Installation of Simple Water Treatment Unit at Cyclone-Aila Affected Koyra Region and Assessment of DALYs Lost due to Diarrhoea

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A thesis submitted to the Department of Civil Engineering of Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in partial fulfillment of the requirements for the degree of

"Master of Science in Civil Engineering"

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DECLARATION

This is to certify that the thesis work entitled “Installation of Simple Water Treatment Unit at Cyclone-Aila Affected Koyra Region and Assessment of DALYs Lost due to Diarrhoea” has been carried out by Md. Farid Munnaf, in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Approval

This is to certify that the thesis work submitted by Md. Farid Munnaf entitled ‘Installation of Simple Water Treatment Unit at Cyclone-Aila Affected Koyra Region and Assessment of DALYs Lost due to Diarrhoea’ has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh on 10th November, 2016.

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ABSTRACT

The South-western coastal region of Bangladesh is composed of Satkhira, Khulna, Bagerhat and parts of Jessore districts. On 25 May 2009, the 'Cyclone Aila' occured into the south-western coastal region where Khulna and Satkhira districts were severely affected. Aila devastated all the drinking water sources and caused destruction of sanitation facilities. In this context, till recent time, many people are compelled to drink such polluted water without any sort of purification and consequently suffer from water borne diseases such as diarrhea, cholera, allergy, and skin disease. Diarrhoeal disease is one of the leading causes of morbidity and mortality in developing countries, especially among children under the age of five. However, water borne diseases can be reduced by improving water quality and preventing casual use of other unimproved sources of water. For instance, simple filtration and disinfection of water at the household level dramatically improves the microbial quality of water, and reduces the risk of diarrheal disease at low cost. Scarcity of safe drinking water is a great phenomenon in Koyra and Kaligonj coastal region. The Disable Adjusted Life Years (DALYs) is a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in health states less than ideal health. DALY is an indicator of Burden of Disease (BoD) in a population. This study aims at investigating the existing drinking water quality, sanitation and hygiene practices in "Cyclone Aila" affected areas and installation of simple household water treatment unit and awareness development for improved sanitation and hygiene practices and finally assessment of improvement in DALYs lost with the adopted intervention. In the study areas, microbiological water qualities in various sources were found to be varied in the range of 8-360 N/100mL as Faecal Coliform. Field survey on toilet facilities in the study area identified that there were 61.64% simple pit latrines, 29.06% pour flush latrines and remaining 9.31% inhabitants had no toilet facilities in Koyra and Kaligonj coastal region. At the commencement of this study, it was found that 8.26% population had been using soap, 13.74% using ash and remains percent using others materials such as soil and only water for hand washing after defecation. However, an awareness development campaign on hygiene practice was undertaken in this research work and with this initiative the use of soap and ash for hand washing after defecation was found to be increased slightly to 12.26% and 16.84%, respectively and about 44% use of soil as hand washing after defecation. In the study area, total disable adjusted life years (DALY) was found to be 0.042 for three months before the installation of water treatment unit. A simple water treatment unit or household filter was developed and installed at five locations of the study area. The efficiency of bacteria removal through these filter units were found to be around 98%. In this case, total disable adjusted life years (DALY) was found to be decreased significantly to 0.01 for three months' time period after the satisfactory efficiency of water treatment units as well as consciousness development about improved sanitation and hygiene practices. Overall, improvement in DALYs lost was found to be 74.1% with facilitating safe drinking water, improved sanitation and hygiene practices.

LIST OF ABBREVIATIONS

DALYs	Disability Adjusted Life Years
WHO	World Health Organization
UNICEF	United Nation Integrated Children Emergency Fund
HWTS	Household Water Treatment & Safe Storage
PSF	Pond Sand Filter
CWF	Ceramic Water Filter
WSP	Water Source Point
WSH	Water, Sanitation & Hygiene
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
YLL	Years of Life Lost
YLD	Years Lived with Disability
MDG	Millennium Development Goal
LGM	Last Glacial Maximum
LMICs	Low and Middle Income Countries
DoE	Department of Environment
DPHE	Department of Public Health Engineering
BGS	Bangladesh Geological Survey
DO	Dissolve Oxygen
IG	Infiltration Gallery
BBS	Bangladesh Bureau of Statistics
SSF	Slow Sand Filter
WASA	Water Supply & Sewerage Authority
LGED	Local Government of Engineering Department
BADC	Bangladesh Agricultural Development Corporation
WGO	World Gastroenterology Organization
NTU	Nephelometric Turbidity Units
UN	United Nation

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Chapter 1

Introduction

1.1 General

The Disability Adjusted Life Years (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death (WHO, 2002). Various diseases people suffering from put different amount of disease-burden on population. The Burden of disease (BoD) as the burden that a particular disease process has in a particular area as measured by cost, morbidity, and mortality. DALY is an indicator of BoD in a population. It takes into account not only premature mortality, but also disability caused by disease or injury. In so doing, mortality and morbidity are combined into a single, common metric. Waterborne diseases are caused by ingestion of contaminated water from pathogens contained in human or animal excreta. It represents a major burden on human health worldwide (WHO, 2007). At present, as basic infrastructure for wide surveillance of water sources is unavailable, a household water management approach appears to be the most attractive short term intervention (Fewtrell *et al.*, 2005 & Mintz *et al.*, 2001). Scarcity of safe water is causing death of about 50 hundred thousand people each year as to different types of water borne diseases and migration of people from their place of habitation. Economic and agricultural development is also impeded and environment and ecosystem are effected as to lack of fresh water. Water resource of the world is abundant but most of it is not useable for human need. Only 2.5% of the total volume of water of the globe is fresh, of which 68.9% is present at the state of ice and frozen rivers, 0.009% are found at the lake and river and 28% is reserved in underground aquifers. Of 2.5% fresh water, 23% is used in industries, 69% in agriculture, 8% in domestic purposes and 0.025% could be used for drinking. This inadequate volume of safe drinking water is getting polluted as to human activities and natural processes. It is getting polluted in different regions as to different reasons, such as, the presence of arsenic, nitrate, and fluoride in water, salinity, disposal of industrial and other waste in the water bodies and use of fertilizer and pesticide. In this contest, it could be noted that as of United Nation, by 2025, more than 2.8 billion people of 48 countries will face scarcity of safe drinking water and by 2050, 54 countries with 4 billion people will encounter same problem (Uttaran & Water Committee, 2006). The global statistics are simply horrific: at the end of 2000, there were around 1.1 billion people (18% of the world's population) without adequate water and 2.4 billion people (40%) without adequate sanitation (WHO, 2000). In 2004, 83% of the world's population had some form of improved water supply, while 59% (3.8 billion) had access to basic sanitation facilities (WHO, 2004). Improved drinking-water sources include piped water to the house or yard, public taps or standpipes, boreholes, protected dug wells, protected springs and rainwater collection. Improved sanitation facilities include flush or pour-flush toilets connected to a piped sewer system, septic tanks or pit latrines, and composting toilets. Inadequate sanitation, hygiene or accesses to water increase the incidence of diarrhoeal diseases. The highest proportion of deaths and DALYs, as well as the highest absolute numbers, occur in countries with high mortality patterns, such as in Africa and parts of South-East Asia. Most diarrhoeal deaths in the world (88%) are caused by unsafe water, sanitation or hygiene. Overall, more than 99% of these deaths are in developing countries, and around 84% of them occur in children. Diarrhoeal disease is one of the leading causes of morbidity and mortality in developing countries, especially among children under the age of five (Pruss *et al.*, 2002). In the developed world, too, it would appear from estimates of the Global Burden of Disease that complacency should be avoided, with 139,000 Disability Adjusted Life Years (DALYs) attributed to water, sanitation and hygiene in established market economies (Pruss *et al.*, 2002). Provision of safe drinking water and the effective removal of bodily waste are vital for human health and well-being (Watson, 2006). Unfortunately about 3.4 million people die each year from different illnesses such as cholera, dysentery, and malaria associated with contaminated water (Watson, 2006). However, the most serious health impact of waterborne diseases is diarrhea, particularly on children. While diarrhea occurs all over the world, certain regions of the globe are especially affected by this disease. Beyond discomfort, embarrassment, or interruption, diarrheal diseases affect millions of people every year and have serious consequences. Diarrhea is caused by a variety of known and emerging infectious organisms, such as viruses, bacteria, protozoa and helminthes, which are transmitted from the stool of one individual to the mouth of another. It is estimated that there are 2.5 billion cases of diarrhea every year, mostly among children under five, and that this results in 1.5 million child deaths every year (UNICEF, 2006). A large number of studies have investigated the impact of water supply and sanitation interventions on child health worldwide (Jalan and Ravallion, 2003). Using DALYs, diarrheal diseases were responsible for a total of 72,777,000 years lost in 2004, compared to 33,976,000 years lost due to malarial (WHO, 2004). The high rate of incidence of diarrheal disease and infant mortality in developing countries are attributed to lack of water supply and sanitation. A comprehensive review conducted by Waddington *et al.*, (2009) on the impact of water, hygiene, and sanitation interventions on diarrhea morbidity highlighted the fact that water quality is more important than water supply in reducing diarrhea. Additionally, the authors found sanitation facilities to be as effective as hygiene in reducing diarrhea morbidity. According to World Health Organization (WHO) estimates for 2004, over 46% of deaths in Africa, almost 38% in South Asia, 9% were caused by diarrheal diseases. Comparing this to 7% in rest of the world during that same timeframe, it is clear that diarrheal diseases have huge impact in developing parts of the world (WHO, 2004). Household water treatment and safe storage (HWTS) interventions are proven to both improve water quality and reduce disease incidence in developing countries (Lantagne, 2007). According to the World Health Organization (WHO), diarrhea claims 5000 lives every day throughout the world.

In Bangladesh, one third of the total child death burden is due to diarrhea. Every year, a rural child suffers on average from 4.6 episodes of diarrhea, from which about 230,000 children die. Acute diarrhoeal diseases are the major causes of infant morbidity and mortality, where 1 in 10 children die before their fifth birthday in Bangladesh (Petri *et al.*, 2000).The South-western coastal region of Bangladesh is composed of Satkhira, Khulna, Bagerhat and parts of Jessore districts. The people of this region are facing severest difficulties in accessing safe drinking water. Water supply and sanitation in Bangladesh is characterized by a number of achievements and challenges.On 25 May 2009, the ‘Cyclone Aila’ hit into the south-west coastal region where Khulna and Satkhira district were severely affected. Since then, about half of the affected people living in that area have their lands and homesteads under water (Uttaran, 2009). Many people in this area have been suffering miserably since the devastating cyclone hit the region as safe drinking water is not easily available. DALYs lost by diarrhea seems to be correlated with the safe water supply as well as sanitation facilities, and its difference among the communities of different social status (Mollah and Aramaki, 2009). However, water borne diseases can be reduced by improving water quality and preventing casual use of other unimproved sources of water (Gleick, 1999). For instance, simple filtration and disinfection of water at the household level dramatically improves the microbial quality of water, and reduces the risk of diarrheal disease at low cost (WHO, 2005).

1.2 Rationale of the study

Cyclone Aila hit the south-western coast of Bangladesh on 25 May 2009. The people of the Aila affected area received the highest amount of sufferings from drinking water shortage and destruction of sanitation facilities soon after Aila had attacked. However, the affected people are still suffering from shortage of pure drinking water. Aila devastated all the drinking water sources (ponds, PSF and tube wells). During Aila, high tidal surges contaminated all fresh water sources with polluted saline water. Many people are compelled to drink such polluted water as they do not have any other option and consequently suffer from water borne diseases such as allergy, skin disease, cholera and diarrhea. Supply of drinking water has now become the most striking challenge for the affected area (Kumar and Masud, 2010). The study (Haque *et al.*, 2010) has revealed that all the households use rain water as primary source and 77.14% households use sweet pond water as secondary source for drinking and cooking purposes. The commonly used of drinking water options in coastal area are low cost technologies such as shallow and deep tube well, rainwater harvesting system, protected pond of sweet water, pond sand filter. Deep and shallow tube wells are easy to use, cost effective and highly accepted by users. But Most of tube wells are affected by saline and/or arsenic. Rainwater harvesting may be a probable alternative solutions. But seasonal variation in rainfall pattern, proper storage of rainwater and public acceptances are some of the issues that need to be adequately addressed. Insufficient numbers of ponds in where sweet water is available but bacteriological contamination are great problem. Sweet water protected ponds needs to be treated with alum or boiled causes of bacteriological contamination to improve water quality as the embankments of the ponds needs constant monitoring to make necessary repairing. Although PSF has very high bacterial removal efficiency, it may not remove 100% of the pathogens from heavily contaminated surface water. The problems encountered are low discharge and difficulties in washing the filter beds. Due to inundation of safe water sources people have to go adjacent unaffected areas that vary from less than 1 km to more than 1.5 km. (Kumar and Masud, 2010). But most of the time it will damage and/or inefficient due to scarcity of proper maintenance.

Sometime they have to need waiting to collect this safer water. “Simple water treatment unit” has been taken to find out a probable solution in this regard. Studies in Cambodia have shown that use of ceramic filters has led to a reduction in diarrheal disease by 50% (Brown and Sobsey, 2007). Household Water Treatment and Safe storage (HWTS) systems are proven, low-cost interventions that have the potential to provide safe water to those who will not have access to safe water sources in the near term, and thus significantly reduce morbidity due to waterborne diseases and improve the quality of life. A study (Mwabi *et al.*, 2013) in Africa showed that ceramic filter as household water treatment efficiency of bacteria removal 90 to100%. Studies in Cambodia have shown that use of ceramic filters has led to a reduction in diarrheal disease by 50% (Brown and Sobsey, 2007). Ceramic water filters are one point-of-use water treatment technology that is effective in reducing bacterial contamination in water and reducing the risk for diarrhea (Clasen *et al.*, 2004). Frequently coated or impregnated with silver for its antibacterial properties, ceramic water filters are considered by some to be, “one of the most promising and accessible technologies for treating water at the household level” (Clasen *et al.*, 2004). The water treatment mechanism of the ceramic water filter (CWF) is a product of gravity filtration and disinfection with colloidal silver (Oyanedel-Craver, 2007; Lantagne, 2001; Van Halem, 2006). Filtration removes contaminants from water through sorption and screening. Sorption is the settling of particles onto the filter surface while screening is the prevention of particle movement through the filter pores due to size restrictions. With time and continual use, the pores of the filter diminish in size due to clogging and therefore become more efficient in retaining particulates from the water (van Halem, 2006). Pore size and void space is determined by the dimensions of the combustible materials used in the production of the filter. As water passes through the CWF it is disinfected with colloidal silver. Silver acts as an antimicrobial agent by interacting with the nucleic acids of bacteria, creating structural changes to the cell membrane and interacting with the Thiel groups of the cell. Research has shown that CWFs with colloidal silver are more effective in removing bacteria from contaminated water sources than CWFs without (Oyanedel-Craver, 2007; Lantagne, 2001). Impregnating the filter through immersion in a colloidal silver solution rather than painting it is more effective in removing bacteria (Oyanedel- Craver, 2007). Also, the addition of silver to the CWF does not seem to affect the filtration flow rate (Lantagne, 2001). No tests to date have discovered effluent levels of silver from the CWF to exceed the WHO or EPA standard of 0.1 mg/L (Lantagne, 2001) (Oyanedel-

Craver, 2007). A study commissioned by UNICEF and water source point (WSP) -Cambodia in 2001 suggest that filters may be used longer and more effectively by households when other water, sanitation, and hygiene (WSH) interventions are bundled with the CWP; that access to replacement filters and spare parts is key to ensuring long-term success of CWP programs; and that cost recovery is positively associated with continued use. Success of this study might significantly contribute towards finding out a sustainable solution of water treatment as household at low cost in coastal areas of Bangladesh if sweet surface water source is available.

1.3 Objectives of the study

The main objectives of this study are outlined as below-

i. Investigation of the existing drinking water quality, sanitation and hygiene practices in the “Cyclone Aila” affected Mothbari village of Koyra upazila;
ii. Determination of DALYs lost due to Diarrhoea in the community people of the study area;
iii. Development and installation of a simple household type water treatment unit for safe drinking water and awareness development for improved sanitation and hygiene practices;
iv. Assessment of the improvement in DALYs lost with the adopted intervention and proposal for sustainable development.

1.4 Scope of the study

Water parameters tests were carried out to determine the efficiency of ceramic candle of simple water treatment unit for effective removal of pH, turbidity, color, total coliform, fecal coliform with sufficient flow rate. Also Hardness, Alkalinity, BOD evaluates satisfying Bangladesh Standards from surface water through simple water treatment unit at the field level through 5 (five) simple water treatment unit at household without using any chemicals. Household hygiene practice was the major concern to develop water quality. The operation and maintenance problems of simple water treatment unit at the field level were assessed through long term monitoring and also by field questionnaire survey regarding the user opinion. The present study was tried to find out disability adjusted life years (DALYs) pre and post installation of simple water treatment unit in coastal areas of Bangladesh and expressed development of DALYs.

1.5 Organization of the thesis

Apart from this chapter, the remainder of the thesis has been divided into four chapters:

Chapter 2 presents literature review concerning Water supply, sanitation & hygiene condition in world, Diarrhoeal disease, Causes of diarrhoea, Global statistics of diarrhoeal disease and DALYs lost, Switching from surface water to underground water in Bangladesh, Geology and hydrogeology of Bangladesh, Water quality in coastal zone of Bangladesh, Causes of lack of safe drinking water in coastal zone of Bangladesh, Effect of lack of safe drinking water in coastal zone of Bangladesh, Water supply of coastal zone of Bangladesh, Sanitation situation in coastal zone of Bangladesh, Distance of water sources and collection status in coastal zone of Bangladesh, Washing status in Coastal zone of Bangladesh, Water supply options in Bangladesh are also discussed in this chapter.

Chapter 3 briefly reviews the methodologies of this thesis paper concerning the associated the processes of simple water treatment unit at household level and installation of field, laboratory model test. The laboratory experimental set up and determination of variable parameters, study area and DALYs calculation are also focused in this chapter.

Chapter 4 represents the detail laboratory analysis and test results that had been carried out through simple water treatment unit at household level to determine pH, Colour, Turbidity, Hardness, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total and fecal coliform, Salinity, Alkalinity, DALYs calculation before and after water treatment installation and DALYs improvement etc.

Chapter 5 major conclusions of the study have been cited. Recommendations for future study are also provided here.

Chapter 2

Literature Review

2.1. General

Terms like ‘water crisis’ and a ‘water-short’ world are now in common usage, but we actually live in a ‘water-desperate’ world. Many of us who live in industrialized countries are ‘water rich’, but there are many millions of us in developing countries who are ‘water poor’ and, in fact, ‘water desperate’. The global statistics are simply horrific: at the end of 2000, there were around 1.1 billion people (18% of the world’s population) without adequate water and 2.4 billion people (40%) without adequate sanitation (WHO, 2000). Although access to safe drinking water is a fundamental human right (Watson, 2006) and providing such a facility is also an important national goal in Bangladesh like other developing countries (Hoque *et al.*, 2004), ironically many populations in both urban and rural areas of Bangladesh have been facing difficulties in getting such a quality water. Bangladesh has a plenty of surface and underground water (Safiullah, 2006) because it is mostly a flat deltaic land formed by the motor action of the great Himalayan Rivers the Ganges, Brahmaputra and Meghna (Safiullah, 2006). Unfortunately, both surface and underground water is highly contaminated in Bangladesh and poses a great challenge to the nation particularly from the public health point of view. Water-borne diseases namely diarrhoea and cholera are still the major killers of infant and child mortality in this populous nation consisting of approximately 145 million populations living in 145,000 square kilometers only.

2.2 Global condition of the water supply, sanitation and hygiene

Nearly one billion people in this world are currently relying on unimproved water sources for drinking and for other domestic activities. These sources can include unprotected wells, ponds and rivers. Even where water sources are considered to be improved, the water may not meet the microbiological standards set by WHO (UN, 2009). Household water treatment is more effective at preventing diarrhea than interventions at the water source (Fewtrell *et al.*, 2005). The use of facilities for sanitation is an important measure to reduce the spread of diarrheal illness, second only to hand washing. Currently, an overwhelming 1.2 billion people, or 18% of the world population, practice open defecation. This action, practiced by nearly half of the population in Southern Asia and more than 25% of people living in Sub-Saharan Africa (SSA), puts an individual’s own health at risk, as well as the health of family, neighbors, and the entire community. Open defecation in fields used for farming can directly contaminate food supplies and enter water supplies. Hand washing after defecation and after cleaning up a child’s feces is a particularly important measure at the individual level to reduce spread of pathogens. Hand washing with soap is most effective, reducing diarrheal illness by 42–47% (Curtis and Caimcross, 2003). When soap is not available, a local material like ashes can be substituted.

Table 2.1 Estimated use of drinking-water sources in LMICs, 2012 (proportion of total population)

		Piped water on premises			Other improved sources			Unimproved sources		
Region ↓	Filtering / boiling in household →	Without	With	Total	Without	With	Total	Without	With	Total
Sub-Saharan Africa		0.16	0.03	0.19	0.36	0.04	0.4	0.38	0.04	0.42
Americas		0.58	0.30	0.88	0.05	0.01	0.06	0.05	0.01	0.6
Eastern Mediterranean		0.54	0.04	0.58	0.25	0.01	0.26	0.15	0.01	0.16
Europe		0.54	0.27	0.81	0.10	0.05	0.15	0.03	0.02	0.05
South-east Asia		0.16	0.09	0.25	0.48	0.14	0.62	0.09	0.04	0.13
Western Pacific		0.31	0.35	0.66	0.13	0.14	0.27	0.04	0.04	0.08
Total		0.31	0.18	0.49	0.27	0.09	0.36	0.12	0.03	0.15

Sources: WHO (2014) Preventing Diarrhoea through better water, sanitation and hygiene.

Table 2.2 Estimated use of improved sanitation facilities in LMICs, 2012 (proportion of total population)

WHO Region	Use of improved sanitation facility
Sub-Saharan Africa	0.35
Americas	0.83
Eastern Mediterranean	0.68
Europe	0.87
South-east Asia	0.47
Western Pacific	0.64
Total	0.58

Sources: WHO (2014) Preventing Diarrhoea through better water, sanitation and hygiene.

Table 2.3 Mean prevalence of hand washing with soap by region, 2012

WHO Region	Prevalence of Hand washing (%)	
	Low & Middle income countries	High income countries
Sub-Saharan Africa	14	No data
Americas	16	49
Eastern Mediterranean	14	44
Europe	15	44
South-east Asia	17	No data
Western Pacific	16	43
World	19	

Sources: WHO (2014) Preventing Diarrhoea through better water, sanitation and hygiene.

Srilanka

In 2004, 79% of the population in Srilanka had access to an improved water source and 91% had access to improved sanitation (WHO, 2004). About 1000 people deaths and disable adjusted life years (DALYs) 2% of total population were in 2004 (Pruss Ustun *et al.*, 2008).

Nepal

Over the past decade, human access to drinking water has been gradually increasing. Overall water coverage in Nepal is reported to be 82%, which reflects a 9% increase in the five-year period from 2001 to 2006 (MOHP, 2007). This suggests an average growth in water coverage of 1.8% per annum. However, the National Demographic Health Survey (NDHS) reports that the proportion of people who spend over 15 minutes a day fetching water is 34%. This is similar to Water Aid in Nepal's (WAN) estimate done in 2004. WAN contends that water coverage is 48%, if a reasonable water fetching time (15 minutes) is factored into the calculation. However, it cannot be assumed that this 48% have access to safe water. The proportion of people who consume water without household treatment (e.g., boiling) is as low as 15% (Water Aid, 2008). Access to sanitation is also gradually increasing, but at a lower rate than access to water. Sanitation coverage (latrinisation) has reached 46% in Nepal. This figure includes shared latrine facilities. The number of households with an individual family latrine stands at 36% (Water Aid, 2008). Latrine sharing is more common in urban settlements than in rural (urban 34% and rural 8%) and is most widespread in slum and squatter dwellings.

India

In 2008, 88% of the population in India had access to an improved water source, but only 31% had access to improved sanitation. In rural areas, where 72% of India’s population lives, the respective shares are 84% for water and only 21% for sanitation. In urban areas, 96% had access to an improved water source and 54% to improved sanitation. Access has improved substantially since 1990 when it was estimated to stand at 72% for water and 18% for sanitation (UNICEF/WHO, 2008). In 2010, the UN estimated based on Indian statistics that 626 million people practice open defecation (UNICEF/WHO, 2012).

Afghanistan

Access to an improved water source in Afghanistan is among the lowest in the world. According to a National Risk and Vulnerability Survey, only 42% of rural dwellers had access to an improved water source as of 2010. About three quarters of Afghans live in rural areas. In urban areas, an estimated 78% had access to an improved water source (WHO/UNICEF, 2010). Access to an improved water source does not mean that the water is safe to drink. For example, protected shallow wells in urban areas are often contaminated with bacteria. Piped water supply can also be contaminated. Households without access to an improved source take water from streams and rivers, open wells and unprotected springs, all of which are also often polluted. In rural areas women and girls walk long distances to fetch water. In 2004 the mortality rate of children under 5 was as high as 25%. Half of these deaths were caused by water-borne diseases (WB, 2010).

Bangladesh

(The world we want & Global water partnership South Asia, 2013)

The water supply coverage was 78% in 1990-1 and (Millennium Development Goal) MDG target as fixed by GOB is 89% by 2015. The proportion of population using an improved drinking water source is at present 81%, out of which, the rural water supply is 80% and the urban water supply is 85% (WHO-UNICEF JMP Report, 2012). The above figures include the piped water supply in rural area to be 1% and the urban area 20% and the national average to be 6%. A disparity exists in rural water supply coverage depending on the depth of ground water table. The coverage in the high-water table area is 98% and in the low ground water table area 64%. In arsenic affected area, the water supply coverage is 36% and in the hard to reach area is 24%. The proportion of population using an improved sanitation facility is at present 56%, whereas in 1990-1, it was 39% and MDG target as fixed by GOB is 70% by 2015. Out of which, the rural sanitation coverage is 80% and the urban sanitation coverage is 83%. (WHO-UNICEF JMP Report, 2012). In city corporation areas and municipalities, the basic sanitation coverage is average 87% and the improved sanitation coverage is 53-60%. However, only 12% of slum population has hygienic sanitation. The conventional sewerage is absent in all urban areas except in Dhaka. The sanitation coverage by hygienic means is often quoted as 85% (Sewerage 20%, septic tanks 45%, water-sealed pit latrine 20%) and by unhygienic means 15%. The actual sanitation coverage is by hygienic means is 42% (Sewerage 7%, septic tanks 20%, water-sealed pit latrine 15%) and by unhygienic means 58%.

2.3 Diarrhoeal diseases

Diarrhoea is defined as having loose or watery stools at least three times per day, or more frequently than normal for an individual. Though most episodes of childhood diarrhoea are mild, acute cases can lead to significant fluid loss and dehydration, which may result in death or other severe consequences if fluids are not replaced at the first sign of diarrhea (UNICEF/ WHO, 2009).

Episodes of diarrheoa can be classified in to three categories (WGO, 2002)-

- ✓ Acute diarrhea- presence of three or more loose, watery stools within 24 hours.
- ✓ Dysentery- Bloody diarrheoa, visible blood and mucous present.
- ✓ Persistent diarrheoa- Episodes of diarrhea lasting more than 14 days.

2.3.1 Causes of diarrhoea

Diarrhoea is a common symptom of gastrointestinal infections caused by a wide range of pathogens, including bacteria, viruses and protozoa. However, just a handful of organisms are responsible for most acute cases of childhood diarrhea. Rotavirus is the leading cause of acute diarrhoea, and is responsible for about 40 percent of all hospital admissions due to diarrhoea among children under five worldwide according to Weekly Epidemiological Record, 2008.

2.3.2 Global statistics of the diarrhoea and DALYs lost

According to the WHO's Global burden of diseases of worldwide in 2004 there were approximately 2 million deaths from diarrhea related to water and sanitation in which 95,000 deaths in Latin America and the Caribbean were from causes related to water and sanitation. More of half of these deaths were from diarrhoea.

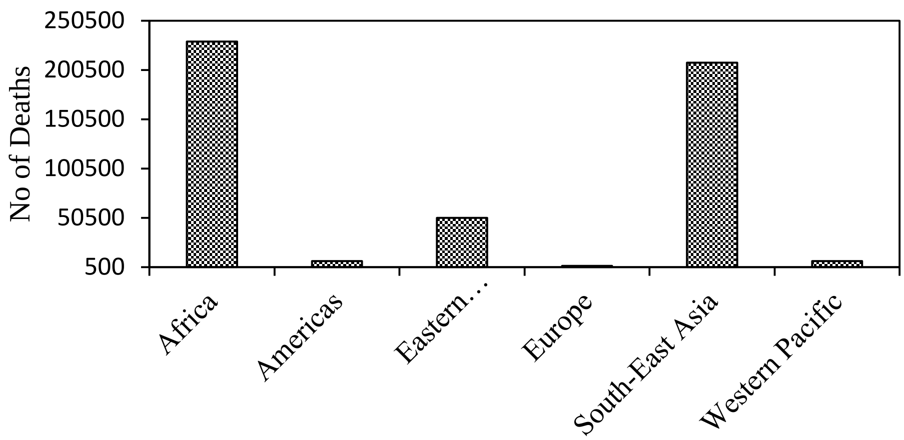


Figure 2.1 Deaths from inadequate drinking-water in LMICs by region, 2012

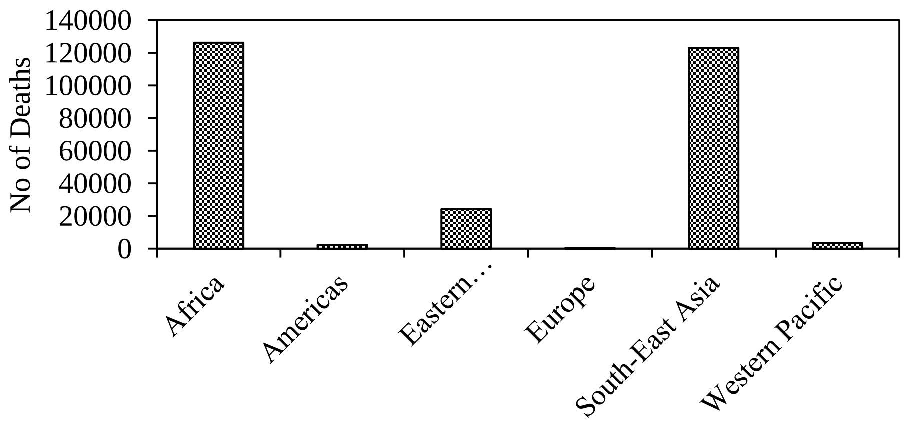
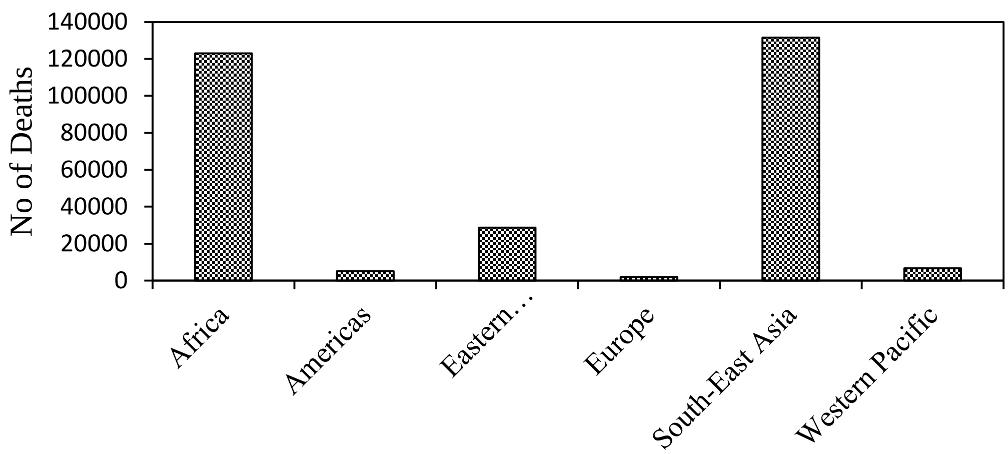
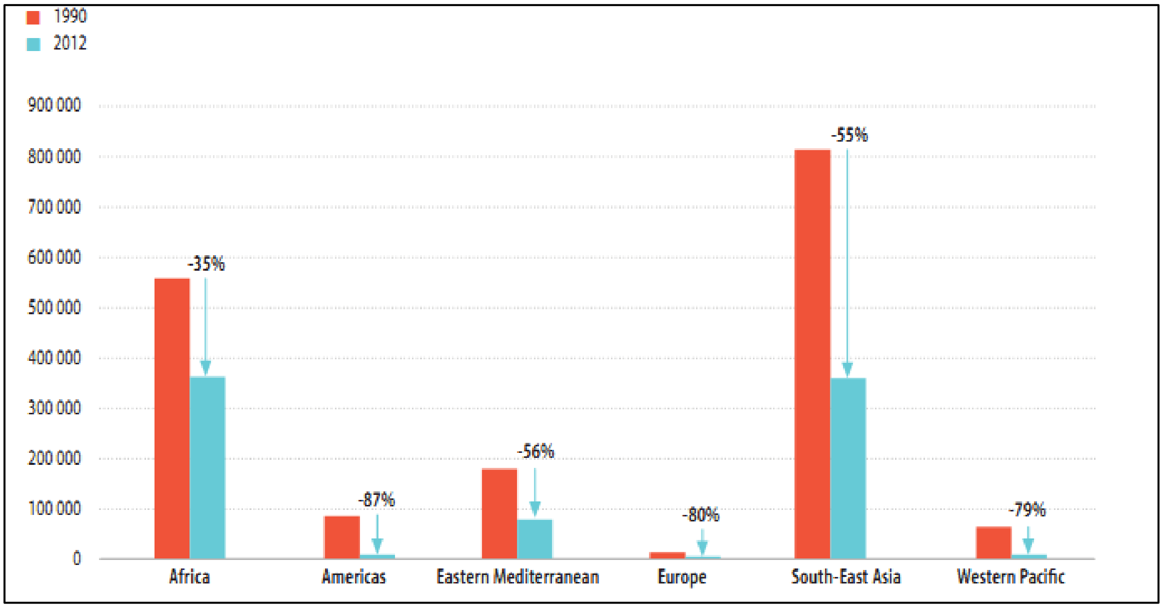


Figure 2.2 Deaths from inadequate sanitation in LMICs by region, 2012



Sources: WHO, 2014 Preventing Diarrhoea through better water, sanitation and hygiene.

Figure 2.3 Deaths from inadequate hand washing practices in LMICs by region, 2012



Sources: WHO (2014) Preventing Diarrhoea through better water, sanitation and hygiene.

Figure 2.4 Decline in diarrhoea deaths attributable to inadequate WASH in LMICs in 1990 and 2012

Table 2.4 Diarrhoea burden attributable to inadequate water, sanitation and hand hygiene for the year 2012

Region	DALYs due to		
	Water	Sanitation	Hand Hygiene
Sub-Saharan Africa	17587	9694	9411
Americas (LMI)	522	188	416
Eastern Mediterranean (LMI)	4046	1914	2314
Europe (LMI)	174	36	202
South-east Asia	10748	6376	6857
Western Pacific (LMI)	716	444	758

Sources: WHO (2014) Preventing Diarrhoea through better water, sanitation and hygiene.

Each year, an estimated 2.5 billion cases of diarrhoea occur among children under five years of age, and estimates suggest that overall incidence has remained relatively stable over the past two decades (Boschi, 2009). Childhood diarrhoea was in South Asia about 783 million within 38% death and Africa 696 million within 46% death in the year of 2004 (WHO, 2007).

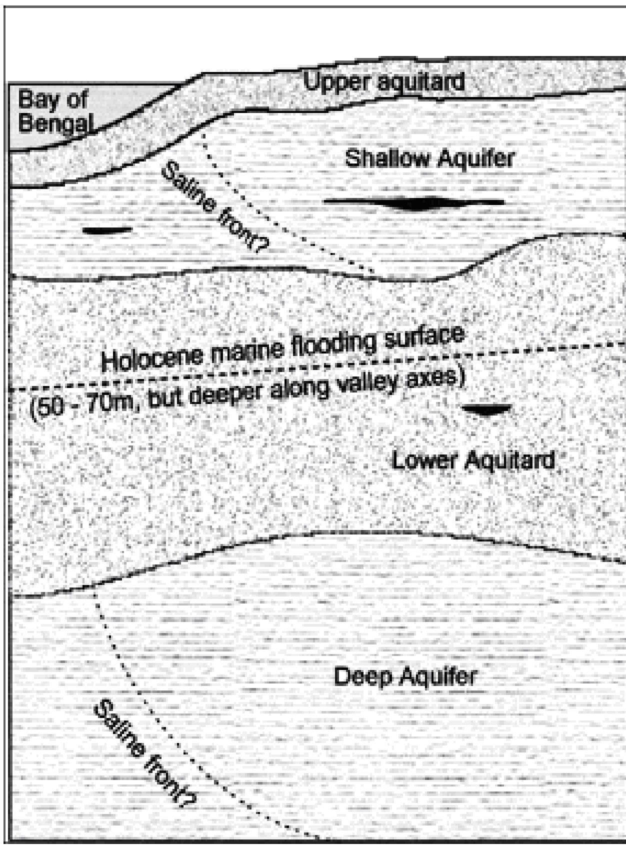
2.4 Switching from surface water to underground water in Bangladesh

Until around the 1970s, people of Bangladesh used to surface water for drinking and cooking purposes. As that water was highly polluted by many sources including micro-organisms, both infant and child mortality was very high, mostly attributed to water-borne diseases such as diarrhoea, cholera, and dysentery (Spallholz *et al.*, 2004 and Caldwell *et al.*, 2003). To reduce the incidence of such diseases including childhood mortality, in 1971 the World Bank and United Nations Children's Fund (UNICEF) began addressing the problem of surface water contamination and motivating people to sink tube wells into the underlying aquifers of Bangladesh which were free from microorganisms causing water-borne diseases (Jones, 2007 and Spallholz *et al.*, 2004). Initially it was difficult to bring a change in their usual habits of using surface water. Therefore, extensive technical, social, financial and motivational efforts at local and international levels were also given to turn them from the surface water to underground water practice (Hoque *et al.*, 2000). Due to these endeavors, people started to drill tube wells into underground aquifers to have microbiologically clean water (Spallholz *et al.*, 2004). Presently at least 10 million tube wells are functioning and about 97% of the rural population is using pathogen-free underground water (Caldwell *et al.*, 2003). The depth of the tubewell varies, although most of the tubewells use shallow aquifers. People adopted this option because underground water has obvious advantages over surface water often contaminated by micro-organisms (MacDonald, 2003). This option is also very popular because most of the families irrespective of socio-economic status can afford the cost. The tubewell save time and it easy to maintain. According to recommendation of the World Health Organization (WHO), the maximum permissible level of arsenic in drinking water is 0.05mg/L in Bangladesh, although for many other countries this limit is 0.01 mg/L (Khan *et al.*, 2007). Based on the present guideline, drinking water is contaminated by arsenic if water contains this element more than 0.05 mg/L. The contamination spreads very quickly all over the country since its first identification in 1993 and presently 61 districts out of 64 (except hilly regions) are affected by excessive level of arsenic in groundwater (Khan *et al.*, 2006 and Khan *et al.*, 2003). This trend may suffer from detection bias, because it was not unlikely that the underground water was contaminated before 1993 but not detected through an investigation. Since 2000, nearly 5 million tube wells were tested for arsenic in Bangladesh, of which approximately 29% were arsenic (Khan *et al.*, 2006). Although several estimates are available in Bangladesh, according to recent studies about 35 million people are chronically exposed to arsenic in drinking water (Mahata *et al.*, 2008). Thus, the provision of tube wells tapping the shallow aquifer substituted one public health risk (e.g. diarrhoeal diseases) by another (e.g. from arsenic) (Howard *et al.*, 2006). Without doubt, the arsenicosis problem is a major public health problem in Bangladesh (Khan *et al.*, 2003; Khan *et al.*, 2006 and Khan *et al.*, 2007).

2.5 Geology and hydrogeology of Bangladesh

(Ravenscroft and McArthur, 2004)

Alluvial and deltaic sediments of the Ganga, Brahmaputra and Meghna rivers build the Bengal Basin the eastern part of which is Bangladesh. The north–south section in Fig. 2.5 provides a generalized description of the aquifers in the coastal zone of Bangladesh. The basin was dissected and infilled many times by the major rivers during Pleistocene times leading up to the last glacial maximum (LGM) at 18 ka BP (ka BP = thousands of years before present, that is before 1950 AD) when sea level stood some 130 m lower than present (Umitsu, 1993; Kudrass *et al.*, 1999; Goodbred and Kuehl, 2000). The flooded coastal plain and incised channels of Bangladesh were rapidly filled by estuarine, deltaic and alluvial sediments in the latest Pleistocene/Holocene transgression. The sediments that fill the accommodation space created by these incised channels have distinctly different hydraulic and geochemical properties from those inter-fluvial sediments (e.g., Barind and Madhupur Tracts) that predate them (BADC, 1992 and Ravenscroft, 2003). Inter-fluvial sediments increasingly contain Cl-rich brackish water towards the coast (Hoque *et al.*, 2003). The post-LGM valley-fill sediments are uncommented dark grey sands containing groundwater that is reducing and sometimes methanogenic (Ahmed *et al.*, 1998), high in Fe and As (DPHE, 1999; Nickson *et al.*, 1998 and 2000; McArthur *et al.*, 2001). The interfluvial and underlying sediments that predate the LGM are formed by oxidized, often brown-colored, sands of lower average permeability (MPO, 1987 and BADC, 1992). The aquifer sands are fine-to-medium grained with typical hydraulic conductivities of 10–50 m/d which contain water that is less reducing, low in Fe and As, and is generally less mineralized (Ravenscroft, 2003). In between aquitards are more prominent in the southwards and normally contain brackish groundwater. The brackish water is connate, and has locally leaked into underlying sands (Hoque *et al.*, 2003). As the aquifers become more strongly confined, the waters tend to become more reducing and higher in iron (Rus, 1985).



Depth	Lithology	Water chemistry	Sediment	Water
< 10 m	Silt			
20 to 40 m	Fine to medium sand, and peat	Anoxic, high in Fe, Mn and HCO_3	< 6 Ka	0 to 5 Ka
150 to 200 m	Silt, clay, fine sand, and peat	brackish to saline and anoxic	< 11 Ka > 30 Ka	?
150 to >350 m	Medium to fine sand	Anoxic, low in Fe and As. high in HCO_3	?	10 to >20 Ka

Figure 2.5 Schematic of aquifer stratigraphy in the coastal zone of Bangladesh (Ravenscroft and McArthur, 2004)

Pliocene to Holocene sediments is extensively tapped to supply drinking water and the majority of irrigation and industrial supplies (MPO, 1987). The deep coastal aquifers are not used for irrigation because of high cost of wells >200 m deep. Aquifers below about 150 m have been intensively pumped for municipal supply over a period of 20–30 a at towns such as Khulna, Barisal and Noakhali, and as yet have not been significantly affected by salinization (LGED, 1994), despite claims to the contrary (Hassan *et al.*, 1998 and Rahman *et al.*, 2000).

2.6 Post-disaster situation in coastal zone of Bangladesh

The south-west coastal regions of Bangladesh have been experiencing acute shortage of safe drinking water and increase in salinity intrusion in surface and ground water over the past few years. The reason is manifold and complex. Due to geographical disadvantage, this south-western region is commonly subjected to floods, river erosion, cyclones, storm & tidal surge etc. It has been estimated that Bangladesh is on the receiving end of about two-fifths of the world's total impact from storm surges. The phenomenon of re-curvature of tropical cyclones in the Bay of Bengal is the single most cause of the disproportional large impact of storm surges on the Bangladesh coast. Also, the coastal areas and off-shore islands of Bangladesh are low lying and very flat. The height above mean sea level of the coastal zone is less than 3m (Sarwar, 2005). According to environment department of the World Bank, existing literature indicates a 1.5–9 m height range during various severe cyclones. Storm-surge heights of 10 m or more have not been uncommon. Larger storm surges threaten greater future destruction, because they will increase the depth of inundation and will move further inland - threatening larger areas than in the past (Sarwar, 2005). Cyclone Sidr in November 2007 and Cyclone Aila in May 2009 when the storm surge of 3 m (10 ft.) impacted western regions of Bangladesh, provide recent examples of devastating storm-surge in Bangladesh (Hafizi, 2011). Such frequent storms have brought much saline water inland and ruined the rice fields that people depend on for employment and food, and surface water. Frequent natural disasters mean that the traditional ponds or surface water bodies become inundated with sea water making these unsuitable for any form of human use. The people in Satkhira received the highest amount of sufferings from drinking water shortage soon after Aila attacked. Aila devastated all the drinking water sources (ponds and tube wells). High tidal surges, during the disaster, contaminated all fresh water sources with polluted saline water. According to the Soil Resources Development Institute, Ministry of Agriculture, about 62% of Bangladesh's coastal land has problems with salinity (Sarwar, 2005). This means there is a major shortage of clean drinking water, which has severe repercussions on the health of the people living along the coast. The situation has become worse with the introduction of shrimp farming and the consequent intrusion of brackish water far inside the coast which seriously affects ground water. Quality of water is the main constraint affecting water supply system in the coastal area. Salt water intrusion in the surface and ground waters in dry season is the major problem. The indiscriminate use and unhygienic sanitary practices of the people have polluted the available low saline surface water sources and made them unsafe for domestic uses. The application of organic and inorganic fertilizers for fish cultivation in ponds has aggravated the deterioration of water quality. Surface waters in rivers and unprotected ponds often show Faecal Coliform counts between 500 and 3000 per 100ml. Ground water from bacteriological point of view, is a more dependable source in Bangladesh. But in the coastal area, the presence of chlorides, and dissolved iron in excess of acceptable limits is the main water supply problem. Ahmed (1981) and Choudhury (1985) assessed people's general opinion about the quality of water they drink. The people in the problem area use tubewell water having 5mg/1 of iron and 1000mg/1 of chlorides without much hesitation but water of such quality is not acceptable in other regions of the country. Since these water quality parameters normally do not involve health risk, people's acceptance receives priority in water supply in the coastal area. Taking this into considerations, Department of Environment (DoE) recommended the maxim limits of 1000mg/1 for chlorides and 5mg/1 for iron in case of hand pump tubewell in the absence of a better alternative source in problem and coastal areas of Bangladesh. Quality of water is the main constraint affecting water supply system in the coastal area. Salt water intrusion in the surface and ground waters in dry season is the major problem. The indiscriminate use and unhygienic sanitary practices of the people have polluted the available low saline surface water sources and made them unsafe for domestic uses. The application of organic and inorganic fertilizers for fish cultivation in ponds has aggravated the deterioration of water quality. Surface waters in rivers and unprotected ponds often show faecal coliform counts between 500 and 3000 per 100ml (Ahmed, 1996). A study has been shown that from the end of April till the beginning of June, salinity level in surface water is considerably higher than drinking water standards as well as standards for irrigation water. Salinity levels of ground water at shallow depths (65 – 70 ft.) are low but these shallow depth tube-wells are not used for drinking purposes because of high arsenic contamination, whereas salinity level at deeper depths (840 – 1350 ft.) are very high (3000 – 4000 µs/cm). A number of health related problems have been identified in the study area due to salinity such as diarrhoea, fever, high blood pressure, gastric and skin problem etc. (Khanom and Salehin, 2012). A study has been shown that to address the status of groundwater salinity for nine upazilas (sub-district) of southwestern coastal region samples from 272 randomly selected tubewells were considered. Qualitative data were also collected to address social implication of the problem. It reveals that the minimum salinity in shallow aquifer was 51 ppm to 338 ppm and the maximum was 294 ppm to 3751 ppm. About 18% shallow tubewells had salinity more than 1000 ppm against 5.6 % deep tubewells. Although most of the respondents (86.7%) used groundwater but 79% did not perceive increase in salinity (Hasan *et al.*, 2013).

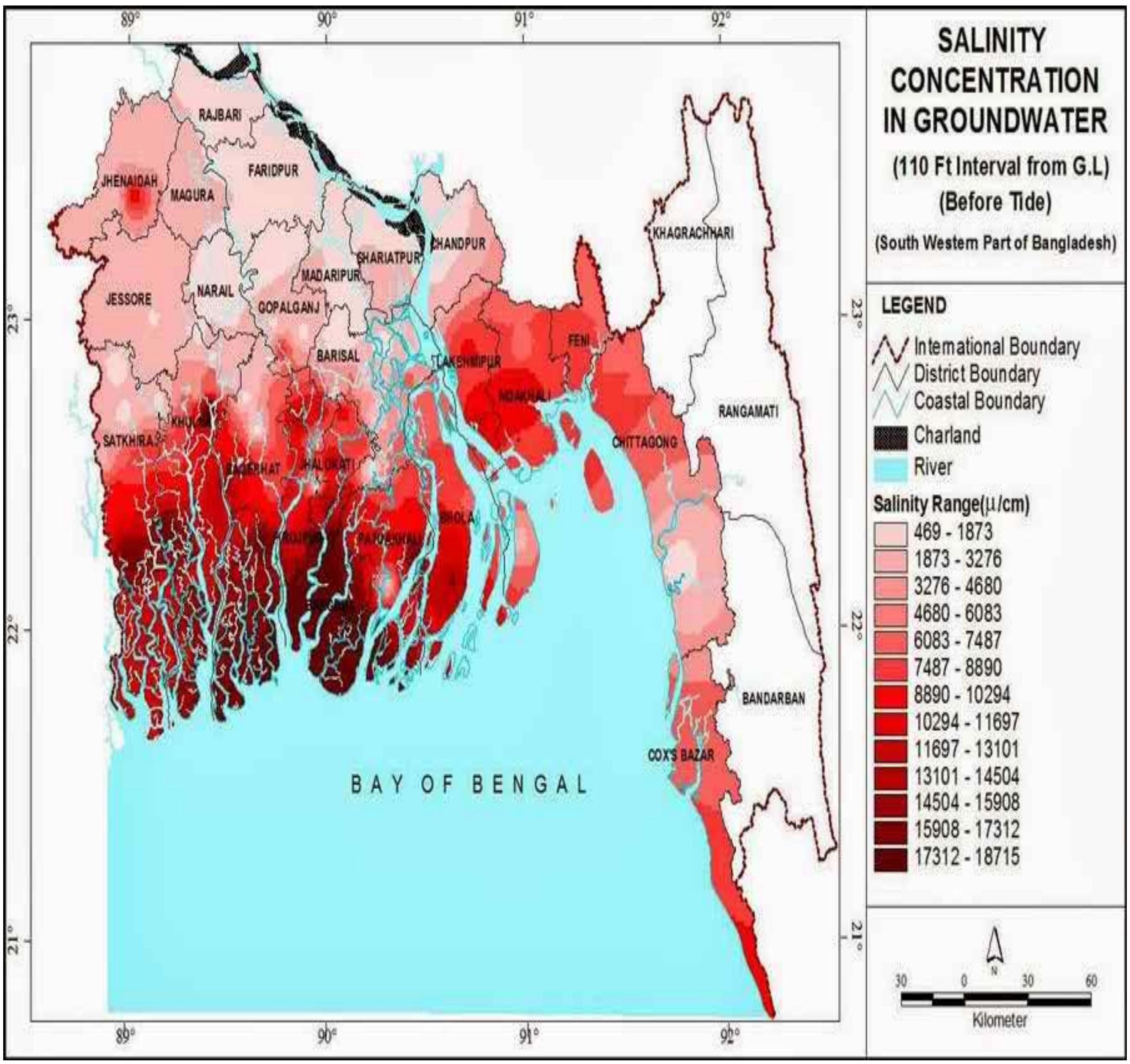


Figure 2.6 Saline affected coastal zone of Bangladesh

2.7 Causes of lack of safe drinking water in coastal zone of Bangladesh

Lack of access to safe drinking water is an impediment to improving health conditions and wellbeing and reducing poverty in southwest coastal regions of Bangladesh. The main causes of scarcity of safe drinking water are saline intrusion in surface and ground water, arsenic contamination of shallow aquifer, water-logging and natural disasters. The causes of drinking water scarcity result in negative health, social and economic outcomes for coastal population.

i. Arsenic Contamination

The arsenic contamination of Bangladesh's groundwater with its genesis and toxic effects on humans has already been reported (Dhar *et al.*, 1997; DCH, 1997; Karim *et al.*, 1997; Nickson *et al.*, 1998 and Karim, 2000). Recent studies in Bangladesh indicate that the groundwater is severely contaminated with arsenic above the maximum permissible limit of 0.05 mg/l for drinking water. Altogether 400 measurements were conducted in Bangladesh in 1996 (Smith *et al.*, 2000). Arsenic concentrations in about half of the measurements were above the maximum permissible limit. In 1998, British Geological Survey (BGS) collected 2,022 tube-well water samples from 41 arsenic affected districts (Smith *et al.*, 2000). In order to mitigate the arsenic disaster, it is essential to treat the arsenic contaminated water and water sources or to avoid the arsenic contaminated water. Removal of arsenic from water is possible by ultraviolet radiation, oxidation, chemical precipitation and filtration (Safiuddin and Karim, 2001).

ii. Sedimentation

The two Himalayan Rivers, the Ganges and Brahmaputra, are among the most sediment laden rivers in the world (Miliman and Meade, 1983). The GBM system carries 2.4 billion tons of sediment to the Bay of Bengal through the country. Part of the sediment goes to the Bay of Bengal and part of its deposits on the river beds and build char lands. This fluvio-morphological activity reduces fresh water discharge to the estuary which leads to increased salinity in the tidal rivers and canals. Sedimentation in the tidal rivers of southwestern area of Bangladesh is the main reason of water logging problem. These troublesome sediments have blocked the rivers, canals and caused upstream drainage congestion and flooding with saline water.

iii. Cultivation of brackish water shrimp

In the southwest region shrimp cultivation is underway in almost all the wetlands. In most of the cases, salt water from the river is brought into the wetland for shrimp cultivation, which is increasing the salinity of the adjacent fresh water ponds and shallow aquifer through seepage. Shrimp aquaculture has raised serious concern about the impact of salt water intrusion in to the surrounding agricultural lands (Flaherty *et al.*, 2000). The spectacular rise of demand of brackish water shrimp (penaeus monodon) in the international market has stimulated the merest of its production. Presently its culture has taken a massive horizontal expansion and engulfed almost the entire coastal belt of the country. Shrimp culture reduced the availability of cropping land by increasing soil salinity. The practice of shrimp culture needs saline water as an input to the shrimp pond as a result salinity intrusion increase with expansion of shrimp culture. Shrimp production in a controlled and enclosed water body is described as Shrimp cultivation. Both saline and fresh water can be used for this cultivation. Shrimp are the swimming crustaceans that inhabit the warm marine waters of the tropics and subtropics (Anwar, 2013). The extensive farming systems negatively expedite the processes: infringement of mangroves, intrusion of salinity, degradation of land, de-stabilization of coastal ecosystems. About 53% of the coastal areas are affected by salinity because of shrimp cultivation. These areas are generally low lying, barely one meter above mean sea level and below high tide level conducive to shrimp fishes production. The Sundarban forest discards about 3.5 million tons of detritus per year (Haque, 2013) that is carried to the farthest corners of the land by the tides.

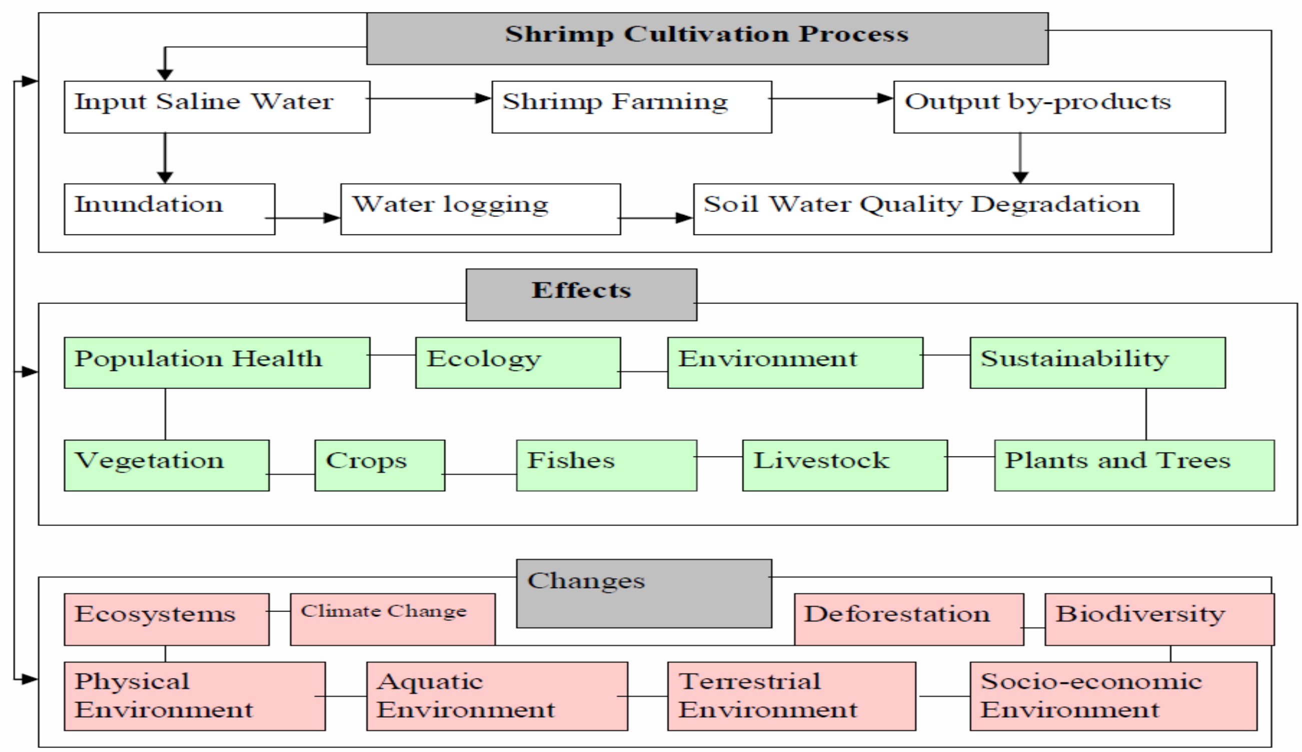


Figure 2.7 Diagrammatic model of Shrimp cultivation process, concomitant effects and changes due to Shrimp farming (Karim, 2006).

iv. Reduction in upstream flow

A total of 57 major rivers of Bangladesh have entered from other countries, of which 54 rivers are from India and 3 rivers are from Myanmar. But among the 54 rivers coming from India more than 25 rivers face one or more upstream diversion basically in dry months (Afroz and Rahman, 2013). In the past the southwest coastal region was rich in fresh water as the Ganges had flowed through it. However, the scenario changed following two disastrous events: the change of the course of the river Ganges due to Ganga water distribution treaty, commonly known as Farakka Treaty due to which only 27500 thousand cusec water becomes available for Bangladesh during the dry period with the remaining amount being diverted by India and the closing of the face of the origin of the river Matha Vanga (http://pravdabangladesh.wordpress.com/access-to-safe-drinking-water/). For this reason, water scarcity during non-monsoon months causes of salinity increase in soil and water of coastal belt in Bangladesh. During the post-Farakka period, salinity in south-western region of Bangladesh increased significantly. For example, at the Khulna station the average monthly maximum salinity for April in the pre-Farakka period was 1626 μmho/cm. during 1976. When the Gorai discharge dropped to 0.5 m^3/sec from its pre-Farakka average of 190 m^3/sec, maximum salinity in April increased to 13,000 μmho/cm. This had a serious implication for safe drinking water available from ground water sources. The reduction of upstream flow deteriorates the recharge rate of the ground water table, reduced fresh water bodies and results in over extraction of groundwater for irrigation and use of water from fresh water ponds.

v. Natural disasters

Due to geographical disadvantage, this southwestern region of Bangladesh regularly experiences natural disasters like water logging, cyclones, tidal surges, floods, river erosion, etc. which are responsible for the destruction of drinking water sources. Bangladesh experienced the deadliest cyclones in 1970, 1990, 1992 and 2007 (Ali, 1996). The coastal zone of the country is still carrying salinity which intruded during Sidr and Aila. Agricultural land and fresh water of ponds, canals and rivers are still saline contaminated and increase the sufferings of the coastal population. Bangladesh faces semi diurnal tide i.e. two flood tide and two ebb tides in a day in a 6 hour consecutive time interval. Coincidence of heavy rainfall and flood tide occurred during monsoon urban area located in the coastal part of our country faces flooding due to water logging. During the monsoon period it makes high tide and overflow saline water surrounding the coastal region (Mahmuduzzaman, 2014). Due to various human activities, carbon dioxide and other greenhouse gases are accumulating in the earth’s atmosphere, resulting in climate change. Rising temperature expand the ocean volume in two ways. Firstly, it melts mass volume of ice of the polar region and secondly, it causes thermal expansion of water of the ocean. Wigley and Raper (1987) commented that the relative contributions of thermal expansion and ice melting to this sea level rise are uncertain and estimates vary widely, from a small expansion effect through roughly equal roles for expansion and ice melting to a dominant expansion effect. These two factors increase volume of ocean water of the earth and rise in the sea level. Sea level rise is one of the major causes for salinity intrusion in the coastal belt of Bangladesh (Wigely and Raper, 1987).

2.8 Effect of lack of safe drinking water in coastal zone of Bangladesh

Before the cyclone Aila, the major drinking water sources in the study area were shallow tube-wells, wells, deep tube-wells, ponds, PSFs etc. Among all sources, the ponds were exceptionally predominant. According to local DPHE office, after the Aila about 98% of water sources have been either broken or partially damaged and become unusable due to submergence. Ponds and other water bodies all have been contaminated by the intrusion of saline water thereby leading to serious crisis of drinking water and that situation is still continuous. The effects of scarcity of safe drinking water people in south-western region suffer from various diseases. Health condition has been found as vulnerable where the outbreak of water borne diseases like skin disease, diarrhoea, dysentery, cholera, fever are very common. A study has ranked the diseases according to community experience. It has been found that skin disease, diarrhoea, dysentery are in first rank among which skin disease is mostly prioritized (76%), 60% have preferred diarrhoea in rank two and 76% considered dysentery in rank three in the study area. Cholera and fever are also in ranking process. The study has found that children (75.71%) and aged people (24.29%) are mostly affected. Kumar *et al.*, (2010) have also estimated almost similar ranking of water borne diseases.

Table 2.5 Ranking status of outbreak of diseases (Kumar *et al.*, 2010)

Fever (%)	Cholera (%)	Dysentery (%)	Diarrhoea (%)	Skin Disease (%)	Rank
-	-	8	16	76	First
-	-	16	60	24	Second
-	-	76	24	-	Third
32	68	-	-	-	Fourth
68	32	-	-	-	Fifth

2.9 Water supply in coastal zone of Bangladesh

Bangladesh made great strides in improving coverage of its population with access to an improved water supply and in the Global water supply and sanitation assessment 2000 report (WHO, 2000). Bangladesh had coverage in rural areas of 97% of the population having access to an improved water supply within one kilometer of their home or 30 minutes total collection time.

The presence of arsenic in groundwater is now reduced this figure to 74% and in the mid-term assessment of progress towards meeting the MDG Target for water, Bangladesh was considered off-track (WHO, 2004). In Chittagong and Khulna cities, WASA has been constituted for domestic water supply and sewerage. In other urban areas, it continues to be the responsibility of the municipal authorities. The conventional notion of urban water supply refers to piped water supply. This is still very low in Bangladesh with only 26 percent households having access to tap water (BBS, 2006). This is even lower in the coastal zone (17%). In eight coastal districts out of 19, less than five percent urban population use tap water for drinking, and in two districts (Patuakhali and Shariatpur) it is even less than one percent. Among the coastal districts, Satkhira has the highest proportion of urban households with access to tap water (34%), followed by Barguna (32%), Chandpur (29%) and Chittagong (26%). Khulna, being the second largest urban center in the coastal zone, has only four percent coverage of tap water supply (Ahmad, 2005). Tube wells are a major source of drinking water in urban areas. About 78 percent coastal urban households use tube well as source of drinking water (shallow 63% and deep 14%). Conventionally tube wells were considered as a dependable source of drinking water. But with increasing arsenic contamination, particularly in the shallow aquifer, the context has changed. This problem is more pronounced in the coastal zone. Besides, salinity in groundwater is a major concern for many areas. The problem is more acute in Khulna and Noakhali. About six percent coastal urban households still use open water sources including pond.

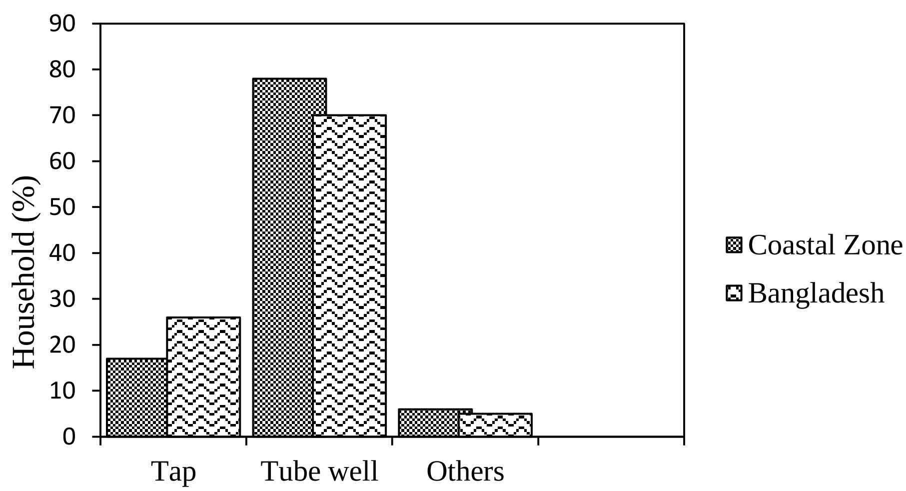


Figure 2.8 Source of drinking water in urban areas (Ahmad, 2005)

2.10 Sanitation situation in coastal zone of Bangladesh

Sanitation is crucial for healthy living that includes hygienic latrine facilities, proper management of solid waste and proper disposal of household wastewater and storm water. Proportion of urban households possessing sanitary latrines is slightly higher (70%) in the coastal zone than in the country (67%). Extent of sanitation is, however, much higher among urban households compared to rural households in the coastal zone (urban and rural together 46%). Sanitation coverage is the highest in Pirojpur (86%), followed by Jhalokati (84%) and Barisal (82%) and the lowest in Bagerhat (32%), followed by Cox's Bazar (53%). About 11 percent urban households have no latrine at all in the coastal zone compared to seven percent urban households in the country as a whole. State of sanitation is poor in big cities in the coastal zone (Ahmad, 2005). In six city corporation areas of the country, 70 percent households have sanitary latrine. This is only 52 percent for three city corporation areas in the coastal zone; Barisal, Chittagong and Khulna.

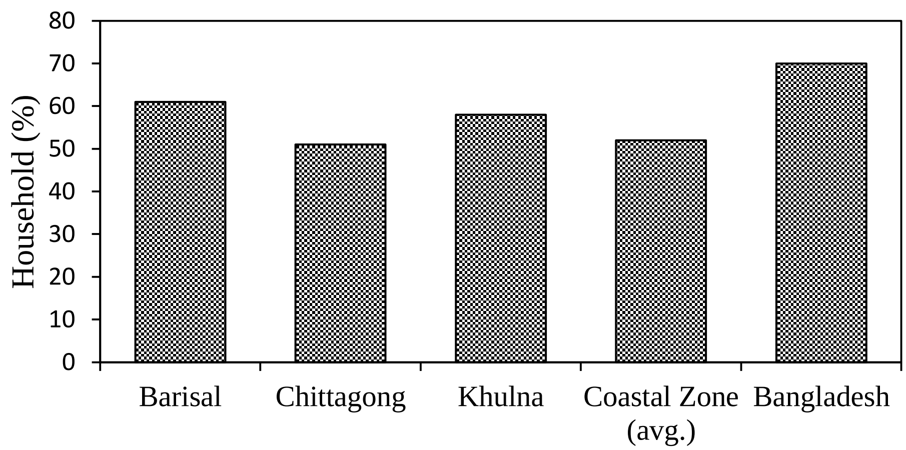


Figure 2.9 Access to sanitary latrine in city corporation areas (Ahmad, 2005)

2.11 Distance of drinking water sources in coastal zone of Bangladesh

Due to inundation of safe water sources people have to go adjacent unaffected areas that vary from less than 1 km to more than 1.5 km. The study has found that, 37.14% respondents collect sweet pond water and 27.14% respondents collect PSF water from a distance of less than 1 km, 44.28% respondents collect sweet pond water and 52.86% respondents collect PSF water from a distance of 1-1.5 km, 18.58% respondents collect sweet pond water and 20% respondents collect PSF water from a distance of more than 1.5 km shown in figure 2.10. According to the latest assessment by an alliance of INGOs (2010) the average distance of drinking water sources from beneficiary's household is about 2.4 km. The study has grouped water collector in three classes as female, male and children. It has been found that the prime rain water collectors are female and sometimes both female and children. In case of sweet pond water, 55.72% collectors are female, 34.28% are children. PSF water is mostly collected by female (57.15%) and 30% children. Relief water has been collected by female (54.28%) and children (27.15%). So female are mostly involved in household safe water management in the study area. Kumar and Masud (2010) have also found that females are involved in water collection than men in the Aila affected coastal areas.

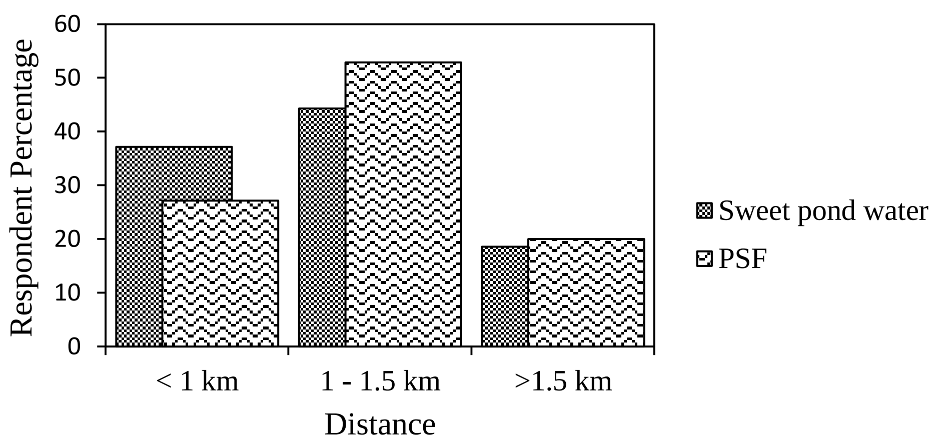


Figure 2.10 Distance of drinking water sources (Haque *et al.*, 2010)

2.12 Hand wash status in coastal zone of Bangladesh

The study has found that 84% respondents wash their hands after defecation or before taking any food regularly, 16% sometimes wash their hands after defecation or before taking any food. The study has grouped different hand washing materials as soap, ash, soil and only water. It has been found that only 10% households have the ability to wash their hands with soap after defecation or before taking any food shown in figure 2.11. The study also shows that maximum number of people is conscious about hand washing, but it is very difficult to maintain the proper hand washing for the people because of the post severe condition of Aila affected areas. HISBSB (2008) evaluated that 55% of rural people wash their hands with soap or ash after defecation and only 17% has observed to do so (Haque *et al.*, 2010).

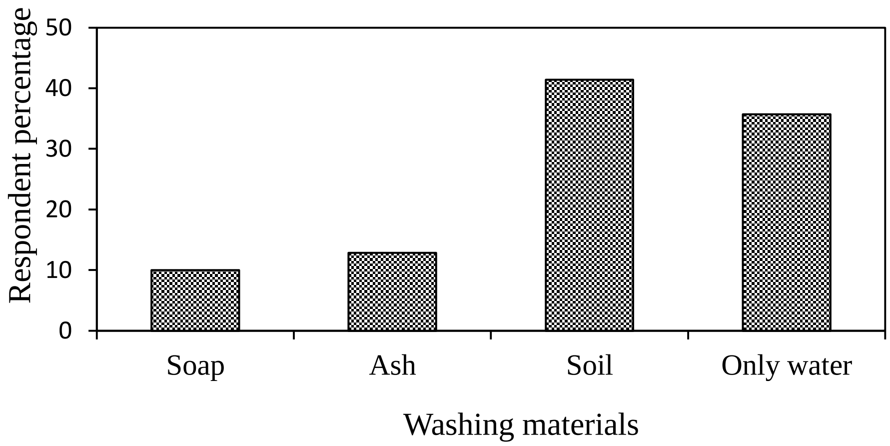


Figure 2.11 Hand washing by soap, ash, soil and only water (Haque *et al.*, 2010)

2.13 Water supply options in coastal zone of Bangladesh

i. Deep Tubewell

In Bangladesh two types of deep tubewells are constructed, manually operated small diameter tubewell similar to shallow tubewells and large diameter power operated tubewells called production well. Deep tubewells installed in those protected deeper aquifers are producing arsenic safe water. The BGS and DPHE study has shown that only about 1% deep tubewell having depth greater than 150 m are contaminated with arsenic higher than 50m g/L and 5% tubewell have arsenic content above 10m g/L. Sinking of deep tubewells in arsenic affected areas can provide safe drinking water but replacement of existing shallow tubewells by deep tubewells involves huge cost. Some of the deep tubewells installed in acute arsenic problem areas have been found to produce water with increasing arsenic content. Post-construction analysis shows that arsenic contaminated water could rapidly percolate through shrouded materials to produce elevated levels of arsenic in deep tubewell water. Experimentation by sealing the borehole at the level of impermeable layer is yet to be conducted to draw conclusions. Some areas of the coastal region of Bangladesh are very suitable for construction of deep tubewell. Department of Public Health Engineering has sunk a total of 81,384 deep tubewell mainly in the coastal area to provide safe water to 8.2 million people (DPHE, 2000).

ii. Infiltration Gallery / Well

Infiltration Galleries (IG) or wells can be constructed near perennial rivers or ponds to collect infiltrated surface waters for all domestic purposes. Since the water infiltrate through a layer of soil/sand, it is significantly free from suspended impurities including microorganisms usually present in surface water. Again, surface water being the main source of water in the gallery/well, it is free from arsenic. If the soil is impermeable, well graded sand may be placed in between the gallery and surface water source for rapid flow of water. Experimental units constructed in the coastal area to harvest low saline surface water show that water of the open infiltration galleries is readily contaminated. The accumulated water requires good sanitary protection or disinfection by pot chlorination. Sedimentation of clayey soils or organic matters near the bank of the surface water source interfere with the infiltration process and require regular cleaning by scrapping a layer of deposited materials.

iii. Protected Ponds

A protected pond in a community can provide water for drinking purpose with minimal treatment and for other domestic uses without treatment. Traditionally, rural water supply, to a great extent, was based on protected ponds before and during early stage of installation of tubewell. Sinking of tubewells under community water supply schemes in rural Bangladesh began in 1928. There are about 1,288,222 nos. of ponds in Bangladesh having an area of 0.114 ha per ponds and 21.5 ponds per mauza (BBS, 1997). About 17% of these ponds are derelict and probably dry up in the dry season. The biological quality of water of these ponds is extremely poor due to unhygienic sanitary practices and absence of any sanitary protection. Many of these ponds are made chemically and bio-chemically contaminated for fish culture. In order to maintain good quality water, a protected pond shall not receive surface discharges or polluting substances and should only be replenished by rain and groundwater infiltration.

iv. Pond Sand Filter (PSF)

A prospective option for development of surface water based water supply system is the construction of community type Slow Sand Filters (SSFs) commonly known as Pond Sand Filters (PSFs). It is a package type slow sand filter unit developed to treat surface waters, usually low-saline pond water, for domestic water supply in the coastal areas. Slow sand filters are installed near or on the bank of a pond, which does not dry up in the dry season. The water from the pond is pumped by a manually operated hand tubewell to feed the filter bed, which is raised from the ground, and the treated water is collected through tap. It has been tested and found that the treated water from a PSF is normally bacteriologically safe or within tolerable limits. On average the operating period of a PSF between cleaning is usually two months, after which the sand in the bed needs to be cleaned and replaced. The program initiated by DPHE with the construction of 20 experimental units in 1984 to utilize low saline pond water for water supply in the coastal area. Pond Sand Filters serve 200-500 people per unit. The PSF is being promoted as an option for water supply in arsenic affected areas. The problems encountered are low discharge and difficulties in washing the filter beds. The PSF is a low-cost technology with very high efficiency in turbidity and bacterial removal. It has received preference as an alternative water supply system for medium size settlements in arsenic affected areas and areas. Although PSF has very high bacterial removal efficiency, it may not remove 100% of the pathogens from heavily contaminated surface water.

v. Rain Water Harvesting

Bangladesh is a tropical country and receives heavy rainfall during the rainy season. In the coastal districts, particularly in the offshore islands of Bangladesh, rainwater harvesting for drinking purposes is a common practice in a limited scale for long time. A study of Hussain and Ziauddin in 1989, some areas of the coastal region with high salinity problem, about 36 percent households have been found to practice rainwater harvesting in the rainy season for drinking purpose. In the present context, rainwater harvesting is being seriously considered as an alternative option for water supply in Bangladesh in the arsenic affected areas.

Chapter 3

Methodology

3.1 General

The coastal area of Bangladesh is more vulnerable due to different types of disasters. Cyclone is major in all of natural hazards. People of here always suffer scarcity of safe drinking water causes of saline intrusion of water sources, Arsenic-iron problems, abandon of water sources etc. Most of the people compel contaminated surface water without sort of any purification as well as suffer from water borne diseases like diarrhea. As result, low cost household water treatment units are very effective to remove bacteria, pH, colour etc.

3.2 Research strategy

The respective activities of this study are given below:

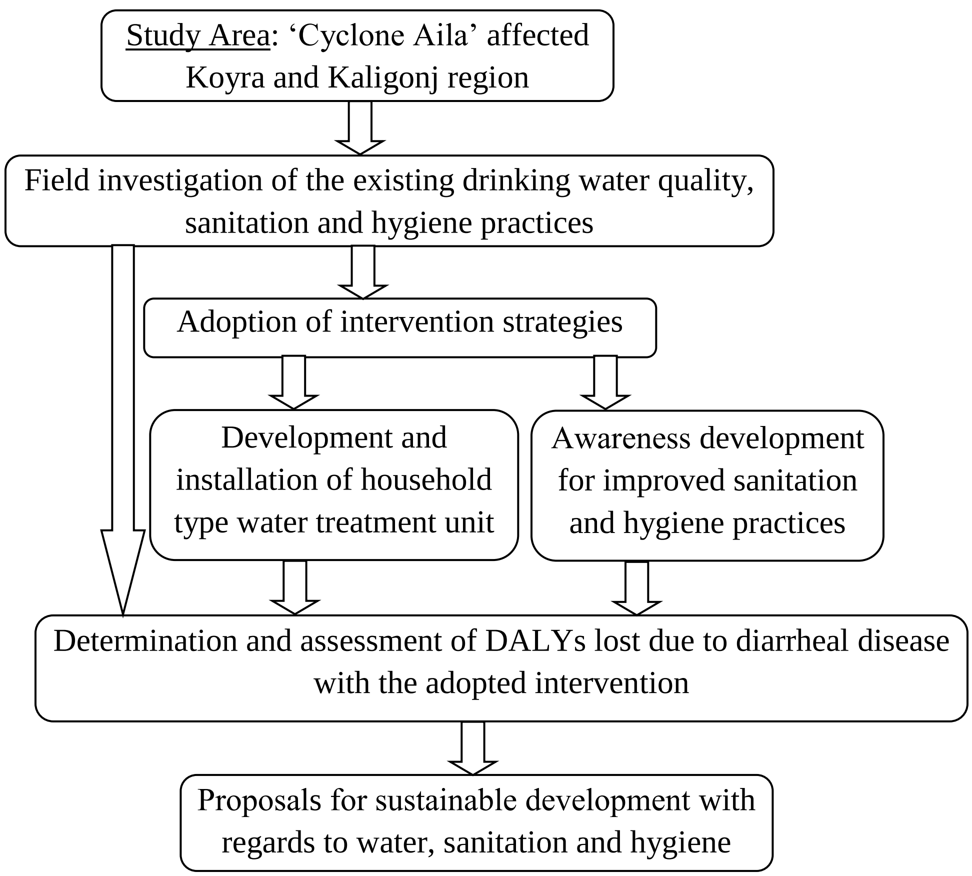


Figure 3.1 Flowchart of the consecutive steps in the research works

3.3 Study area

Koyra is the largest upazila of Khulna district. It is located at 22.34° N and 89.30° E with a total land area of 1775.40 km^2, including 951.66 km^2 of forest. The total population of Mothbari village are 2278 and land area 8.21 km^2 according to union parisad. In Koyra upazila water supply and sanitation coverage was about 50-60% before Aila (Kumar and Masud, 2010).

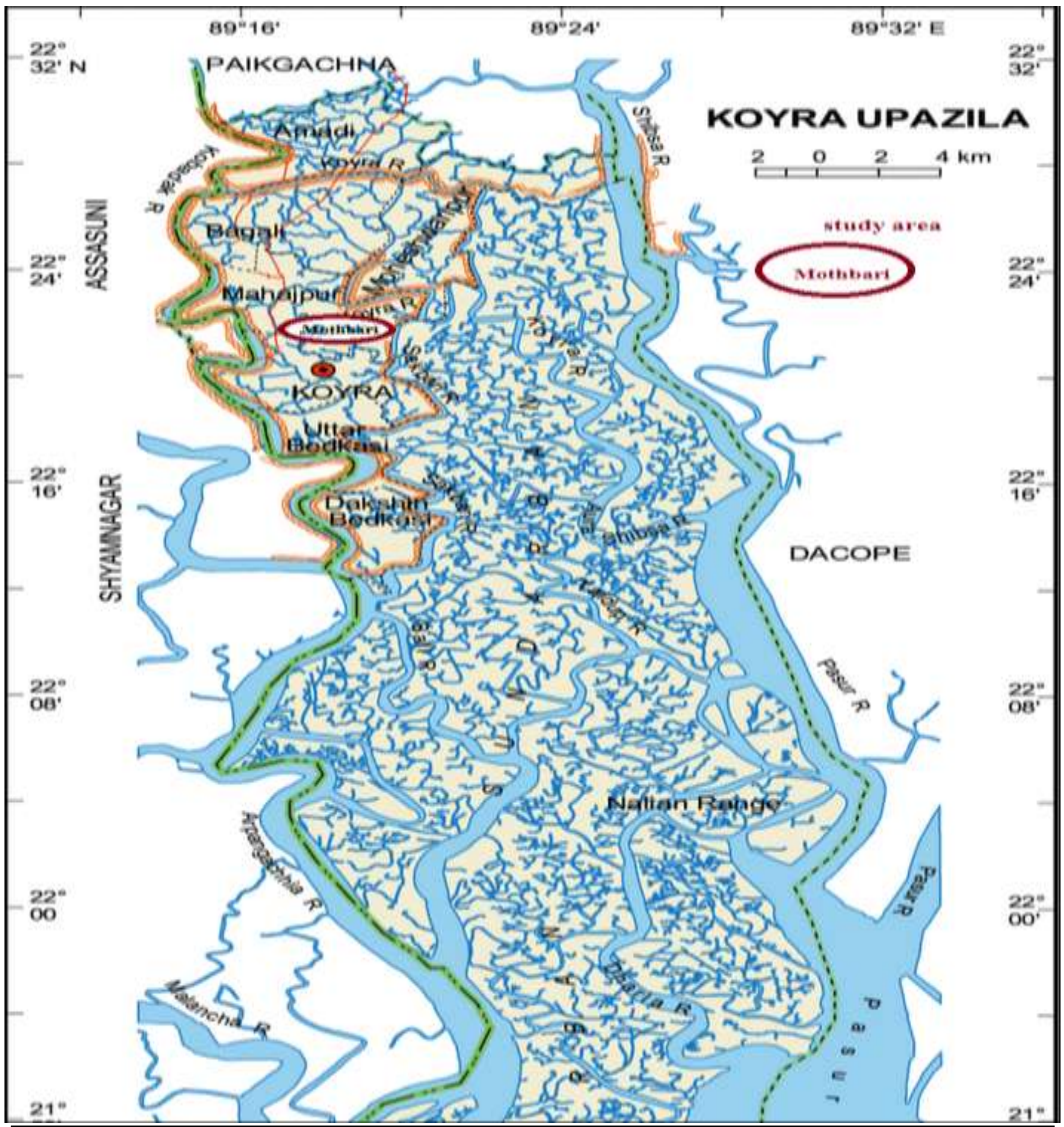


Figure 3.2 Koyra Upazila Map

Kaligonj upazila area 333.79 sq km, located in between 22˚19’ and 22˚33’ north latitude and in between 88˚58’ and 89˚10’ east longitudes. Total population of Kaligonj upazila is 256384 and

Average literacy 46.83%. Mainly water bodies are river Jamuna, Kakshiali, Galghasia, Kalindi, Gutiakhali, Bilgali, Banshtala and Bagarkhali canals are notable. Sources of drinking water tube-well 84.49%, tap 2%, pond 8.80% and others 4.71%. The level of arsenic in the shallow tube-well and saline contamination in shallow and deep tubewell water of the upazila is very acute. Sanitation 42.91% (rural 41.47% and urban 66.66%) of dwelling households of the upazila use sanitary latrines and 48.36% (rural 49.48% and urban 29.94%) of dwelling households use non-sanitary latrines; 8.73% of households do not have latrine facilities (Bangladesh Population Census 2001, Bangladesh Bureau of Statistics, 2007). According to Ministry of Health and Family Welfare, 2014 coverage of households having access to safe drinking water 89% and household sanitation coverage 79%.

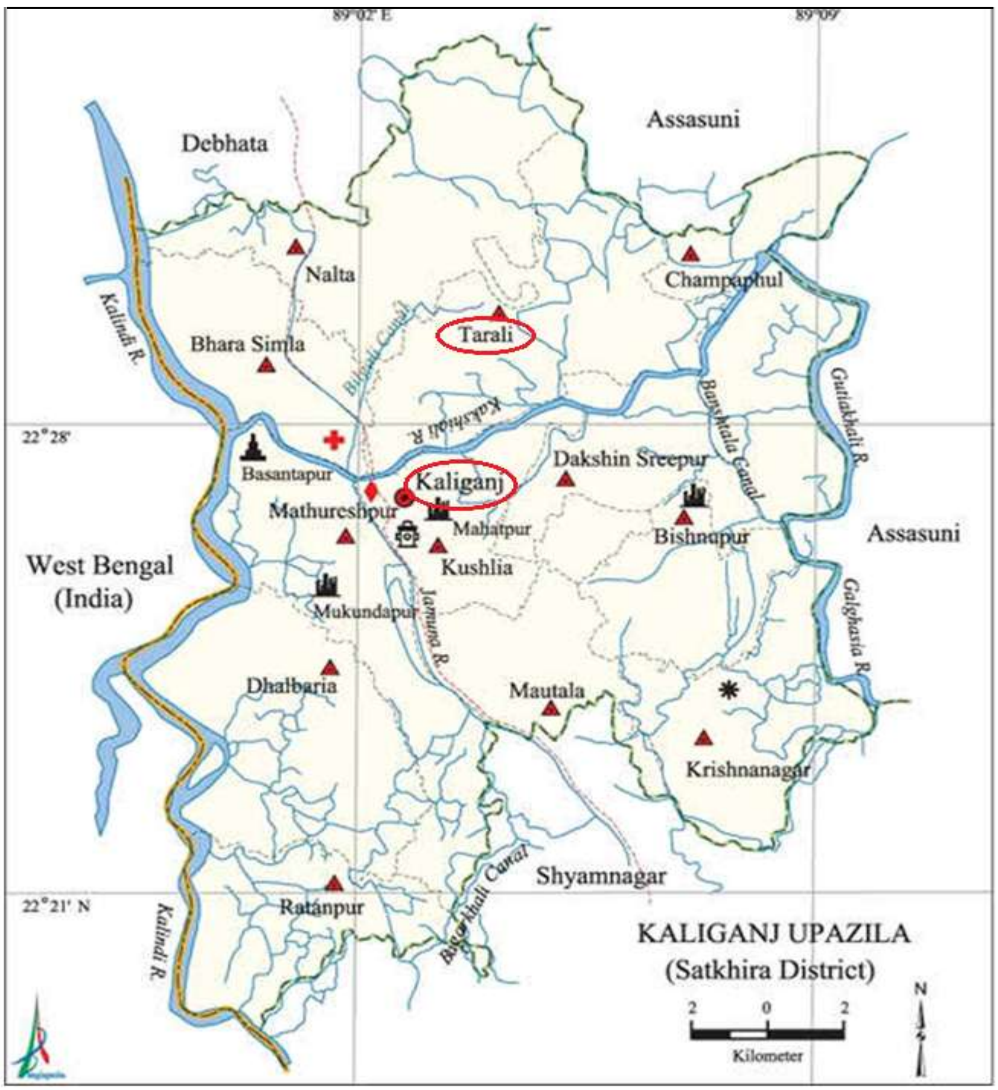


Figure 3.3 Kaligonj Upazila Map

These regions were wrecked by ‘Cyclone Aila’ in May 2009 leaving a trail of death, devastation, breached the embankments that have protected villages for decades and producing a humanitarian disaster. Crisis of safe drinking water has taken a serious turn in the Aila-hit Khulna and Satkhira districts. The tubewell water in both shallow and deep aquifers are highly saline in this area, therefore, cannot be used for drinking. Most of the rivers, canals, ponds and wetlands in the coastal belts are affected by salinity. Many people have to walk a long distance to fetch relatively safer water from a few ponds and canals. However, the waters of these ponds are dirty, turbid and smelly which cause various water-borne diseases specially diarrhea. On the other hand, people have been living in unhygienic situation which deems a threat to health hazards. However, high tidal surges during Aila contaminated all the fresh water sources with saline water. People living in poor rural regions are the most likely to rely on poor quality water –defined as microbiologically unsafe water contaminated with disease causing organisms (WHO, 2002). Frequent flooding, and poor sanitation render surface water bodies in this region particularly vulnerable to fecal contamination, thus leading to a high prevalence of diarrheal diseases (Caldwell *et al.*, 2003).

3.4 Field investigation

3.4.1 Existing drinking water quality

The South Western coastal region is composed of Satkhira, Khulna, Bagerhat and parts of Jessore districts. The people of this region are facing severest difficulties in accessing safe drinking water. The major problem of this area is prsence of saline in ground and surface water as well as arsenic contamination in shallow aquifer, lack of aquifer, abandon of water sources etc. In this study, water samples were collected from three various surface water sources, which could use as drinking purposes. Unit 1 and 2 were used same pond’s water as raw and same case for unit 4 and 5. In this study, developed five household type water treatment units and provided these units to five households. Raw water and filtrated water both were collected from the field were tested water quality parameters such as pH, color, turbidity, salinity, hardness, alkalinity, BOD_5, COD, TC and FC for any possible contamination of water.

3.4.2 Existing sanitation and hygiene practices

Sanitation refers to the principles and practices relating to the collection, treatment or disposal of human excreta, household wastewater and refuse as they impact on people and the environment. Hand washing with soap after defecation or before the preparation of food has previously been shown to reduce diarrhoeal disease. In this study, were completed reconnaissance and household interview with questionnaire data form. In addition, this study was arranged awareness development program like campaigns in three times as well as given toilet cleaner and soap for hand washing. In this study, were accomplished questionnaire data form in two times from existing situation and after satisfactory effectiveness. However, household surveys have begun including an observation of the availability of soap, visibility of latrines condition and water in the place where household members usually wash their hands etc.

3.5 Intervention strategies

A simple and inexpensive household type water treatment unit was constructed using locally available materials. The treatment units were used for removal of bacteria, turbidity, color, etc. from surface water. Household water treatment units consist of two chambers and one or multiple ceramic filter elements, shaped like a thick candle. Ceramic candle was installed in the bottom of first chamber. Bricks chips were used on candle. Inner surface of chambers and brick chips were washed by water before installation. Bricks chip were washed at several times. Hot water also used to wash of chambers and brick chips. The contaminated raw water flows downward through the ceramic filter element into the lower collection chamber. The capacity of each container was approximately 10 L.

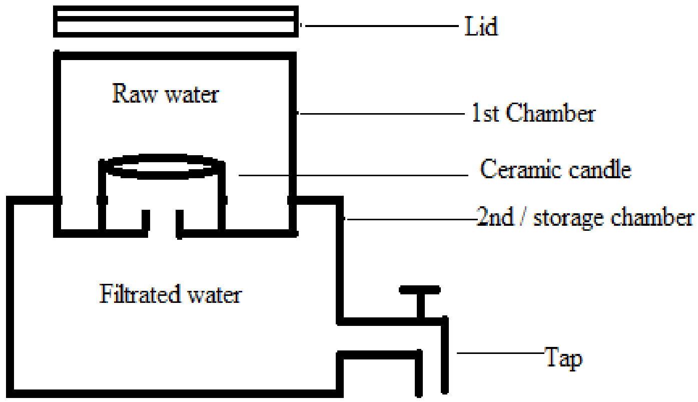


Figure 3.4 Household water treatment unit

3.6 Development and installation of water treatment units

- The filter was made with locally available and cheap materials as rice bran, clay soil and water (Kumar *et al.*, 2012). Oven-dry soil was grind with hammer. Then soil and rice bran was screened through 0.5 mm and 1 mm sieve respectively. Soil (640g for 1 filter) and rice bran (160g for 1 filter) was taken in ratio of 4:1.

Figure 3.5 Sieve analysis and rice bran

- Soil and rice bran was mixed homogeneously with water to make dough. Then dough was placed around the bar of the dice and two pieces of PVC pipe were pushed by hand from both sides to make cylindrical shape.

Figure 3.6 Mixing of soil & rice bran and making dough with water

Figure 3.7 Shaping of candle from dough using dice

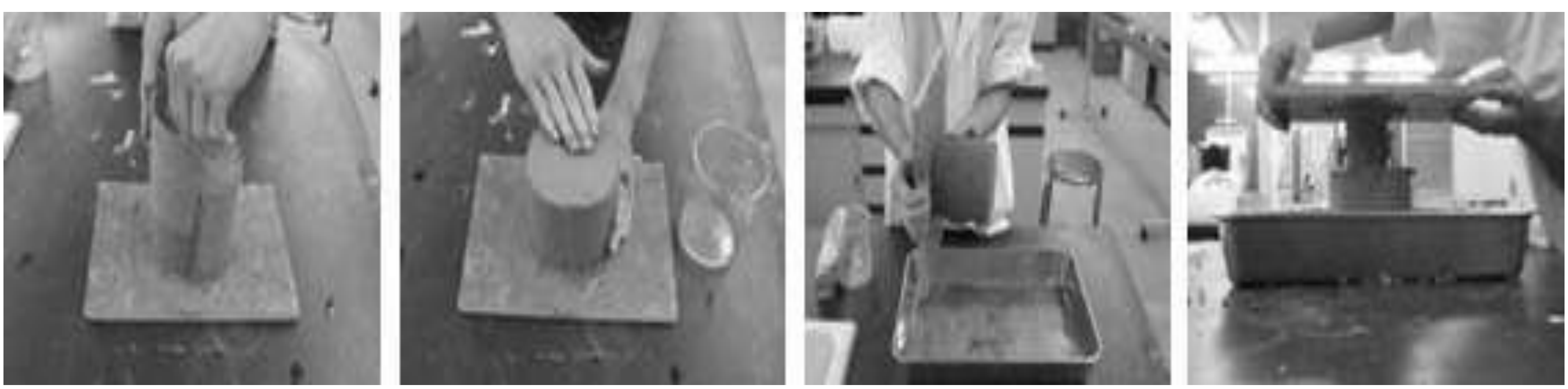


Figure 3.8 Final steps to get raw ceramic candle

- The resulting cylindrical ceramic filters were hollow with one side open. This soft filter was then dried in the sun for at least 3 days. The air dried filters were burnt in potter kiln at 900 to 1000℃. After continuous burning for 6 to 8 hours, the kiln was kept to cool down. After some hours the filters were taken out from the kiln. The final ceramic filters had a height of 10 cm and a thickness of 2 cm.

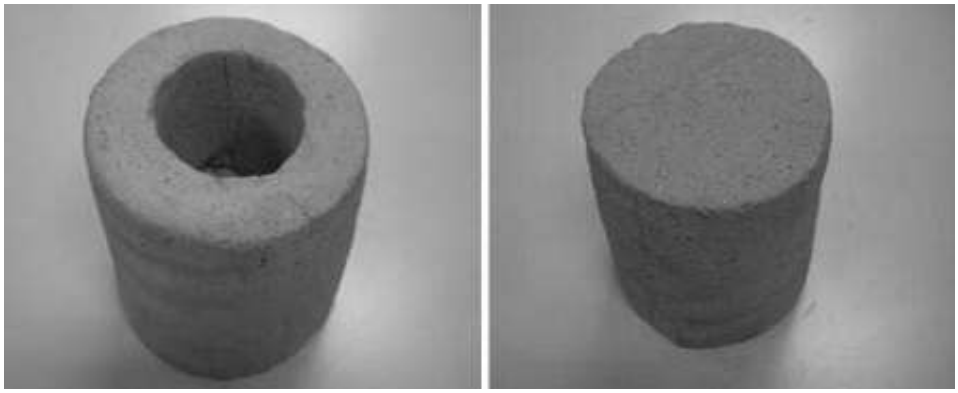


Figure 3.9 Final ceramic filters before burning

Figure 3.10 Candle burning in potter kiln

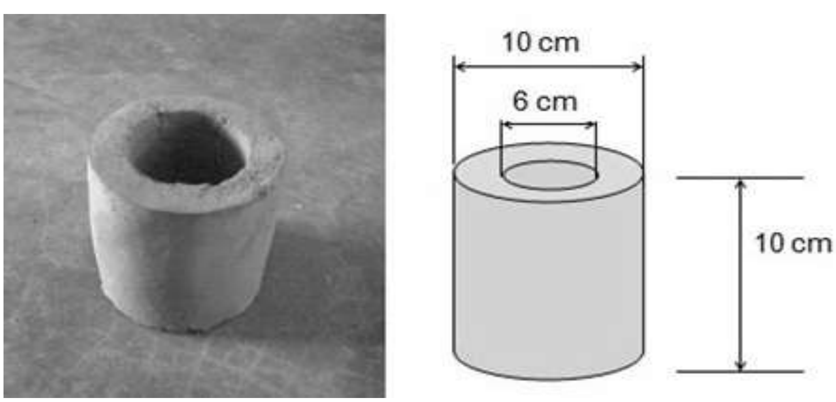


Figure 3.11 Final ceramic candles after burning

3.6.1 Simple water treatment unit setup

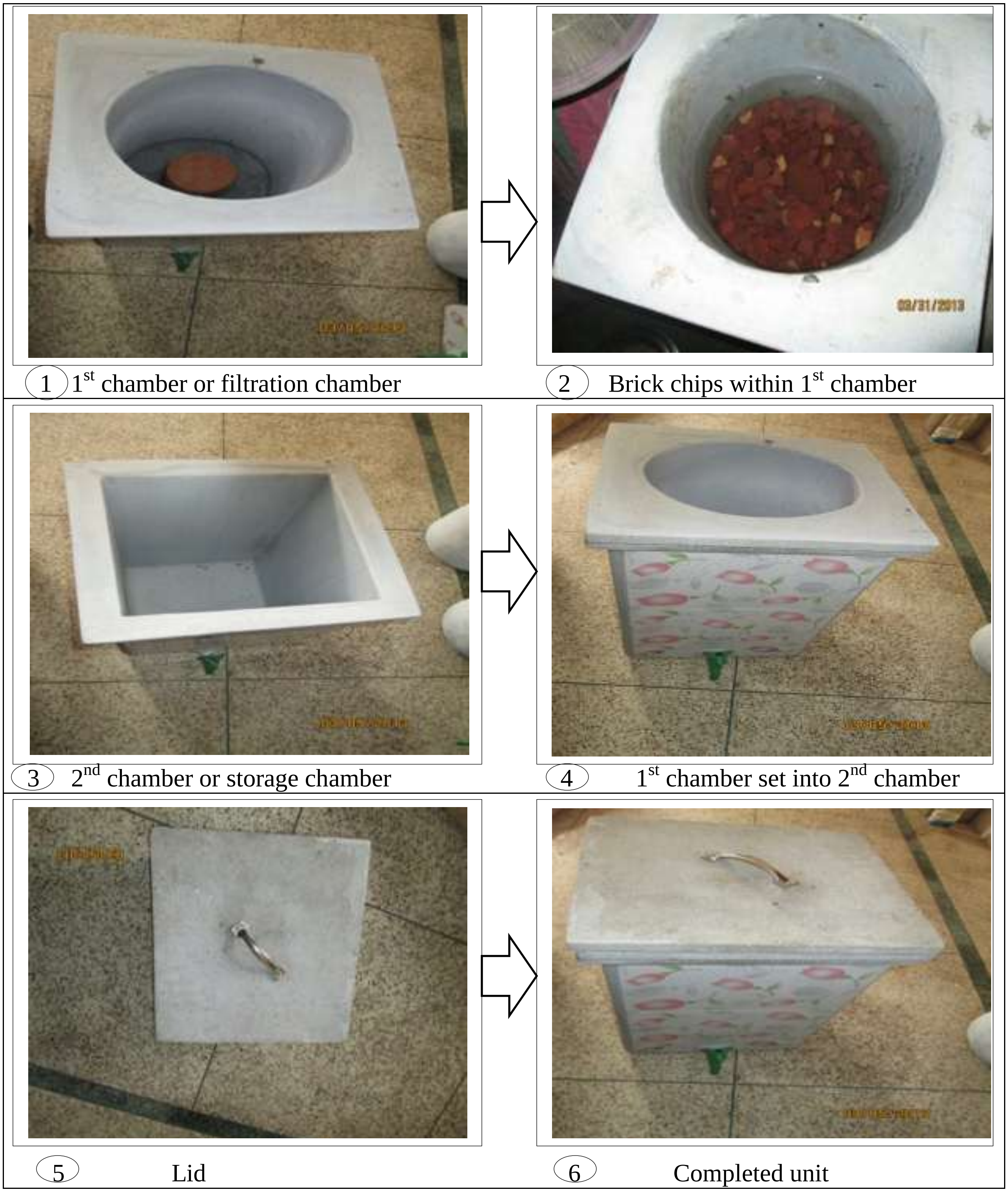


Figure 3.12 Flow diagram of simple household water treatment unit

3.7 Field and laboratory tests

The water samples were collected from field and tested in laboratory. The data of raw water and filtrated water both were determined by various standard and dependable apparatus. Table 3.1 shows the detail about the tests.

Table 3.1 Laboratory test parameters

SL. No	Parameters	Instruments
01	pH	pH meter (HACH Sens*I*on2, USA)
02	Colour	HACH Spectrometer (DR/2500)
03	Turbidity	Turbidity meter (HACH 2100p, USA)
04	Dissolve Oxygen	DO meter (HACH HQ 40d, USA)
05	Salinity (Chloride)	Titration
06	Hardness, Alkalinity	Aqua Check Method, ECO

3.8 DALYs lost calculation

The Disability Adjusted Life Years (DALYs) have been widely used to assess the magnitude of diseases, health risks, and premature deaths both globally and at the national and local levels (Grosse *et al.*, 2009). DALY was developed as a measure of population health so that nonfatal outcomes could be considered alongside mortality in the prioritization of health resources. DALYs are composed of two components: (1) years of life lost (YLL) due to premature death and (2) years lived with disability (YLD) associated with nonfatal injuries and disease. The formulas for DALYs calculation (WHO, 2001):

$$DALY = YLL + YLD$$

$$YLL = N * L_1$$

$$YLD = I * DW * L_2$$

Where,

DALY = disability-adjusted life year

YLL = years of life lost due to premature death

YLD = years lived with disability

N = number of deaths

L_1 = standard life expectancy minus age of death (years)

I = number of incident cases in reference period

DW = disability weight (0 to 1)

L_2 = average duration of condition (years)

The developers of the preliminary DALY defined six disability classes based on presumed deficits in physical functioning (Table 3.2), from a reduction of at least 50% in functional ability to perform at least one recreational, educational, reproductive, or occupational activity (disability class 1) to needing assistance with activities of daily living such as eating, personal hygiene, or toilet use (disability class 6). Medical experts assigned a weight to each class, on a scale of 0 (perfect health) to 1 (death).

Table 3.2 Definitions of six classes of disability will be used in determining DALYs and the weights assigned to each (WB, 1993).

Class	Description	Weight
1	Limited ability to perform at least one activity in one of the following areas: recreation, education, procreation or occupation	0.096
2	Limited ability to perform most activities in one of the following areas: recreation, education, procreation, or occupation	0.220
3	Limited ability to perform most activities in two or more of the following areas: recreation, education, procreation, or occupation	0.400

4	Limited ability to perform most activities in all of the following areas: recreation, education, procreation, or occupation	0.600
5	Needs assistance with instrumental activities of daily living such as meal preparation, shopping, or housework	0.810
6	Needs assistance with activities of daily living such as eating, personal hygiene, or toilet use	0.920

Chapter 4

Results and Discussion

4.1 General

Crisis of safe drinking water has taken a serious turn in the Aila affected area. It is learnt that the tube-well water in the shallow and deep aquifer level in this area is highly saline, therefore, cannot be used for drinking. Most of the rivers, canals, ponds and wetlands in the coastal belts are heavily affected by salinity. Excessive salinity also makes water of the local ponds undrinkable. Many people have to walk a long distance to fetch relatively safe water from a few ponds and canals. The water of these ponds are dirty, turbid and smell which cause various water-borne diseases specially diarrhea. However, water borne diseases can be reduced by improving water quality and preventing casual use of other unimproved sources of water. For instance, simple filtration and disinfection of water at the household level dramatically improves the microbial quality of water, and reduces the risk of diarrheal disease at low cost.

4.2 Field performance of developed water treatment units

Three water treatment filter units were set in three households in Kaligonj region and another two were set in coastal area of Koyra. These filter units denoted by unit 1 to 5. Pond’s water was used as raw in these filter units. It should be mentioned that, unit 1 and unit 2 were used same pond’s water as raw. Similarly, unit 4 and unit 5 used same raw water. After installation, these filters were monitored and samples were collected 3 times for laboratory test. Water quality parameters like pH, Colour, Turbidity, Dissolved Oxygen (DO), Chloride, Alkalinity, Hardness, COD, TC, and FC were checked.

4.2.1 pH

The pH of solution is a measure of Hydrogen (H^+) ion concentration, which is, in turn, a measure of acidity. Pure water dissociates slightly into equal concentrations of hydrogen and hydroxyl (OH^-) ions. Low pH is associated with high acidity, high pH with caustic alkalinity. It is expressed on a scale ranging from 0 to 14. The recommended pH range for treated drinking water is 6.5 to 8.5. The pH value of raw water was 8.5 for unit 1 and 2, 7.61 for unit 3 and 8.8 for unit 4 and 5. After filtration, 7.20, 7.01, 8.34, 7.61 and 8.41 were found for unit 1, 2, 3, 4 and 5 respectively. After removing lime units were coated with mortar and then cured them. The slight increase in the pH of water passed through the ceramic filter is due to presence of mineral Wollastonite in the ceramic. Wollastonite is slightly soluble and alkaline. So, it may partly dissolve in the water as it passes through the filter causing a minor pH shift. All pH values of filtrated water were found within recommended value of Bangladesh standard. Figure 4.1 represents the pH values of raw and treated water of unit 1, 2, 3, 4 and 5.

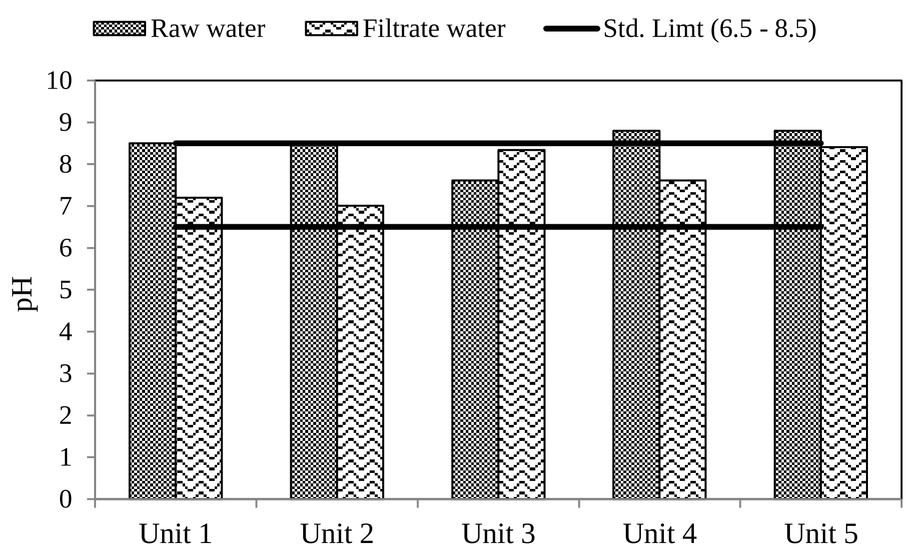


Figure 4.1 pH of raw and filtrated water

4.2.2 Colour

Colour in water is primarily found due to the presence of coloured organic substance, metals such as Fe, Mn or highly coloured industrial wastes. The supply of visibly coloured water to consumers may not be acceptable to them for aesthetic reason. Colour caused by suspended matter is defined as "apparent colour" can be removed by centrifugation or filtration. Most consumers can detect a colour of 15 pt.co (allowable limit according to WHO) in a glass of water. The colour of raw water was found 0 pt.co for unit 1and 2, 696 pt.co for unit 3 and 82 pt.co for unit 4 and 5. After filtration, these values stood on 0 except unit 5 which are within the Bangladesh standard. From Figure 4.2 noticed that colour of raw water about 696 pt.co was found for unit 3. Because, cow or goat shed, garbage place is situated besides of this pond. Water was contaminated by mixed of urine and waste of garbage. Figure 4.2 showed the graphical presentation of colour of raw and filtrated water.

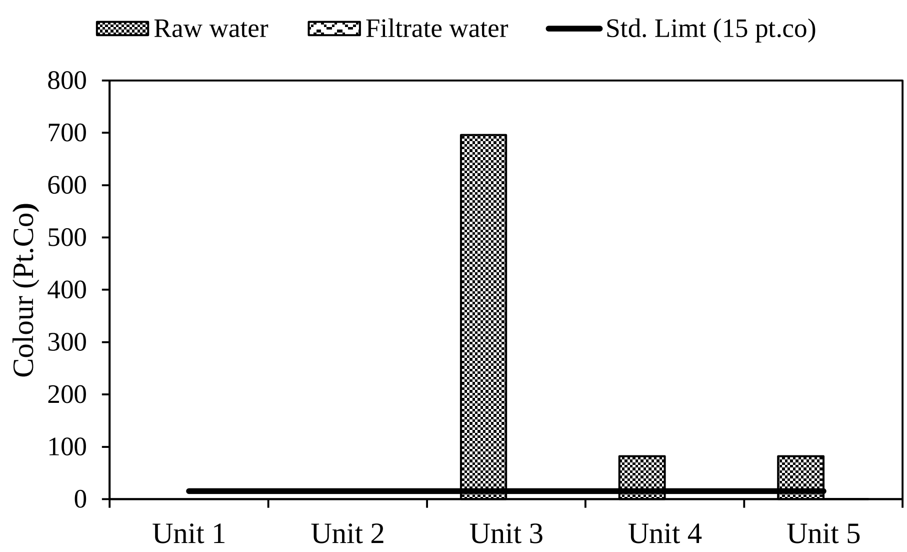


Figure 4.2 Colour of raw and filtrated water

4.2.3 Turbidity

Turbidity occurs in most surface water due to the presence of suspended clay, silt, finely divided organic and inorganic matters, plankton (algae) and micro-organisms. Turbidity is an expression of certain light scattering and light absorbing properties of water sample and depend in a complex manner, on such factors like the number, size, shape and refractive index of particulate matter present in water. The turbidity of raw water was 15.5 NTU for unit 1and 2. Consequently, 92.4 NTU for unit 3 and 15.9 NTU for unit 4 and 5. After filtration, these values stand on 1.74, 2, 2.71, 1.4 and 1.42 NTU respectively which are within Bangladesh standard limit. From Figure 4.3 noticed that turbidity of raw water about 92.4 NTU was found for unit 3. Because cow or goat shed, garbage place situated beside of this pond. Water was contaminated by mixing of urine and waste of garbage. Figure 4.3 represents the turbidity values of raw and treated water.

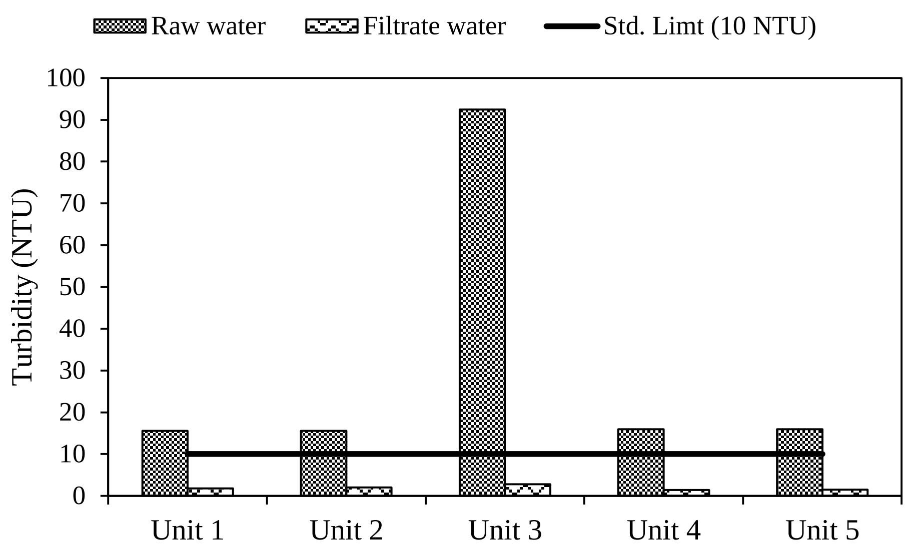


Figure 4.3 Turbidity of raw and filtrated water.

4.2.4 Dissolve Oxygen (DO)

Dissolve Oxygen (DO) content in surface water depends on the amount and characteristics of the unstable organic matters in the water. It is an important factor in assessing the self-purification capacity of polluted streams. DO is the fundamental requirement for aquatic life and hence the ability of the water to maintain certain minimal concentration of DO is vital importance. DO in water affects oxidation-reductions involving arsenic, iron, manganese, copper and compounds containing nitrogen and sulfer. A high DO level in water supply is good because it makes water taste better. Figure 4.4 shows the graphical presentation of values of DO in raw and filtrated water. The dissolve oxygen of raw water varied between 5.65 to 9.67 mg/l. DO 5.65 mg/l remarks, water is not good and this value is also below the standard limit of Bangladesh. DO after filtration respectively 7.46, 7.67, 7.58, 7.96 and 7.88 mg/l for unit 1, 2, 3, 4 and 5.

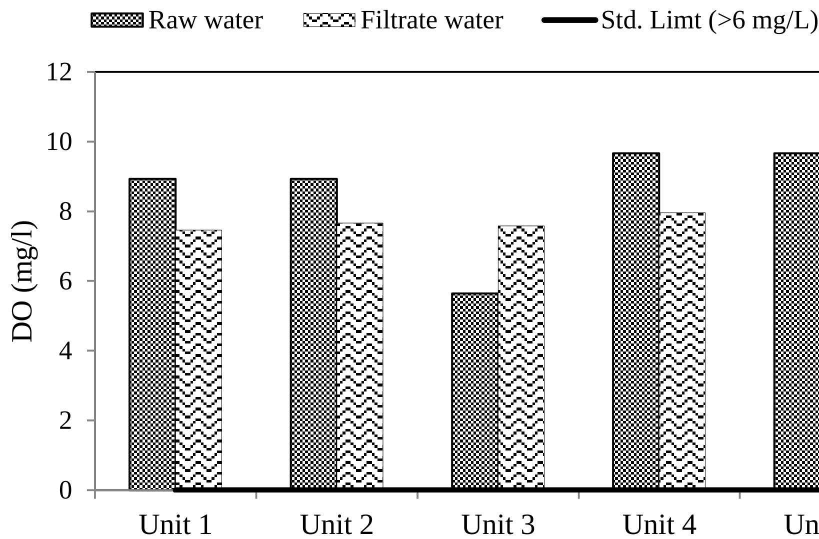


Figure 4.4 DO of raw and filtrated water.

4.2.5 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is usually defined as the amount of oxygen required by micro-organisms while stabilizing decomposable organic matter under aerobic condition. The BOD test is the measurement of oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matters present in a waste (or water sample), under conditions as similar as possible to those that occur in nature. The allowable value of BOD in Bangladesh is 0.2 mg/l for drinking purposes. The BOD_5 of raw water was 1.99mg/l for unit 1 and 2. Similarly, this value was found 1.73 mg/l for unit 3 and 1.14 mg/l for unit 4 and 5 respectively. In addition, BOD_5 after filtration was found 0.23, 0.08, 1.2, 0.28 and 0.31 mg/l for unit 1, 2, 3, 4 and 5 respectively. These values are almost nearby Bangladesh standard. Figure 4.5 shows the graphical presentation of BOD_5 of raw and filtrated water.

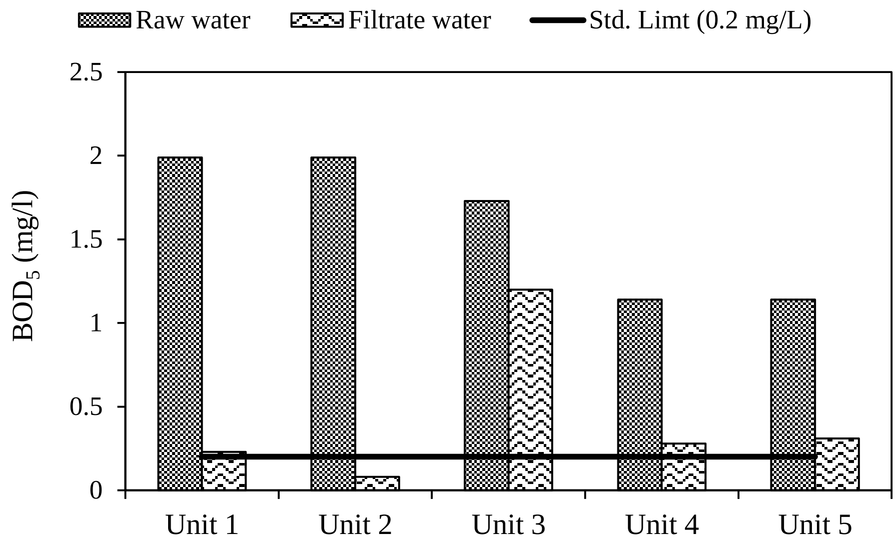


Figure 4.5 BOD_5 of raw and filtrated water.

4.2.6 Total Coliform (TC)

The most common and widespread danger associated with natural water bodies such as rivers and streams, is contamination by sewage, human and animal excrement or other wastes. Coliform organisms (total coliform) are characterized broadly by their ability to ferment lactose in culture at 35˚C or 37˚C and include E. Coli Citrobacter, Enterobacter and Klebsiella species. The coliform group (specifically Escherichia Coli) normally inhabits the intestinal track of man and other warm-blooded animal and is excreted in large numbers with the faces. The presence of such organisms indicates faecal pollution and therefore, intestinal pathogens could be present. Thus, the coliform group is of great importance in the microbiological quality analysis of water. The total coliform of raw water was 170, 170, 410, 82 and 82 N/100 ml for unit 1, 2, 3, 4 and 5 respectively. After filtration, total coliform was found 2, 0, 0, 2 and 4 N/100ml for unit 1, 2, 3, 4 and 5 respectively. Figure 4.6 shows the graphical presentation of TC of raw and filtrated water.

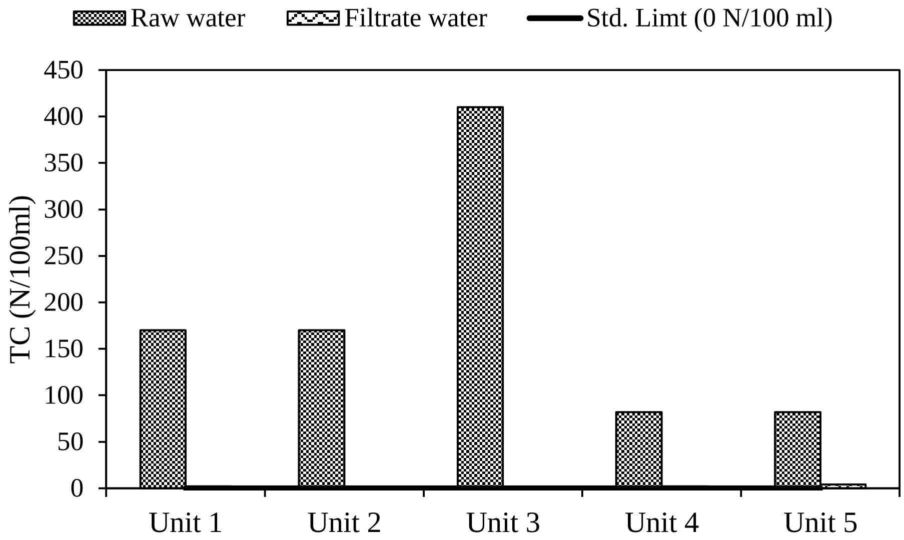


Figure 4.6 Total coliform (TC) of raw and filtrated water.

4.2.7 Faecal Coliform (FC)

Since coliform bacteria are derived not only from the faces of warm blooded animals but also from vegetation and soil, therefore, to confirm any positive fecal pollution, further tests are done to ascertain the presence of fecal coliform organisms. Fecal coliform organisms, which are exclusively of fecal origin, are characterized as coliform organisms that are able to ferment lactose at 44˚C or 45˚C. Fecal pollution of water may introduce a variety of intestinal pathogens e.g., bacterial, viral or parasitic. The fecal coliforms in raw water were 70, 70, 360, 8 and 8 N/100 ml for unit 1, 2, 3, 4 and 5 respectively. After filtration, these values placed on 0 N/100 ml except unit 3. Figure 4.7 shows the graphical presentation of FC of raw and filtrated water.

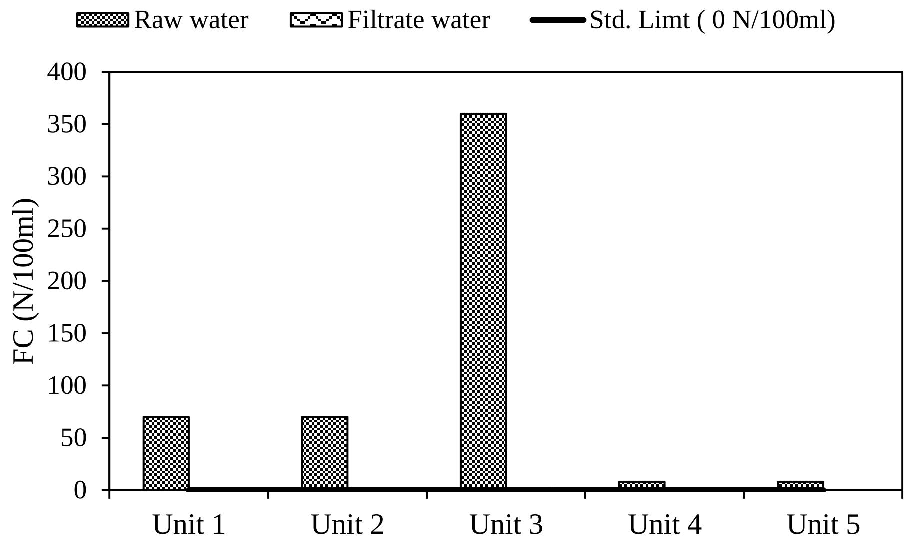


Figure 4.7 Faecal coliform (FC) of raw and filtrated water.

4.2.8 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) test is widely used as a means of measuring the organic strength of domestic and industrial wastes chemically. This test allows measurement of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water. It is based upon the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions. The COD of raw water were found 256, 256, 512, 160 and 160 mg/l for unit 1, 2, 3, 4 and 5 respectively. After filtration, these values varied between 96 to 192 mg/l. Figure 4.8 shows the graphical presentation of COD of raw and filtrated water.

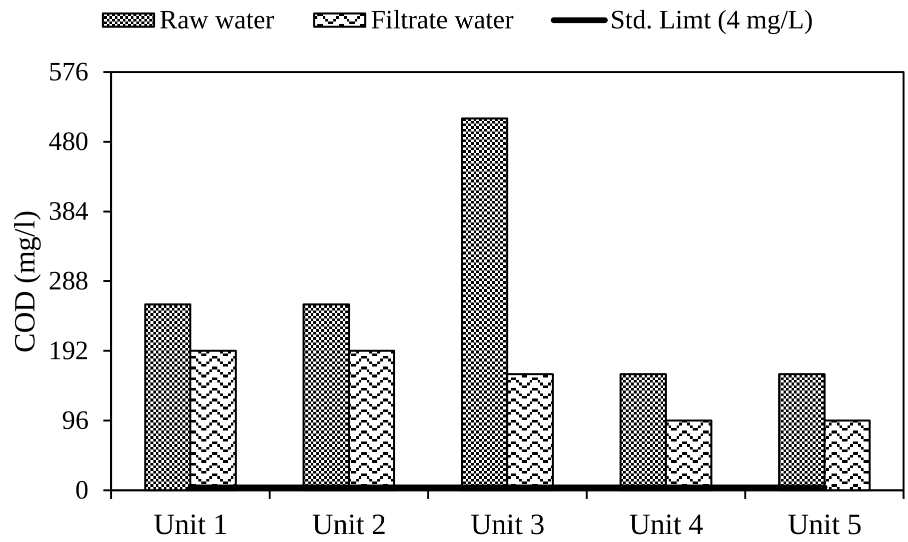


Figure 4.8 COD of raw and filtrated water

4.2.9 Salinity (Chloride)

Chloride is widely distributed in nature, generally in the form of Sodium Chloride (NaCl), Potassium Chloride (KCl) and Calcium chloride ($CaCl_2$). Chlorides occur in natural water in widely varying concentrations. Upland and mountain supplies are quite low in chlorides, whereas river and ground water usually have a considerable amount. Sea and ocean water represent the residuals resulting from partial evaporation of natural water that flow into them and chloride level are very high. The allowable limit of chloride in Bangladesh is 150 – 600 mg/l for drinking purposes but highly saline affected coastal region this limit up to 1000 mg/l. The chloride of raw water was 70, 70, 2030, 592.5 and 592.5 mg/l for unit 1, 2, 3, 4 and 5 respectively. After filtration, these values were found 72.5, 67.5, 1210, 645 and 320 mg/l respectively. Figure 4.9 shows the graphical presentation of chloride of raw and filtrated water.

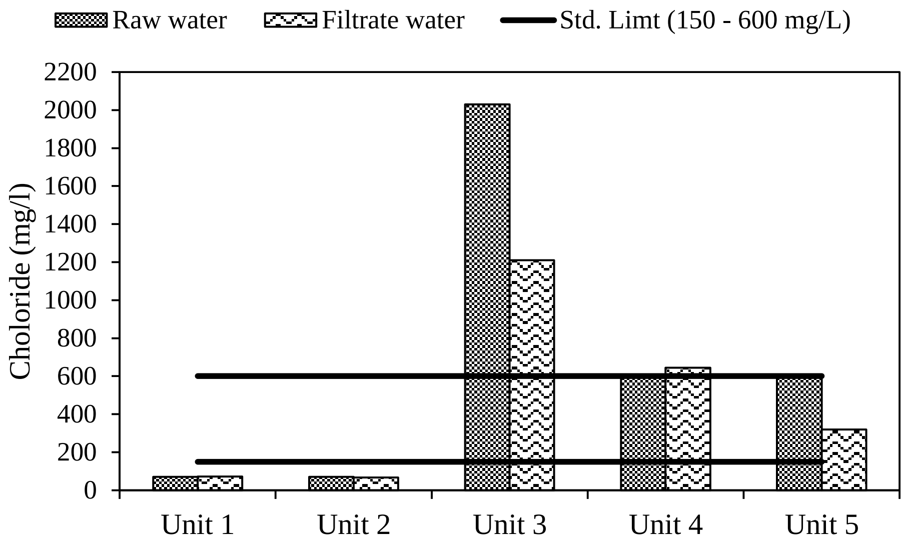


Figure 4.9 Chloride of raw and filtrated water

4.2.10 Hardness

Hard water is generally considered to be that water that require considerable amount of soap to produce a foam or lather and that also produce scale in hot water pipes, heaters, boilers and other units in which the temperature of water is increased materially. The principle hardness causing cations are the divalent Calcium and Magnesium, Strontium, Ferrous ion and mangenues ion. A hardness level of about 100 mg/l of $CaCO_3$ provides an acceptable balance between corrosion and the problem of encrustation. The Bangladesh drinking water quality standards recommended hardness between 200 – 500 mg/l. The hardness of raw water was 319.47, 319.47, 1365.85, 245.39 and 245.39 mg/l for unit 1, 2, 3, 4 and 5 respectively. Respected values 180.57, 171.3, 926, 171.3 and 224 mg/l were found for unit 1, 2, 3, 4 and 5 after filtering the raw water. Figure 4.10 shows the graphical presentation of hardness of raw and filtrated water.

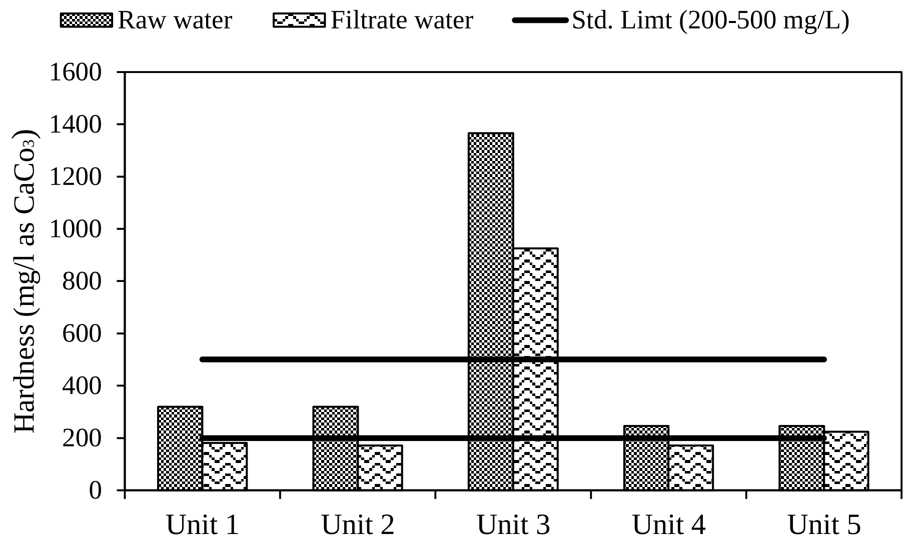


Figure 4.10 Hardness of raw and filtrated water

4.2.11 Alkalinity

Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to neutralize acids. In large quantities, alkalinity imparts a bitter taste to water. The principle objection to alkaline water, however, is the reactions that can occur between alkalinity and certain cations in the water. The resultant precipitate can foul pipes and other water system appurtenances. The allowable limit of alkalinity in Bangladesh is 100 mg/l for drinking purposes. The alkalinity of raw water was 100, 100, 155, 105 and 105 mg/l for unit 1, 2, 3, 4 and 5 respectively. After filtration, these values placed on between 80 to 125 mg/l. Figure 4.11 shows the graphical presentation of alkalinity of raw and filtrated water.

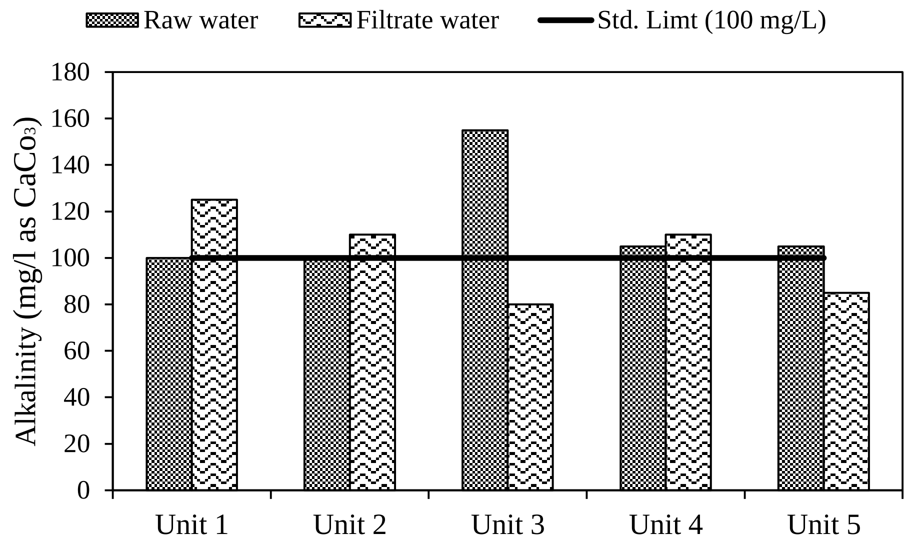


Figure 4.11 Alkalinity of raw and filtrated water

Table 4.1 Lab test of raw and filtrate water

Parameter	Unit	Raw Water			Filtrated Water					Bangladesh standard
		Unit 1 & 2	Unit 3	Unit 4 & 5	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	
pH	-	8.50	7.61	8.8	7.20	7.01	8.34	7.61	8.41	6.5 – 8.5
Colour	Pt.Co	0	696	82	0	0	0	0	1	15
Turbidity	NTU	15.5	92.4	15.9	1.74	2	2.71	1.4	1.42	10
DO	mg/l	8.93	5.65	9.67	7.46	7.67	7.58	7.96	7.88	6
BOD_5	mg/l	1.99	1.73	1.14	0.23	0.08	1.2	0.28	0.31	0.2
TC	N/100 ml	170	410	82	2	0	0	2	4	0
FC	N/100 ml	70	360	8	0	0	2	0	0	0
COD	mg/l	256	512	160	192	192	160	96	96	4
Salinity	mg/l	70	2030	592	72	67	1210	645	320	150 - 600
Hardness	mg/l	319	1365	245	180	171	926	171	224	200 - 500
Alkalinity	mg/l	100	155	105	125	110	80	110	85	100

4.3 Performance of HWTU and Market filter

This study also tested treated water which was filtrated through market filter. The difference between HWTU and market filter unit are given below.

Table 4.2 Difference between HWTU and Market filter.

HWTU	Market filter
Bacteria removal efficiency about 98%.	Bacteria removal efficiency about 85%.
Flow rate approximately 2300 ml/hr.	Flow rate approximately 1100 ml/hr.
No problems in taste and odor. Turbidity, colour and other parameters are lies between Bangladesh standard.	Turbidity, colour, taste and odor problems were found due to using lime in raw and storage chamber.

To initiate with, in this study collected filter units from market as well as tested water quality parameters. Market filter units were coated by lime of inner surface of filter units. As result, users faced some problems like odor and taste. Similarly, turbidity and colour were rose very much. In this study, removed this lime from inner surface market filter units and coated by mortar. In addition, candle of market filter units replaced by candle of HWTU due to efficiency and slow flow rate. Noticed that, 1.1 L/Hr. was found from market filter unit, in while 2.3 L/Hr. from HWTU. Because of the surface area of HWTU's candle is greater than market's candle.

4.4 Sanitation and Hygiene Practices in the study area

Improve sanitation facilities and change the habit is not possible at quick time. Toilet facilities and hand washing can great role to reduce or prevent diarrhea besides safe water supply. Some cases two or more households share a latrine. These latrines are not health improved. Moreover, some households use latrine at day not night. But About 61.64% have simple pit latrine, 29.06% have pour flush latrine and 9.31% have no latrine average in Koyra and Kaligonj coastal region. Before study, about 8.26% people use soap and 13.74% people use ash and about 42% use soil for hand washing after defecation. In addition, remain percent of people use only water for hand washing after defecation. In this study, arranged awareness program at three times in three month successively as well as gave soap and toilet cleaner among households for improvement sanitation and hygiene practices. About 12.26% people use soap, 16.84% used ash and about 44% used soil for hand washing after defecation through awareness campaign program about safe drinking water collection, management, improved sanitation and hygiene practices during study.

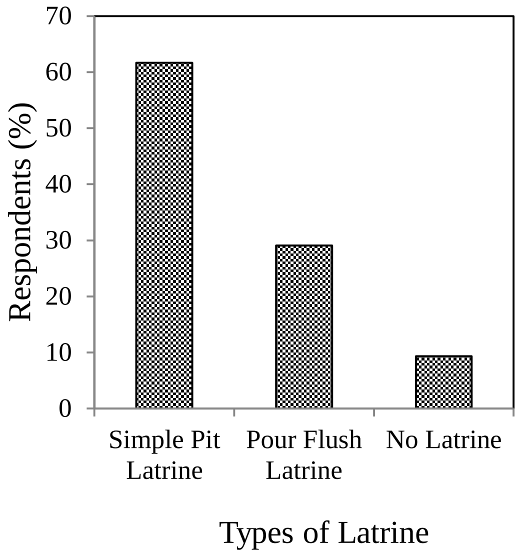


Figure 4.12 Respondents of latrine

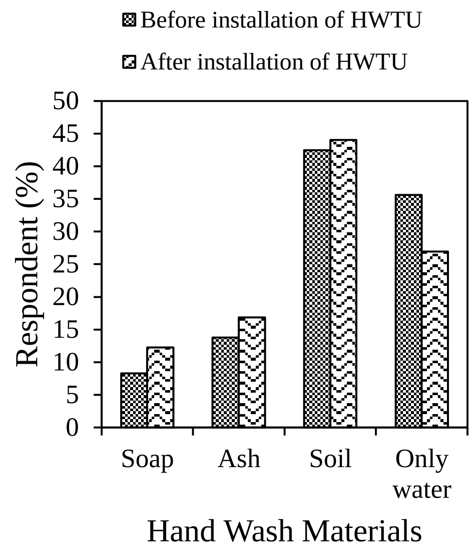


Figure 4.13 Hand wash improvement

4.5 Disability Adjusted Life Years (DALYs)

The effects of scarcity of safe drinking water and sanitation facilities people in south-western region suffer from diarrhea. Health condition has been found as vulnerable where the outbreak of water borne diseases like skin disease, diarrhoea, dysentery, cholera, fever is very common. After hit of Aila and Sidar, ground and surface water sources both are affected by saline. Some ponds have in locality which is free from saline. Ensure safe drinking water, improved sanitation facilities and hygiene practices can reduce DALYs loss due to diarrhoea mostly.

4.5.1 DALYs lost Calculation

Table 4.3 DALYs lost before installation of HWTU-1

				Morbidity										Mortality		
				Diarrhoea affected in last 3 month before installation												
				1st		2nd		3rd			Disability Weight					
Unit	Users ID	Male / Female	Age	Times	Affected days	Times	Affected days	Times	Affected days	Avg. duration	1st	2nd	3rd	Suffered	Gender	Age when died
1	01	M	35	-	-	1	2	1	2	2	-	0.096	0.096	-	-	-
	02	F	30	1	2	-	-	1	2	2	0.096	-	0.096	-	-	-
	03	M	76	-	-	1	2	1	3	2.5	-	0.096	0.4	-	-	-
	04	M	10	1	3	1	2	1	2	2.3	0.22	0.096	0.096	-	-	-
	05	F	6	1	3	-	-	1	4	3.5	0.22	-	0.22	-	-	-
	06	F	6	1	2	1	-	-	2	2	0.096	-	0.096	-	-	-

From Table 4.1 noticed that, time represents episodes of diarrhea in successive month as well as affected day's shows duration. Average duration may be found in two ways. Firstly, total affected days divided by number of month. Secondly, total affected days divided by total times. In this study followed second way to give priority on intensity. Moreover, disability weight provides intensity of diarrhea which depends on physical function. In addition, three columns of disability weight in the table refer month and used value represents weight of disability. DALYs specialist divided six disability classes (table 3.2) and medical experts assigned disability weight from 0 to 1. As an example, for user's identity one here used disability weight 0.096 which was identified on physical condition. According to table 3.2 the performance ability was limited at least one activity in one of the following areas: recreation, education, procreation or occupation as result 0.096 set. Here, disability weight was assumed to consider physical condition of user's identity. Another hand, in this study did not get any death due to diarrhea. As result, the mortality shows as blank.

DALYs Calculation for HWTU-1

DALY = YLL + YLD

Here, YLL = 0, because there had no mortality, No one died due to diarrhea during study time. [See appendix of YLL calculation]

For 1: DALY = 0 + (2*0.096*0.0055) = 0.001

For 2: DALY = 0 + (2*0.096*0.0055) = 0.001

For 3: DALY = 0 + (0.096*0.0068) + (0.4*0.0068)

= 0.0034

For 4: DALY = 0 + (0.22*0.0063) + (2*0.096*0.0063)

= 0.0014 + 0.0012 = 0.0026

For 5: DALY = 0 + (2*0.22*0.0096) = 0.0042

For 6: DALY = 0 + (2*0.096*0.0055) = 0.001

Total DALYs = 0.013

In this study, disability adjusted life years were found 0.013, 0.0074, 0.0081, 0.0056 and 0.008 from five units respectively in existing situation, in while 0.0033, 0.0016, 0.00079, 0.001 and 0.0044 DALYs (Table A1-A9) were originated correspondingly after installation as well as satisfactory functioning of HWTUs. The percentage of improvement of disability adjusted life years were found different from above units. Because, older and children were easily affected by diarrhea with higher disability weight. To the contrary, adults were affected diarrhea with lower intensity as well as short duration. Unhealthy sanitary latrine, unhygienic conditions also responsible for diarrhea.

4.6 DALYs improvement

The high rate of incidence of diarrheal disease and infant mortality in developing countries are attributed to lack of water supply and sanitation. A comprehensive review conducted by Waddington et al. (2009) on the impact of water, hygiene, and sanitation interventions on diarrhea morbidity highlighted the fact that water quality is more important than water supply in reducing diarrhea. However, water borne diseases can be reduced by improving water quality and preventing casual use of other unimproved sources of water. For instance, simple filtration and disinfection of water at the household level dramatically improves the microbial quality of water, and reduces the risk of diarrheal disease at low cost (WHO, 2005). Community education approach is required in order to establish at grassroots level. It is not easy to create an understanding among illiterate people on the relation between the consumption of contaminated drinking water, hygiene practices and the effect of invisible pathogens on human health. The awareness on the importance of treating water before the consumption and adequate hygiene practices such as washing hand with soap however needs to be established before people will use a water treatment method. Such processes for changing habits and establishing new behaviors require much time and intensive coaching from community workers. In this study, tried to awareness among selected households about safe drinking water and storage, sanitation and hygiene practice besides installation of simple water treatment unit for five households. DALYs improvement for five households was about 74.1%.

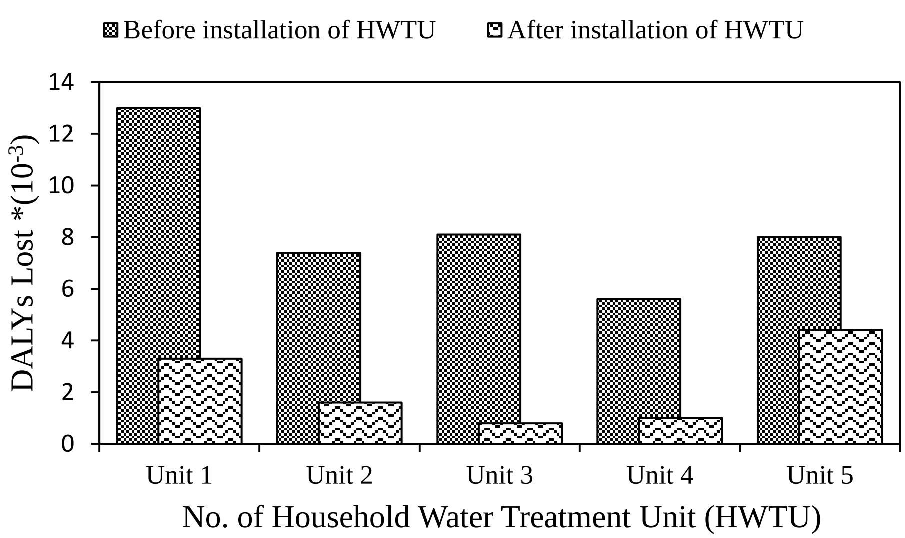


Figure 4.14 DALYs improvement

Noticed from figure 4.14 that, DALYs lost at initial condition was 0.013, but after installation of HWTU-1 this value was placed on 0.0033. For unit -2, DALYs decreased by above 4.5 times higher than existing condition. Moreover, DALYs lost were found 0.0081 and 0.0056 for unit-3 & 4 respectively at before installations of HWTUs, in while DALYs slightly decreased by 0.0073 and 0.0046 separately. Similarly, DALYs reduction was found almost 45% compared with existing condition. Here observed that, DALYs reduction rate differs compared with each other. Because of diarrheal diseases depends on safe drinking water as well as proper sanitation and hygiene practices. Furthermore, children's and older easily affected by diarrhea with severity.

Chapter 5

Conclusions and Recommendations

5.1 General

Diarrhoeal diseases spread through not only by WASH. Food security, unhygienic environment is related to diarrhoeal diseases. But use of household filtration or boiling of water with subsequent safe storage, use of improved sanitation facility and hand washing with soap after contact with excreta can reduce diarrhoea mostly.

5.2 Conclusions

Major results obtained from this study are summarized below-

- According to the first objective microbiological water quality in various sources was found to be varied in the range of 8-360 N/100mL as Faecal Coliform in these study areas. Nevertheless, almost all households were found to have individual toilet facilities while few households had shared toilets. Field survey on toilet facilities in the study area identified that there were 61.64% simple pit latrines, 29.06% pour flush latrines and remaining 9.31% inhabitants had no toilet facilities. At the commencement of this study, it was found that 8.26% population had been using soap, 13.74% using ash, about 42% using soil and rest of percentages using only water for hand washing after defecation.

- According to the second objective total disable adjusted life years (DALY) were found about 0.042 for three months in existing situation in these study areas.

- According to the third objective simple water treatment units or household filters were developed and installed at five locations in the study area. The efficiency of bacteria removal through these filter units were found to be around 98%. An awareness development campaign on hygiene practice was undertaken in this research work and with this initiative the use of soap and ash for hand washing after defecation was found to be increased slightly to 12.26% and 16.84%, respectively. Similarly, about 44% use of soil as hand wash material for hand washing after defecation.

- According to the fourth objective, total disable adjusted life years was found to be 0.01 within three months after the installation of simple household water treatment unit and awareness development campaign. In this context, DALYs improvement was found to be around 74.1% with the adaptation of intervention suggested in this study.

5.3 Recommendations

Improvement of water quality, it not only depends on water treatment unit, hygiene practice can play a great role to improve water quality. Volume capacity of HWTU may be extended. Then numerous of candle will set into chamber. However, improvement of water quality by household's filter is remarkable.

Following are the major recommendations for further study

- In this study, brick chips were used on the candle to prevent algae formation. Other materials such as charcoal, stone chips could be used to prevent algae and improve water quality.
- To determine Ground water quality such as Arsenic, Iron and other water quality parameters.
- To study the performance of candle filter instead of plate filter and to find out water quality.
- To determine DALYs for other diseases.
- To study DALYs performance using other formulas like DALYs $= -\frac{DCe^{-\beta a}}{(\beta+r)^2}\, e^{-(\beta+r)L}\, [\{1+(\beta+r)(L+a)\} - \{1+(\beta+r)a\}]$.

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Appendices

Table A1 DALYs lost before installation of HWTU-2

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month before installation										Suffered	Gender	Age when died
				1st		2nd		3rd		Avg. duration	Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days		1st	2nd	3rd			
2	01	M	40	1	2	-	-	2	2	1.3	0.096	-	0.096	-	-	-
	02	F	30	-	-	2	3	1	2	1.67	-	0.096	0.096	-	-	-
	03	M	18	1	2	-	-	1	1	1.5	0.096	-	0.096	-	-	-
	04	M	15	1	2	1	2	-	-	2	0.096	0.096	-	-	-	-
	05	F	14	1	4	1	2	-	-	3	0.4	0.096	-	-	-	-

Table A2 DALYs lost before installation of HWTU-3

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month before installation										Suffered	Gender	Age when died
				1st		2nd		3rd		Avg. duration	Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days		1st	2nd	3rd			
3	01	M	45	1	2	-	-	2	4	2	0.096	-	0.096	-	-	-
	02	F	40	1	2	1	3	-	-	2.5	0.096	0.22	-	-	-	-
	03	F	70	1	4	1	2	-	-	3	0.4	0.096	-	-	-	-
	04	M	20	-	-	1	2	1	2	2	-	0.096	0.096	-	-	-

Table A3 DALYs lost before installation of HWTU-4

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month before installation												
				1st		2nd		3rd			Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days	Avg. duration	1st	2nd	3rd	Suffered	Gender	Age when died
4	01	M	48	2	4	1	2	-	-	2	0.096	0.096	-	-	-	-
	02	F	42	1	3	-	-	1	1	2	0.096	-	0.096	-	-	-
	03	M	18	1	2	2	4	1	1	1.75	0.096	0.096	0.096	-	-	-
	04	M	15	1	2	2	3	1	1	1.5	0.096	0.096	0.096	-	-	-
	05	F	27	-	-	1	2	2	4	2	-	0.096	0.096	-	-	-

Table A4 DALYs lost before installation of HWTU-5

Unit	No of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month before installation												
				1st		2nd		3rd			Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days	Avg. duration	1st	2nd	3rd	Suffered	Gender	Age when died
5	01	M	50	2	3	-	-	1	3	2	0.096	-	0.22	-	-	-
	02	F	39	1	3	1	2	1	1	2	0.22	0.096	0.096	-	-	-
	03	M	20	-	-	1	2	-	-	2	-	0.096	-	-	-	-
	04	F	1	2	3	1	2	1	4	2.25	0.096	0.096	0.4	-	-	-

Table A5 DALYs lost after installation of HWTU-1

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month after installation												
				1st		2nd		3rd		Average Duration	Disability Weight			Suffered	Gender	Age when died
				Times	Affected days	Times	Affected days	Times	Affected days		1st	2nd	3rd			
1	01	M	35	-	-	-	-	-	-	-	-	-	-	-	-	-
	02	F	30	-	-	-	-	-	-	-	-	-	-	-	-	-
	03	M	76	-	-	1	2	-	-	2	-	0.096	-	-	-	-
	04	M	10	-	-	-	-	-	-	-	-	-	-	-	-	-
	05	F	6	1	4	-	-	-	-	4	0.22	-	-	-	-	-
	06	F	6	-	-	-	-	1	2	2	-	0.096	-	-	-	-

Table A6 DALYs lost after installation of HWTU-2

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month after installation												
				1st		2nd		3rd		Average Duration	Disability Weight			Suffered	Gender	Age when died
				Times	Affected days	Times	Affected days	Times	Affected days		1st	2nd	3rd			
2	01	M	40	-	-	-	-	-	-	-	-	-	-	-	-	-
	02	F	30	1	2	-	-	-	-	2	0.096	-	-	-	-	-
	03	M	18	-	-	-	-	-	-	-	-	-	-	-	-	-
	04	M	15	-	-	1	2	-	-	2	-	0.096	-	-	-	-
	05	F	14	1	2	-	-	-	-	2	0.096	-	-	-	-	-

Table A7 DALYs lost after installation of HWTU-3

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month after installation												
				1st		2nd		3rd			Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days	Total Duration	1st	2nd	3rd	Suffered	Gender	Age when died
3	01	M	45	-	-	-	-	-	-	-	-	-	-			
	02	F	40	-	-	1	1	-	-	1	-	0.096	-			
	03	F	70	1	2	-	-	-	-	2	0.096	-	-			
	04	M	20	-	-	-	-	-	-	-	-	-	-			

Table A8 DALYs lost after installation of HWTU-4

Unit	No. of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month after installation												
				1st		2nd		3rd			Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days	Total duration	1st	2nd	3rd	Suffered	Gender	Age when died
4	01	M	48	1	2	-	-	-	-	2	0.096	-	-	-	-	-
	02	F	42	1	1	-	-	-	-	1	0.096	-	-	-	-	-
	03	M	18	-	-	-	-	-	-	-	-	-	-	-	-	-
	04	M	15	-	-	1	1	-	-	1	-	0.096	-	-	-	-
	05	F	27	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A9 DALYs lost after installation of HWTU-5

Unit	No of users	Male / Female	Age	Morbidity										Mortality		
				Diarrhoea affected in last 3 month after installation												
				1st		2nd		3rd			Disability Weight					
				Times	Affected days	Times	Affected days	Times	Affected days	Avg. duration	1st	2nd	3rd	Suffered	Gender	Age when died
5	01	M	50	1	2	-	-	-	-	2	0.22	-	-	-	-	-
	02	F	39	-	-	-	-	-	-	-	-	-	-	-	-	-
	03	M	20	-	-	-	-	-	-	-	-			-	-	-
	04	F	1	-	-	-	-	1	3	3	-	-	0.4	-	-	-

<u>Questionnaire Survey for WASH</u>

Drinking Water

1. Where do you collect your drinking water?

Ans:

2. Where do you store your drinking water?

Ans:

3. Do you use lid on your storage?

Ans:

4. How many distances from where you collect your drinking water?

Ans:

Sanitation

1. Do you have latrine? Can you show it to me?

Ans:

2. Who uses this latrine?

Ans:

3. Do your children use the latrine? If not, where do they defecate?

Ans:

4. How often do family members use this latrine?

Ans:

Food & Hygiene Practice

1. How do you wash your hands?

Ans:

2. Where do you prepare food for cooking?

Ans:

3. Do you wash your food before cooking?

Ans:

4. Do you wash your hands before food distribution?

Ans:

5. Where do you store your food (cooked/prepared)? How long?

Ans:

6. Do you reheat your stored food?

Ans:

Table A10 Personal information of users

SL No.	Name of Users	Address	Family members	Occupation	Age	Education
01						
02						
03						
04						
05						
06						
07						
08						
09						

Questionnaire Survey for DALYs

Table A11 DALYs information about above users

			Morbidity					Mortality		
SL No	Name of Users	Dirrhoea affected	How many times?	Affected days	Avg. affected days	Needed of others that time?	Activities were stopped?	How many days	Male /Female	Age when died
01										
02										
03										
04										
05										
06										
07										
08										
09										

A scenario: a woman who had moderate depression since she was 20. She commits suicide at age 50. Calculating the YLL.

$YLL = N*L_1$
YLL = years of life lost due to premature death
N = number of deaths
L_1 = standard life expectancy at age of death in years

In context of Bangladesh, life expectancy of men is 69.1 years and women 71.6 years.

Here, N = 1
$L_1 = 71.6 – 50 = 21.6$ years,
YLL = 21.6 years.

Photo Gallery

Figure 01 Raw water Source (unit 1 & 2, Kaligonj)

Figure 02 Raw water source (unit 3, Kaligonj)

April, 2014

Figure 03 Homemade pit latrine (unit 5), Koyra
May, 2014

Figure 04 Offset pit latrine (unit 3, Kaligonj)
April, 2014

Figure 05 Removing lime from filter unit, March, 2014. Kaligonj

Figure 06 1st chamber of filter unit (available in market)

Figure 07 Coating by mortar, March, 2014. Kaligonj

Figure 08 Filtrated water (unit 2), Kaligonj
Julay, 2014

Figure 09 Filtrated water (unit 4), Koyra
August, 2014