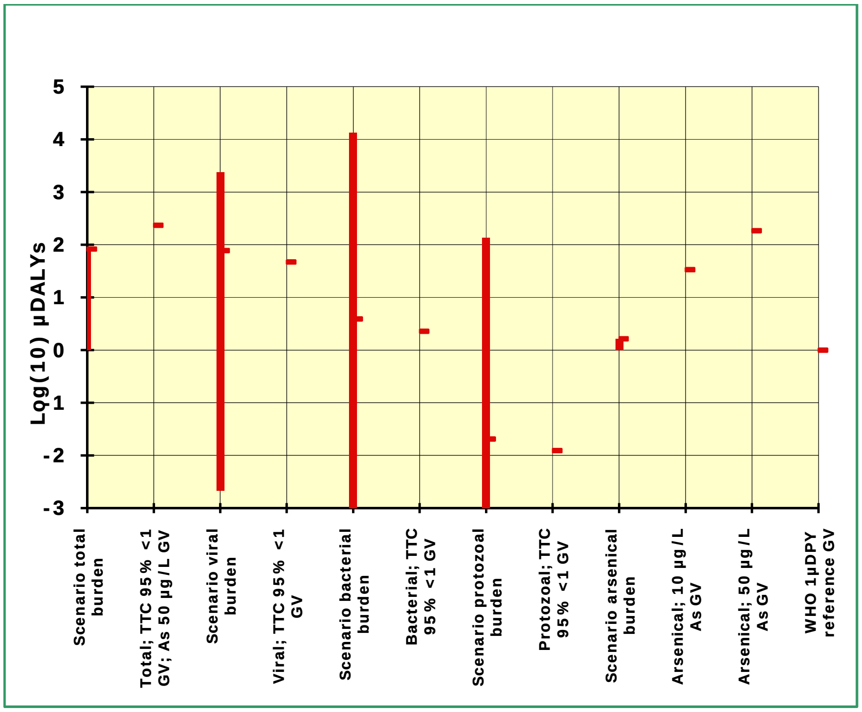

Figure 4.17: Graphical output from QHRA Model (pond)

Table 4.12: Graphical output from QHRA Model-(RWH)

Disease Burden	Total Burden(RWH)	UCL(RWH)	MCL(RWH)	LCL(RWH)
		Log Additional µDaly/person year(DPY)		
Viral	1.9	3.4	1.9	-2
Bacterial		4.1	.6	-3.6
Protozoan		2.0	-1.7	-5.6

Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level

The total burden due to *E.coli* is 1.9 DPY and the tolerance value is 2.4DPY. Hence the total burden due to *E.coli* in RWH water is over the tolerable range. The viral burden for *E.coli* of 95% ile with <1GV (guiding value) it varies 1.7 DPY to 3.4 DPY that is tolerable loss of healthy life per million over a year whereas the acceptable tolerance value is 1.7 DPY. Hence the viral burden due to *E.coli* in RWH water is beyond over the tolerable range. The bacterial burden for *E.coli* of 95%ile with <1GV (guiding value) is ranging from 0.4 DPY to 4.1DPY whereas the minimum tolerable limit is 0.40 DPY. Here it also appears that bacterial burden due to *E.coli* in RWH water is beyond over the tolerable range. The protozoan burden for *E.coli* of 95%ile with <1 GV (guiding value) is ranging from –1.9 DALYs to 2.0 DPY whereas the minimum tolerable limit is –1.9 DPY. Here it also appears that protozoan burden due to *E.coli* in RWH water is beyond the tolerable range.

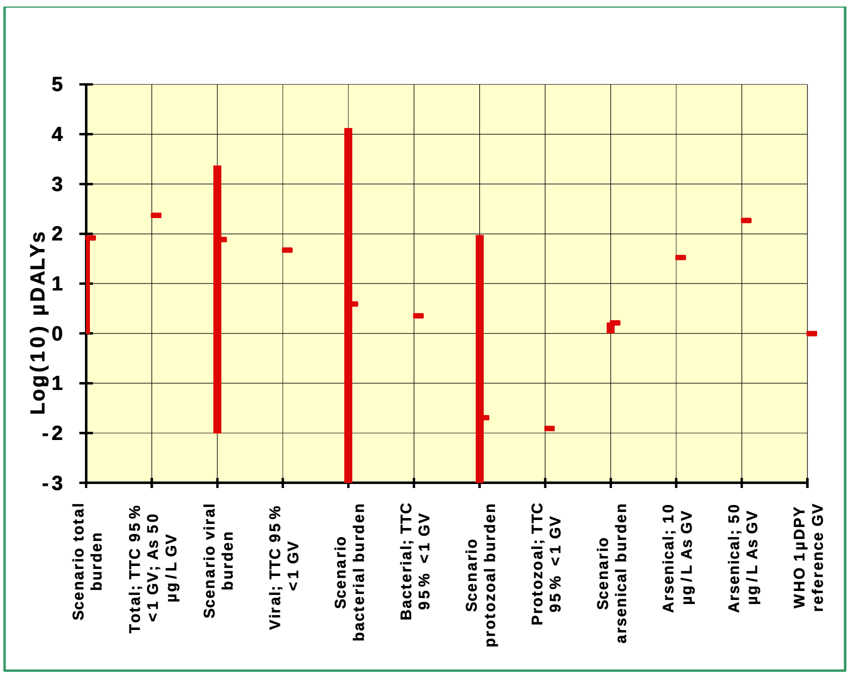

Figure 4.18: Graphical output from QHRA Model (RWH)

The above discussions indicate that the disease burdens for viral, bacterial and protozoan diseases are beyond over the tolerable range. But compare to the baseline or unfiltered condition mostly it shows a decreasing trend. The following figures provide the comparison of disease burden associated with baseline, unfiltered and filtered condition. From the figures it can also be observed that for few cases it shows negative disease burden or constant/same disease burden for baseline, unfiltered and filtered condition.

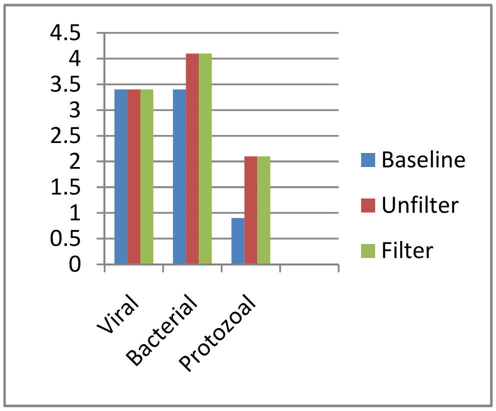

Figure 4.19: Comparison of disease burden by upper (95th percentile) for PSF water supply.

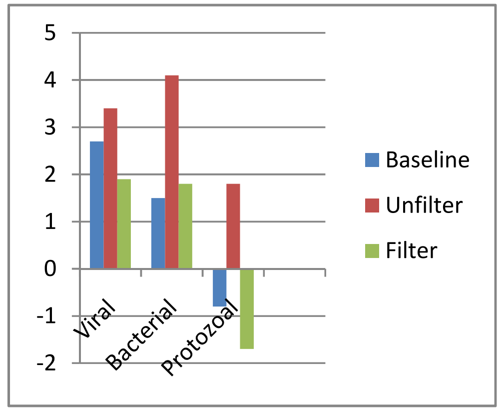

Figure 4.20: Comparison of disease burden by Median for PSF water supply.

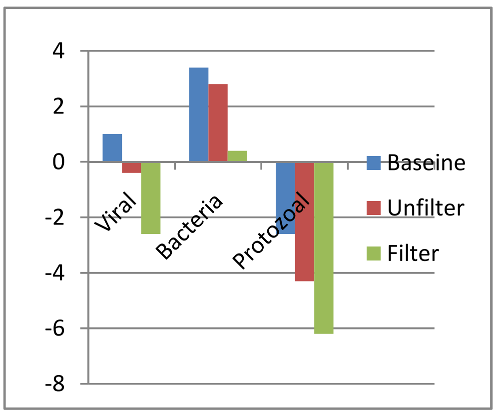

Figure 4.21: Comparison of disease burden by lower (5th Percentile) for PSF water supply

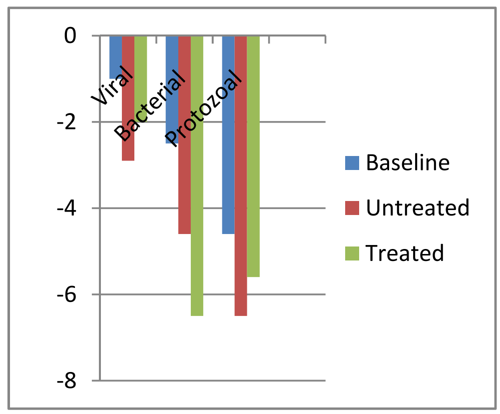

Figure 4.22: Comparison of disease burden by lower (5th Percentile) for RWH water supply

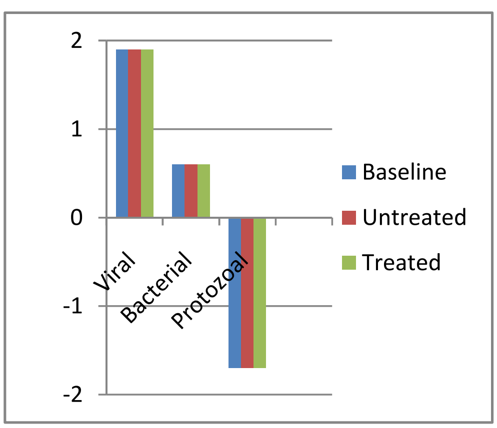

Figure 4.23: Comparison of disease burden by Median for RWH water supply .

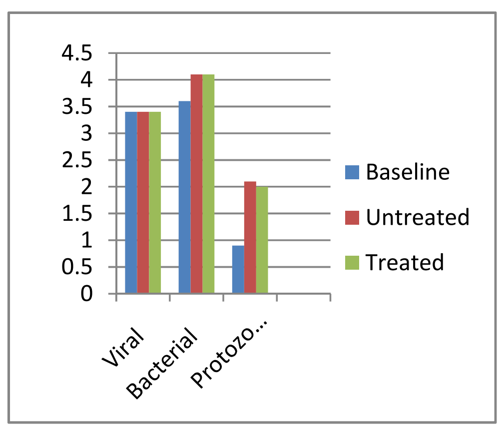

Figure 4.24: Comparison of disease burden by upper (95th percentile) for RWH water supply.

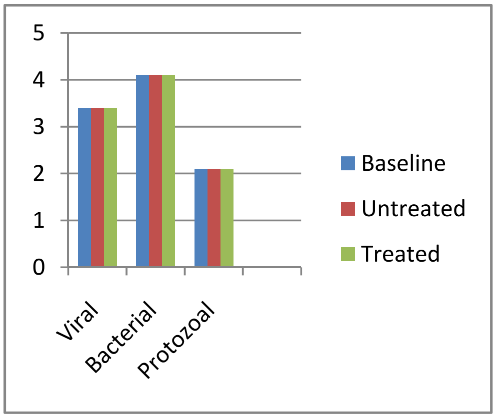

Figure 4.25: Comparison of disease burden by upper (95th percentile) for Pond water supply.

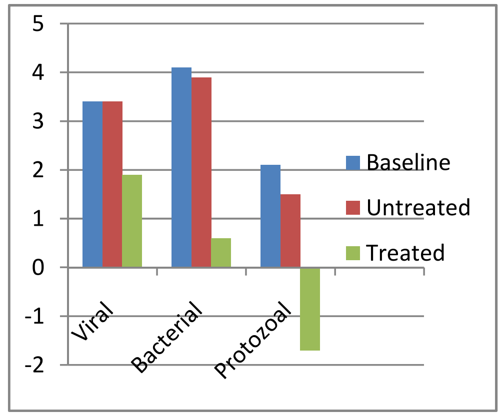

Figure 4.26: Comparison of disease burden by Median for Pond water supply.

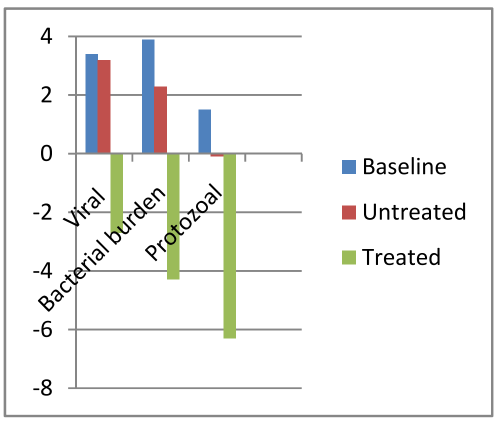

Figure 4.27: Comparison of disease burden by lower (5th Percentile) for RWH water supply

Table 4.13: Comparison of Disease Burden due to *E.coli* input

Comparison of Disease Burden **due to *E.coli* input** (in · DPY)										
Disease Burden	UCL -PSF	UCL-Pond	UCL - RWH	MCL - PSF	MCL-Pond	MCL - RWH	LCL-PSF	LCL-Pond	LCL - RWH	WHO GV - μDPY
Viral	3.4	3.4	3.4	1.9	1.9	1.9	-2.6	-2.7	-2	1.7
Bacterial	4.1	4.1	4.1	.6	.6	.6	-4.3	-4.3	-3.6	0.4
Protozoan	2.1	2.1	2	-1.7	-1.7	-1.7	-6.2	-6.3	-5.6	-1.9

Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level

This is a comparison shown among PSF, pond RWH of *E.coli* values in Log format. Comparison shows us PSF has viral concentration in 95%ile value of -2.6 to 3.4 µDPY where as pond has value of -2.7 to 3.4 µDPY and RWH has value of -2 to 3.4 µDPY which is quite same. In bacterial concentration pond, PSF, RWH has almost similar values. In protozoan concentration it is seen that a lot of them also exhibit similar values. In median value comparison all the concentrations are quite same. But the 5%ile values are quite variable. The viral concentration for RWH is -2 µDPY where as PSF has -2.6 µDPY which means RWH has only 5% values, less than -2 µDPY and PSF has also 5%ile values, less than -2.6 µDPY. We also see some negative values in 5%ile and Median values for Protozoan case.

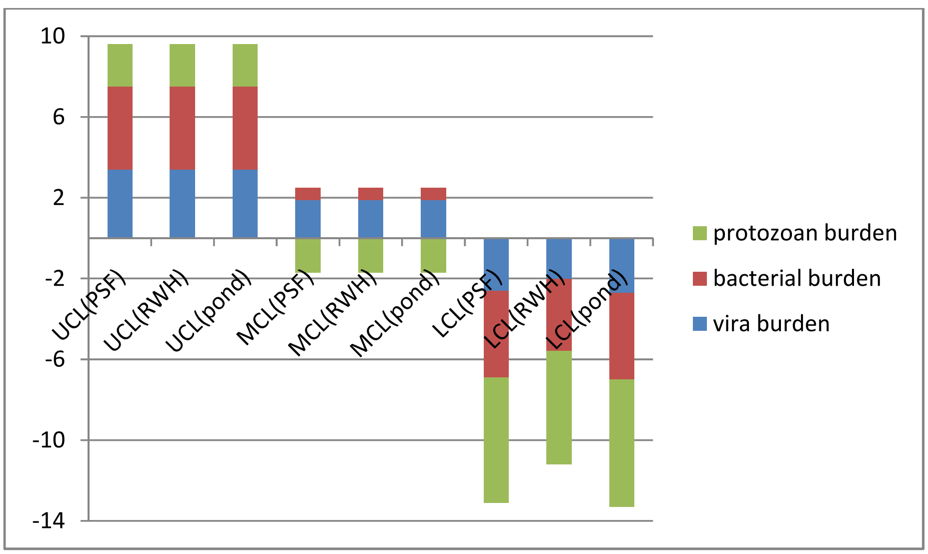

Figure 4.28: Comparison shown among PSF, pond RWH of *E.coli* values in Log format.

CHAPTER FIVE

CONCLUSION & RECOMMENDATIONS

5.1 CONCLUSION:

This study examined the prevalence of indicator and pathogenic bacteria in alternative drinking water supply options present in southwest coastal areas of Bangladesh. This study found that people from both areas suffer greatly from safe drinking water supply system. The TC, FC, *E.coli* and HPC of all different sources were significantly higher than the permissible value. An in house water supply system is needed to overcome the situation and introduce of ceramic filter is highly appreciable. Because the results from this study show a significant reduction in microbiological parameter after filtration of water. It is also observed that the filter is not consistent with its performance in removing the parameter and the rate of reduction varies for different parameter. However, it achieves a higher percentage in case of satisfying the WHO guideline compare to untreated condition. The result of third cycle shows a better reduction rate for all parameters compare to the other two cycles which is due to the seasonal variation. The reduction efficiency also varies due to variation in source and RWHS water satisfies the guideline more than the PSF and pond water. The estimated disease burden related with the currently available water supply system is much higher than the WHO recommended value which is 1 μDALY/ person-year. The disease burden was primarily predominated by bacterial and viral pathogens. Though the disease burden decrease is less in treated water than untreated water. Therefore, proper maintenance is required to get better quality of drinking water and to do so the Department of Public Health and Engineering and other working NGOs should provide adequate information and training to the coastal communities to let them understand the operation and maintenance of the ceramic filter.

5.2 RECOMMENDATIONS:

Based on this study the following points may be considered for improving future analysis:

- When data is collected about samples in a particular area, water quality parameter may be studied /measured at the nearest location that provides required lab facilities to obtain more reliable result.

- Detailed information may be collected on the location and distance of the sources to household, so that this information might be used to correlate the contamination as a function of distance and travel time.
- Seasonal variation could have been carried out.
- A survey could have been carried out to get the feedback of the users.
- The change in bacterial growth could have been observed in terms of pH.

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APPENDIX A: TC, FC, *E.coli*, HPC values of rain water source

ID.	T.C.(c.f.u./100ml)	F.C.(c.f.u./100ml)	*E.coli*(c.f.u./100ml)	HPC(c.f.u./10ml)
R1	1000	200	500	2500
R2	0	0	0	157000
R3	0	0	0	106000
R4	20	0	0	5000
R5	360	50	0	94000
R6	0	0	0	73000
R10	0	0	0	172000
R11	10	0	0	117000
R13	30	0	0	77000
R14	130	80	0	111000
9	0	0	0	3000
10	400	150	140	1230000
11	0	0	0	2970000
13	700	570	0	2500000
14	0	0	0	126000

APPENDIX B: TC, FC, *E.coli*, HPC values of PSF water source

ID.	T.C.(c.f.u./100ml)	F.C.(c.f.u./100ml)	*E.coli*(c.f.u./100ml)	HPC(c.f.u./10ml)
5	22	3	0	1720000
6	30	24	0	2590000
7	150	61	100	2450000
8	27	22	2	2650000
15	200	46	100	2540000
16	20	10	5	1660000

APPENDIX C: TC, FC, *E.coli*, HPC values of pond water source

ID.	T.C.(c.f.u./100ml)	F.C.(c.f.u./100ml)	*E.coli* (c.f.u./100ml)	HPC(c.f.u./10ml)
P2	60000	350	20000	2010000
P3	5000	420	140	1600000
P4	60000	250	4000	1170000
P5	15000	940	19000	1860000
P6	40000	290	14000	2050000
P7	20000	180	15000	1910000
P8	110000	47000	20000	1440000
P9	12000	1000	7000	1390000
P10	10000	60	7000	1700000
P11	25000	26000	11000	1130000
P12	15000	330	8000	1830000
P13	240000	103000	25000	1440000
P14	30000	uncountable	50000	2120000
P15	120000	67000	30000	1190000
1	5000	910	3000	1470000
2	28000	17000	9000	1410000
3	62000	10000	20000	1600000
4	140	120	10	3040000

APPENDIX D: TC values of 1st, 2nd and 3rd cycle for untreated & treated water sample and the %reduction rate after treatment.

	Unfiltered	Filtered	%Removal	Unfiltered	Filtered	%Removal	Unfiltered	Filtered	%Removal
D1	270000	120	99.96	900	700	22.22	1000	0	100.00
D2	50000	30000	40.00	400	70	82.50	3000	1000	66.67
D3	40000	30000	25.00	58	15	74.14	23000	500	97.83
D4	10000	15000	-50.00	40	33	17.50	300	0	100.00
D5	350	290	17.14	6500	0	100.00	22000	0	100.00
D6	900000	7000	99.22	2900	1400	51.72	43000	0	100.00
D7	11000	3000	72.73	700	20	97.14	178	0	100.00
D8	13000	2000	84.62	110	0	100.00	200	0	100.00
D9	10000	200	98.00	18000	3000	83.33	200	0	100.00
D10	48000	7000	85.42	5800	4	99.93	1200	300	75.00
D11	31000	4000	87.10	33000	4	99.99	0	0	100.00
D12	4000	70	98.25	5800	17	99.71	3000	0	100.00
D13	1300	70	94.62	3000	1900	36.67	100	10	90.00
D14	120	0	100.00	800	100	87.50	300	0	100.00
D15	0	0	100.00	400	100	75.00	100	0	100.00
D16	0	0	100.00	13	0	100.00	0	0	100.00
D17	210	170	19.05	45	4	91.11	1300	0	100.00
D18	520	50	90.38	100	0	100.00	500	0	100.00
D19	3000	300	90.00	2700	300	88.89	100	0	100.00
D20	2000	350	82.50				100	300	-200.00
D21	6000	2000	66.67	300	100	66.67	4000	400	90.00
D22	230	0	100.00	115	78	32.17	1000	0	100.00
D23	410	20	95.12	9	25	-177.78	0	0	100.00
D24	990	780	21.21	98	10	89.80	1700	0	100.00
D25	130000	840	99.35	75	0	100.00	5800	0	100.00
D27	52000	41000	21.15	800	15	98.13	100	0	100.00
D28							0	0	100.00
D29	500	300	40.00	1000	500	50.00			
D30	5000	50	99.00				4800	2100	56.25
D31	75000	12000	84.00	3100	334	89.23	0	0	100.00
D32	29000	18000	37.93						
D33	9000	24000	-166.67	1400	600	57.14	1100	0	100.00
D34	1000	100	90.00	100	56	44.00	5000	0	100.00
D35	63000	10000	84.13	11200	10	99.91	8500	100	98.82
D36	30000	31000	-3.33	500	0	100.00	400	200	50.00
D37	7000	14000	-100.00	400	33	91.75	2800	1500	46.43
D38	14000	40	99.71	100	47	53.00	6500	100	98.46

M1	480	350	27.08	920	380	58.70	1900	0	100.00
M2	160	260	-62.50	1550	250	83.87	1600	1700	-6.25
M3	14000	3000	78.57	460	570	-23.91	1300	100	92.31
M4	1000	10	99.00	640	64	90.00	0	0	100.00
M5	40	10	75.00	2000	0	100.00	0	0	100.00
M6	60000	14000	76.67	960	700	27.08	6000	2700	55.00
M7	200	50	75.00	4000	10	99.75	0	0	100.00
M8	2000	330	83.50	5200	290	94.42	7000	0	100.00
M9	200	0	100.00	510	30	94.12			
M10	20000	1320	93.40	410	130	68.29	2200	0	100.00
M11	1000	0	100.00	25000	1360	94.56	900	0	100.00
M12	14000	260	98.14	4000	720	82.00	2400	0	100.00
M13	170	0	100.00	350	0	100.00	3400	0	100.00
M14	350	0	100.00	4200	0	100.00	400	0	100.00
M15	1410	120	91.49	760	70	90.79	1000	770	23.00
M16	240	650	-170.83	120	0	100.00	3300	0	100.00
M18				30	10	66.67	0	0	100.00
M19	60	50	16.67	450	0	100.00	8400	1000	88.10
M20	21000	1000	95.24	330	0	100.00	5100	0	100.00
M21	61000	250	99.59	1000	420	58.00			
M22	820	0	100.00	440	0	100.00	300	30	90.00
M23	136000	120	99.91	220	140	36.36	8000	0	100.00
M24	720	0	100.00	160	0	100.00	3500	0	100.00
M25	900	590	34.44	390	0	100.00	400	0	100.00
M26	135000	180	99.87	13000	5000	61.54	1400	700	50.00
M27	19000		100.00	260	40	84.62	3500	400	88.57
M28	10	0	100.00	650	220	66.15	5200	0	100.00
M29	1140	110	90.35	30000	17000	43.33	2000	0	100.00
M30	6000	320	94.67	400	40	90.00	1800	600	66.67
M31	2720	690	74.63	790	90	88.61	15000	0	100.00
M32	87000	680	99.22	5000	70	98.60			
M33	621000	272000	56.20	16000	3300	79.38	4500	800	82.22
M34	550	400	27.27	0	0	100.00	3200	0	100.00
M35	7360	570	92.26	20000	370	98.15	5800	330	94.31

APPENDIX E: *E.coli* values of 1st, 2nd and 3rd cycle for untreated & treated water sample and the %reduction rate after treatment.

	Unfiltered	Filtered	% reduction	Unfiltered	Filtered	% reduction	Unfiltered	Filtered	% reduction
D1	49000	0	100.00	100	0	100.00	0	0	100.00
D2	21000	7000	66.67	32	0	100.00	0	0	100.00
D3	20000	0	100.00	0	0	100.00	25	0	100.00
D4	10000	1000	90.00	1000	300	70.00	200	0	100.00
D5	0	0	100.00	400	0	100.00	9000	0	100.00
D6	470000	1000	99.79	100	0	100.00	100	0	100.00
D7	2000	0	100.00	76	2	97.37	1900	0	100.00
D8	2000	1000	50.00	0	0	100.00	0	0	100.00
D9	3000	80	97.33	9400	1400	85.11	300	0	100.00
D10	9000	1000	88.89	5700	0	100.00	200	0	100.00
D11	10000	0	100.00	7000	0	100.00	200	0	100.00
D12	620	0	100.00	100	0	100.00	2400	0	100.00
D13	0	0	100.00	1500	1100	26.67	0	0	100.00
D14	50	0	100.00	40	100	-150.00	0	0	100.00
D15	0	0	100.00	0	0	100.00	0	0	100.00
D16	0	0	100.00	0	0	100.00	0	0	100.00
D17	0	0	100.00	0	0	100.00	0	0	100.00
D18	1000	0	100.00	100	25	75.00	0	0	100.00
D19	2000	0	100.00				0	0	100.00
D20	0	0	100.00	400	100	75.00	0	0	100.00
D21	2600	1000	61.54	0	0	100.00	100	100	0.00
D22	30	0	100.00	0	0	100.00	700	175	75.00
D23	310	20	93.55	0	0	100.00	0	0	100.00
D24	190	100	47.37	800	0	100.00	100	0	100.00
D25	0	0	100.00	19	0	100.00	100	0	100.00
D27	0	0	100.00	1200	0	100.00	100	0	100.00
D28							0	0	100.00
D29	1000	1000	0.00	2300	500	78.26			
D30	0	0	100.00				5600	1500	73.21
D31	40000	8000	80.00	5200	0	100.00	7000	15000	-114.29
D32	28000	10000	64.29						
D33	5000	1300	74.00	1200	500	58.33	30000	0	100.00
D34	0	0	100.00	200	0	100.00	0	0	100.00
D35	900	150	83.33	600	0	100.00	4000	0	100.00

D36	21000	2000	90.48	0	0	100.00	200	0	100.00
D37	3000	1400	53.33	1	0	100.00	0	0	100.00
D38	60	10	83.33	100	100	0.00	98000	13000	86.73
M1	0	0	100.00	3000	250	91.67	1800	0	100.00
M2	20	0	100.00	30	0	100.00	1000	0	100.00
M3	6000	0	100.00	0	0	100.00	200	100	50.00
M4	4000	0	100.00	0	0	100.00	0	0	100.00
M5	0	0	100.00	0	0	100.00	0	0	100.00
M6	29000	0	100.00	0	0	100.00	2500	800	68.00
M7	0	0	100.00	4000	1000	75.00	0	0	100.00
M8	2000	0	100.00	4200	5700	-35.71	8900	200	97.75
M9	100	220	-120.00	0	0	100.00			
M10	1300	320	75.38	1000	175	82.50	200	0	100.00
M11	21000	9000	57.14	2700	0	100.00	700	0	100.00
M12	8000	0	100.00	7000	2000	71.43	700	0	100.00
M13	0	0	100.00	160	0	100.00	0	0	100.00
M14	3000	0	100.00	7000	0	100.00	100	100	0.00
M15	24000	0	100.00	1400	0	100.00	8000	1000	87.50
M16	80	200	-150.00	50	0	100.00	100	0	100.00
M18				0	0	100.00	0	0	100.00
M19	10	0	100.00	0	0	100.00	5800	0	100.00
M20	31000	20	99.94	20	0	100.00	2900	0	100.00
M21	25000	0	100.00	10	0	100.00			
M22	30	0	100.00	4000	0	100.00	400	800	-100.00
M23	5000	0	100.00	19000	0	100.00	0	0	100.00
M24	36000	0	100.00	10	0	100.00	4400	0	100.00
M25	37000	2000	94.59	0	0	100.00	1000	0	100.00
M26	15000	0	100.00	27000	2000	92.59	2800	600	78.57
M27	80		100.00	230	0	100.00	1700	0	100.00
M28	0	0	100.00	9000	0	100.00	2700	6	99.78
M29	13000	2700	79.23	13000	1400	89.23	3200	500	84.38
M30	4000	0	100.00	3000	0	100.00	0	0	100.00
M31	0	0	100.00	1000	40	96.00	300	700	-133.33
M32	0	0	100.00	40	100	-150.00			
M33	1200	560	53.33	32000	6000	81.25	3100	1100	64.52
M34	480	0	100.00	450	1000	-122.22	180	500	-177.78
M35	85000	50	99.94	9000	0	100.00	2300	100	95.65

APPENDIX F: HPC values of 1st, 2nd and 3rd cycle for untreated & treated water sample and the %reduction rate after treatment.

ID									
	Unfiltered	Filtered	% Removal	Unfiltered	Filtered	% Removal	Unfiltered	Filtered	% Removal
D1	112	0	100	262	169	35.4961	50.8	17	66.5354
D2	42	58	-38.09	179	NA		8	40.8	-410
D3	11	39	-254.54	364	620	-70.32	29.8	57	-91.27
D4	49	69	-40.8163	624		100	144	18	87.5
D5	20	12	40	710	218	69.295	37	16	56.7567
D6	41	38	7.31707	148	140	5.4054	19	41.2	-116.84
D7	119	62	47.8991	8490	4680	44.876	55	3	94.545
D8	133	110	17.2932	5900	4860	17.627	11	118	-972.7
D9	112	75	33.0357	11100	8410	24.234	62	436	-603.22
D10	88	70	20.4545	8710	9500	-9.0703	151	251	-66.221
D11	130	104	20	5460	11340	-107.62	163	1872	-1048.4
D12	98	88	10.2040	7270	3120	57.0839	40	1	97.5
D13	90	68	24.4444	8040	4380	45.5223	33	3	90.9090
D14	17	115	-576.470	540	165	69.4444	15	13	13.3333
D15	36	64	-77.7777	227	107	52.8634	87	1	98.8505
D16	25	26	-4	402	242	39.8009	23	20	13.0434
D17	82	27	67.0731	332	216	34.9397	21	8	61.9047
D18	46	74	-60.8695	389	312	19.7943	36	13	63.8888
D19	72	42	41.6666				14.3	22.1	-54.544
D20	89	47	47.1910	382	50	86.9109	3	13	-333.33
D21	57	31	45.6140	415	164	60.4819	76	6	92.1052
D22	92	22	76.0869	268	262	2.23880	6	15	-150
D23	53	59	-11.3207	150	163	-8.6666	192	5.5	97.1354
D24	560	588	-5	6850	3800	44.5255	185	310	-67.575
D25	366	656	-79.2349	5130	6750	-31.579	2	6	-200
D27	516	392	24.03100	18360	8240	55.1198	4	1	75
D28							9	7	22.2222
D29	385	918	-138.441	13080	4410	66.2844			
D30	140	82	41.4285				384	240	37.5
D31	100	98	2	4380	6250	-42.640	117	270	-130.79
D32	158	134	15.1898						
D33	150	58	61.3333	1120	1190	-6.25	0	1260	

D34	61	37	39.34426	217	164	24.4239	16	2	87.5
D35	15	48	-220	153	217	-41.800	30.1	30	0.33222
D36	170	112	34.1176	222	144	35.1351	43	41	4.65116
D37	27	61	-125.925	242	217	10.3305	8	32	-300
D38	62	52	16.1290	20640	9400	54.4573	10	10	0
M1	195	200	-2.56410	1788	1395	21.9798	100	288	-188
M2	512	217	57.6171	2400	1034	56.9166	255	4	98.4313
M3	347	470	-35.4466	1221	480	60.6879	169	0	100
M4	366	216	40.9836	1207	1092	9.52775	56	65	-16.074
M5	221	108	51.1312	1352	959	29.0680		200	
M6	99	119	-20.2020	1480	972	34.3243	92	40	56.5217
M7	403	107	73.4491	1626	1026	36.9003	7	91	-1200
M8	343	124	63.8483	877	1233	-40.529		45	
M9	107	254	-137.383	1590	890	44.0251			
M10	448	352	21.4285	1353	1173	13.3037	2	0	100
M11	87	399	-358.620	1446	1020	29.4605	158	136	13.9240
M12	273	338	-23.8095	960	1062	-10.625	98	83	15.3061
M13	448	124	72.3214	912	1160	-27.199	114	95	16.6666
M14	278	448	-61.1510	612	1880	-207.18	15	5	66.6666
M15	380	313	17.6315	945	994	-5.1858	10	2	80
M16	425	104	75.5294	2239	1287	42.5189	105	4	96.1904
M18				1846	1482		18	8	55.5555
M19	315	227	27.9365	1125	2084	-85.244	35	1	97.1428
M20	194	105	45.8762	624	800	-28.251	5	103	-1960
M21	152	711	-367.763	1344	1546	-15.027			
M22	623	532	14.6067	1289	990	23.1962	1054	1	99.9051
M23	381	407	-6.82414	1794	830	53.7346	2	3	-50
M24	714	426	40.3361	1300	1187	8.69230	27	2	92.5925
M25	310	520	-67.7419	1160	1472	-26.895	59	62	-5.0474
M26	57	54	5.46737	1495	1112	25.6187	145	110	24.1379
M27	21	17	20.4761	1215	763	37.2016	51	46	9.80392
M28	136	43	68.0442	1810	702	61.2154	39		100
M29	27	33	-18.6131	852	1269	-48.436	84	260	-209.52
M30	30	26	13.8047	1230	946	23.0894	255	600	-135.2
M31	683	504	26.2079	3684	1224	66.7752	29	0	100
M32	476	457	3.99159	1136	840	26.0563			
M33	371	792	-113.477	2705	1504	44.3992	30	3	90
M34	442	612	-38.4615	1584	918	42.0454	24	2	91.6666
M35	396	496	-25.2525	770	1390	-80.519	675	3	99.5555

APPENDIX G: Percent removal for PSF water samples after treatment collected in cycle 1.

	TC	*E.coli*	FC	HPC
	% removal	% removal	% removal	% Removal
D5	17.142857		-300	40
D6	99.222222	99.787234	98.951049	7.3170732
D21	66.666667	61.538462	100	45.614035
D30	99		100	41.428571
D31	84	80	86.046512	2
D32	37.931034	64.285714	-33.33333	15.189873
D33	-166.6667	-160	-233.3333	61.333333
D35	84.126984		99.931818	-220
				#DIV/0!
M22	100	100	100	14.606742
M23	99.911765	100	100	-6.824147
M24	100	100	100	40.336134
M31	-2436.765		-445.4545	26.207906
M32	99.218391		-1.923077	3.9915966

APPENDIX H: Percent removal for PSF water samples after treatment collected in cycle 2.

	TC	*E.coli*	FC	HPC
	% Removal	% Removal	% Removal	% removal
D24	89.795918	100	80.555556	44.525547
D25	100	100	62.5	-31.57895
D27	98.125	100	89.795918	55.119826
D29	50	78.26087	100	66.284404
D35	99.910714	100	88.235294	-41.83007
M22	100	100	100	23.196276
M23	36.363636	100	100	53.734671
M24		100	100	8.6923077

APPENDIX I: Percent removal for PSF water samples after treatment collected in cycle 3.

	TC	*E.coli*	FC	HPC
	%removal	%removal	%removal	%removal
D31		-114.2857		-130.7692
D34	100			87.5
D35	98.823529	100	98.360656	0.3322259

APPENDIX J: Percent removal for Pond water samples after treatment collected in cycle 1.

	TC	*E.coli*	FC	HPC
I. D.	% Removal	% removal	% removal	% removal
D1	99.955556	100	99.875	100
D2	40	66.666667	83.6	-38.09524
D3	25		-20	-254.5455
D4	-50	-900	-352	-40.81633
D7	72.727273	100	81.651376	47.89916
D9	98	97.333333	98	33.035714
D11	87.096774	100	75.111111	20
D12	98.25	100	100	10.204082
D27	21.153846			24.031008
D29	-500	0	100	-138.4416
D36	-3.333333	90.47619	-126	34.117647
D37	-100	-366.6667	66.666667	-125.9259
M1	27.083333			-2.564103
M6	76.666667	100	65.384615	-20.20202
M15	91.489362	100	100	17.631579
M26	99.866667	100	100	5.4673721
M27	100	100	100	20.47619
M28				68.04428
M29	-864.9123	-107.6923	-197.4359	-18.61314
M30	94.666667	100	100	13.804714

APPENDIX K: Percent removal for Pond water samples after treatment collected in cycle 2.

	TC	*E.coli*	FC	HPC
ID	% removal	% removal	% removal	% removal
D1	22.222222		28.571429	35.496183
D2	-75		45	
D3	74.137931		-333.3333	-70.32967
D4	17.5	70	70.454545	100
D5	100	100		69.295775
D9	83.333333	85.106383	73.786408	24.234234
D11	99.987879	100	100	-107.6923
M2	-520	100	0	56.916667
M15	-985.7143		100	-5.185185
M27	84.615385	100	90.47619	37.201646
M29	43.333333	-7.692308	-1.960784	-48.94366
M30	-9900	100		23.089431
M31	88.607595	96	83.333333	66.775244
M32	98.6	-2400	30.769231	26.056338

APPENDIX L: Percent removal for Pond water samples after treatment collected in cycle 3.

	TC	*E.coli*	FC	HPC
ID	% removal	%removal	%removal	%removal
D3	97.826087			-91.27517
D9	100			-603.2258
M2	-6.25		28.571429	98.431373
M6	55	68		56.521739
M12	100	100	100	15.306122
M15	-670	-700	-3950	80
M16	100	100	44.444444	96.190476
M 20	100	100	100	-1960
M22	0	-1900		99.905123
M23	100		100	-50
M29	100	84.375	-257.1429	-209.5238
M30	66.666667			-135.2941

APPENDIX M: Percent removal for RWHS water samples after treatment collected in cycle 1.

	TC	*E.coli*	FC	HPC
ID	%removal	%removal	%removal	%removal
D8	84.615385	50	97.166667	100
D10	85.416667	88.888889	96.774194	100
D13	94.615385			100
D14	100	100	71.428571	100
D15				100
D16				100
D17	19.047619			100
D18	-861.5385		-1066.667	
D19	0	100	-200	100
D20	82.5		100	-4900
D22				100
D23	95.121951	93.548387		100
D24	21.212121	47.368421	12.987013	100
D25	99.353846		97.637795	100
D34	0			-2400
D38	99.714286	83.333333	100	100
				100
M2	-62.5	100	100	100
M3	78.571429	100	98	-22400
M4	99	100	100	-4900
M5	75			100
M7	75		50	100
M8	83.5	100	8.3333333	100
M9				100
M10	93.4	75.384615	100	100
M11	100	-133.3333	-1447.619	-2400
M12	98.142857	100	100	-2400
M13				100
M14	100	100	-33.33333	100
M16	-170.8333		-250	100
M19	16.666667	100	50	100
M20	95.238095	99.935484	99.052632	100
M21	99.590164	100	100	100
M25	34.444444	94.594595	-3500	100
M33	56.199678		100	-2400
M34	-7172.727		72	-2400
M35	92.255435	99.941176	-81.48148	-79900

APPENDIX N: Percent removal for RWHS water samples after treatment collected in cycle 2.

	TC	*E.coli*	FC	HPC
ID	%removal	%removal	%removal	%removal
D6	51.724138	100	99.588235	5.4054054
D7	97.142857	97.368421	96.385542	44.876325
D8	100		100	17.627119
D10	99.931034	100	95.16129	-9.070034
D12	99.706897	100	99.896552	57.083906
D13	36.666667	26.666667	-181.25	45.522388
D14	87.5		37.5	69.444444
D15	75		-20	52.863436
D16			-550	39.800995
D17	-1025		-1750	34.939759
D18			-100	19.794344
D20	-800	-300	-7841.176	86.910995
D21	-200		0	60.481928
D22	32.173913		-51.11111	2.238806
D23	-177.7778		100	-8.666667
M1	58.695652		-5.882353	21.979866
M3	-23.91304		-61.53846	60.687961
M4	0		81.25	9.5277548
M5	100			29.068047
M6	27.083333		33.333333	34.324324
M7	99.975	75	93.939394	36.900369
M8	44.230769	-35.71429	21.367521	-40.59293
M9	94.117647		100	44.025157
M10	68.292683		81.132075	13.303769
M11	94.56	100		29.460581
M12	82	71.428571		-10.625
M13	100	100	100	-27.19298
M14	100	100	100	-207.1895
M16	100	100	65.306122	42.518982
M18	66.666667			19.71831
M19	100		100	-85.24444
M20	100	100	100	-28.20513
M21	58	100	100	-15.02976
M25	100		100	-26.89655
M26	61.538462	92.592593	37.704918	25.618729
M28	66.153846	100	100	61.21547
M33	-106.25	-433.3333	11.320755	44.399261
M34				42.045455
M35	98.15	100	3.4482759	-80.51948

APPENDIX O: Percent removal for RWHS water samples after treatment collected in cycle 3.

	TC	*E.coli*	FC	HPC
ID	%removal	%removal	%removal	%removal
D1	100			66.535433
D2	-200		77.777778	-410
D4	100	100		87.5
D5	100	100		56.756757
D6	100	100	100	-116.8421
D7	100	100	100	94.545455
D8				-972.7273
D10	75	100	100	-66.22517
D11				-1048.466
D12	100	100	100	97.5
D13	0		-800	90.909091
D14				13.333333
D15	100			98.850575
D16				13.043478
D17	100		100	61.904762
D18	100			63.888889
D19	100			-54.54545
D20	-200		0	-333.3333
D21	90	0		92.105263
D22				-150
D23			100	97.135417
D24	100	100		-67.56757
D25	100	100	100	-200
D27	100	100		75
D28				22.222222
D34	100			87.5
D36	50	100		4.6511628
D37	46.428571			-300
D38	98.461538	86.734694	15.789474	0