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Assessment of Disease Burden from Microbial and Arsenic Contamination of Drinking Water in Dhaka City

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Abstract: *The investigation has been done on the basis of laboratory tests on 60 water samples obtained from several consumer categories of Dhaka city, which includes tap water from residential area provided by the Dhaka Water Supply and Sanitation Authority (DWASA), tube well water consumed by slum dwellers, commercial water supply known as vending water and bottle mineral water at the point of consumption. The aim of the paper has been to compare the quality of drinking water and also to assess microbial and arsenic burden to human health using APSU QHRA (Arsenic Policy Support Unit and Quantitative Health Risk Analysis) model, which has been especially developed in context of Bangladesh for two main parameters arsenic and fecal coliform (FC). Results showed that health risks in Dhaka has been higher for FC not for arsenic as the arsenic concentration has been found too low, mean value ranging from 0 to 2.2 ppb(parts per billion). In 80% of the samples, FC counts have been found more than 50 cfu (colony forming units) per 100 ml, except bottle mineral water. Results of disease burden obtained using the model showed that the people living in studied area have been more susceptible to bacterial and protozoal diseases than viral diseases. Statistical significance test showed that the higher risk has been associated with people living in slum area. The results of this paper will help in enhancing awareness among the consumers and also in drawing attention of health regulatory authorities.*

Keywords: *microbial burden, arsenic, health risk, Bangladesh.*

Introduction

The present study has been planned to monitor the quality of water consumed by the population of Dhaka city for drinking purposes and the impact of the quality of water on health. The population constituted all classes of people including the low income class living in the slum area who had to consume water even though the quality was poor because they could not afford bottled or vending water from the market.

According to WHO (World Health Organization) 2004 a, each year 36000 children under 5 die of diarrhea. They suffer from 3-5 episodes of diarrhea each year; suffer 2-3 days and sometimes more than two weeks resulting in severe dehydration, malnutrition, which may cause death.

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Presence of elevated levels of arsenic in ground water, especially from shallow aquifer has become a major concern in Bangladesh. Since then higher levels of arsenic have been detected in many regions of the country (Khan, A.W. et. al. 1997) and many slum dwellers in Dhaka city use tube well water as well as tap water from Dhaka WASA. In a recent study by the National Institute of Preventive and Social Medicine (NIPSOM), arsenic related diseases termed as arsenicosis have been identified in 37 districts (Ahmed et al. 2000). A total of 6000 cases were identified in 162 villages in 37 districts, mostly in the rural areas. The most common presentations were melanosis, keratosis, hyperkeratosis and depigmentation. Although arsenic concentration in Dhaka has been found below alarming result, the study has been done to assess the present level of arsenic in drinking water at the point of consumption in Dhaka city. From the prospective of human consumption, the most important organisms in water are the pathogens. It has been known that most pathogens that are likely to be transmitted via the water route are shed in human and or animal feces (Le chevalier et al. 1996). The coliform bacterium is most common indicator in use today. So, the aim of the paper has been to explore and compare all types of drinking water sources of Dhaka city and to make a health risk assessment of all the water samples collected from different consumer categories of Dhaka city.

Types of supply in Dhaka city

Presently DWASA can meet only 60 percent of the demand of its service area population (http://www.wasa.gov.tt/). The gap between demand and supply is also rapidly increasing. In Dhaka the water supply is ground water based and 82 percent of the supply is abstracted from the underground aquifers. The rest 18 percent is derived from surface water sources. Available data indicates that due to overexploitation ground water table is falling rapidly and ground water is being mined significantly. This had not only made water supply system unsustainable but the city had been exposed to environmental hazards.

Methodology

All the sampling and preservation procedures for water samples have been done according to the standard methods for the examination of water according to the guidelines of drinking water quality given by WHO.

Sampling Plan

The study has been done on different consumer category. Out of these 60 samples. 33.33% has been from residential, 33.33% has been from slum and 33.33% from commercial supply. Two different residential areas have been studied. One located in Mohammadpur has been termed as residential area 1 and other in Dhanmondi as residential area 2. Slum area in Mohammadpur has been termed as slum area 1 and

that in Lalbagh has been termed as slum area 2. Vending water companies have been Apang, Sabeel, Nilgiri, Niagra, Enueres, Pure Water Company, Reliable Pure Drinking Water, Ahad Company, Shamim Water Supply and Drops Drinking Water. Tested mineral water companies have been 'Shanti', 'Acme', 'Spa', 'Jibon' , 'Pran', 'Mum', 'Fresh' , 'Libra', 'Fyne' and 'Duncan'. Water samples have been taken to Environmental laboratory of BUET for tests.

Sample Collection Procedure

Plastic Poly Ethylene (PET) bottles have been washed with sampling water for three times and rinsed carefully. Sampling for bacteriological analysis has been done especially with care, ensuring that there is no external contamination of the samples. During sample collection, ample air space has been left in the bottle to facilitate mixing by shaking, before examination. Sample bottles have been kept close until filled without rinsing and caps have been replaced immediately. In case of tap water samples, tap has been opened fully and water has been let to run to waste for two to three minutes. For determination of arsenic concentration, spectrophotometric method (APHA, 1998) and for Bacteriological analysis membrane filter method has been used.

Use Of APSU QHRA Model and Statistical Analysis

The APSU QHRA model provides a prediction of disease burdens associated with water supplies based on reference pathogens and arsenic. Disease burden has been expressed in disability adjusted life year (DALY) as recommended by WHO (2004b). Arsenic DALYs have been estimated considering skin, lung and bladder cancers as end points. Microbial DALYs has been estimated with 3 reference pathogens (a composite model bacterial pathogen, rotavirus, and Cryptosporidium parvum). DALYs are calculated using E .coli (or thermotolerant coliform) concentration as input data and the relationship between these organisms and the reference organism had been derived from the long term observation of the sewage. The arsenic and microbial DALYs of the concerned water supply are estimated and added to determine the total DALY. This model has been used because the model can estimate the disease burden from a single measurement of microbial quality. To observe the overall quality, samples have been compared by Student's t- test (Steel and Torrie, 1960). It is commonly applied if the value of a scaling term in the test statistic has been known. Here, $p< 0.05$ was considered the minimum value for statistical significance.

Results

Chemical Analysis

Water samples have been tested for arsenic contamination and Fig.1 shows the mean value of arsenic concentration. Arsenic concentration of all the samples has

been much below the acceptable value of WHO which is 10 ppb and 50 ppb for Bangladesh Standard (Ahmed, 2006).

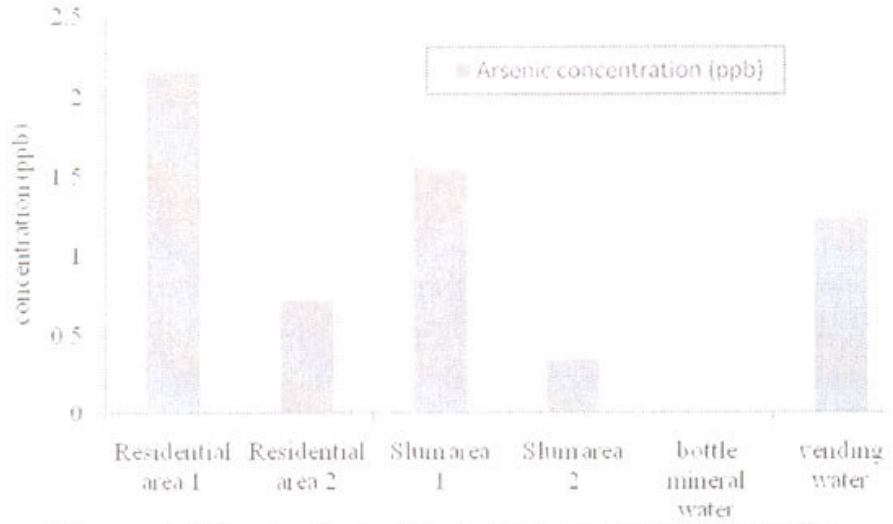

Figure 1. Mean value of Arsenic concentration (ppb).

The highest mean value of arsenic has been found 2.15 ppb in Residential Area 1 and 1.55 ppb in Slum Area1 which showed there was significant difference ($p < 0.05$) of Arsenic concentration between residential and slum area. Both these value obtained has been too low to cause hazard.

Bacteriological Analysis

Results of microbial examination of the samples collected showed that most of these water samples have been positive for fecal coliforms except the bottle mineral water.

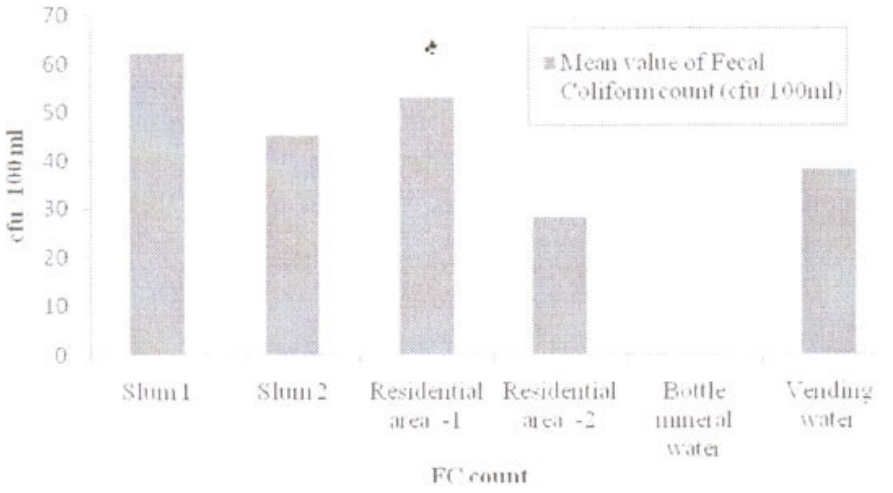

Figure 2. Mean value of Fecal Coliform (cfu /100 ml)

According to fig. 2. Slum Area 1 and Residential Area 1 have the greatest microbial burden.

Comparison of Different Categories

The samples collected from both the residential and slum areas have been found 100% positive for faecal coliform. 60% of the total samples have been found contaminated by coliform bacteria. Residential area 1 and 2 are 100% positive for FC where as the samples of slum areas has been found TNTC (too numerous to count). Bottle mineral water has been free from microbial contamination but the vended water samples has been found contaminated which had bacterial growth as high as 200 per 100 ml in some samples.

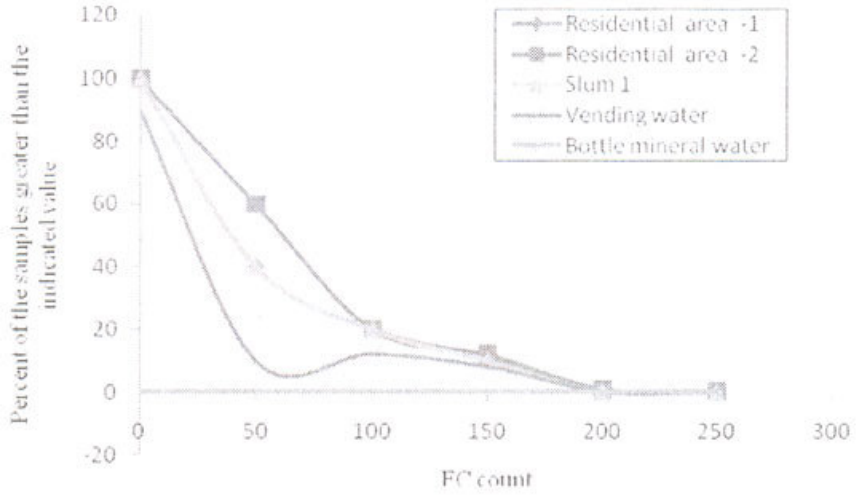

Figure 3. Percent of the samples greater than the indicated values versus FC count.

Fig.3 shows, except bottle mineral water 20% of the samples of the remaining categories have FC count more than 150. Again, 60% of the samples of studied Residential Area1, Residential Area 2 and Slum Area 1 have FC count more than 50.

Assessment of Disease Burden by APSU QHRA Model

Using APSU QHRA Model Both Arsenic and Microbial Disease Burden can be assessed. Fig.4 shows the user interface of APSU QHRA model with data of Vending water.

Microbial indicator data	*Arsenic data*
Enter observed values in the columns below	
Ensure any data not required is removed from the columns	
Substitute text data (e.g. TNTC, <, >) with numeric values	
101	*1.56*
67	*3.41*
22	*1.93*
20	*1.83*
55	*2.02*
48	*0.8*
4	*0.39*
10	*0.72*
65	*0.95*
11	*0.69*

Simple statistics for data in columns A and B

	Median	95%ile	Minimum	Maximum
Microbial (A)	*35*	*85.7*	*4*	*101*
Arsenical (B)	*1.255*	*2.7845*	*0.39*	*3.41*

Percentile: *95%* *ile*

Figure 4. User interface of APSU QHRA model of Vending Water.

Putting the experimental results in both the columns A and B, maximum, minimum and statistical mean value have been calculated. The model gives the disease burden in terms of viral burden, bacterial burden, protozoal burden and total burden. Finally from graphical interface as shown in Fig. 5 disease burden for arsenic as well as fecal coliform has been found for Vending Water. Protozoal and bacterial disease burden has been predicted to be a greater proportion of the total DALYs. Arsenical burden has some contribution to the total DALYs and is well below the guideline values both for 10 μg/l and 50 μg/l arsenic GV. The water samples are subjected to more microbial related health risk than arsenic.

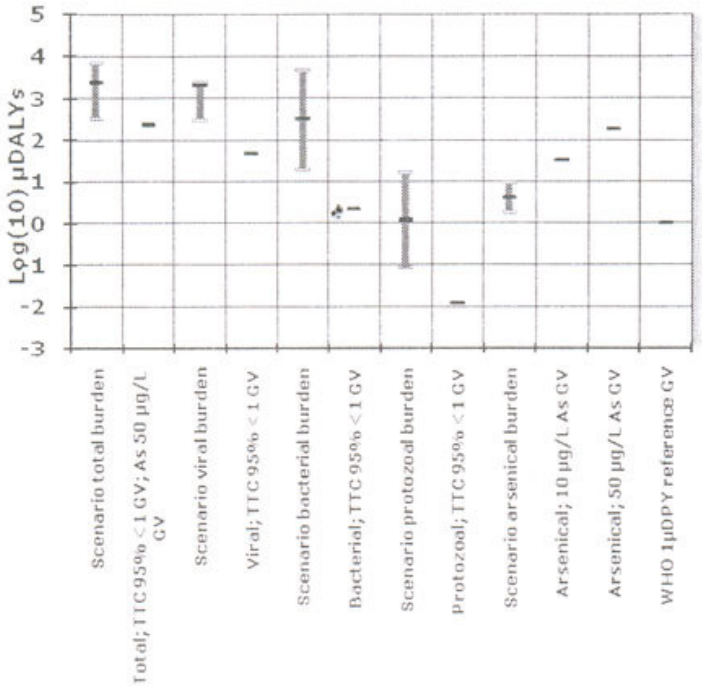

Figure 5. Assessment of disease burden of Vending Water.

Residential Area 1: The range of disease burden as well as guideline values are shown in Fig.6 which indicates that bacterial and protozoal DALYs are greater that Viral DALYs. So the consumers are more susceptible to bacterial and protozoal diseases. Viral, bacterial and protozoa burden has been more than the guideline values. Arsenical burden is well below the guideline value and do not pose any health risk. So, Vending water is not safe due to microbial contamination.

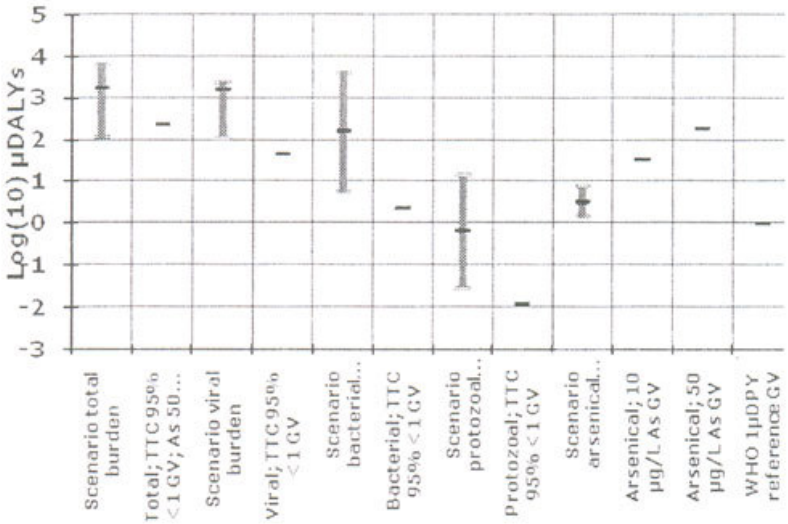

Figure 6. Assessment of disease burden of Residential Area 1.

Residential Area 2: In total burden, bacterial and protozoal burden has been predicted to be of greater proportion. Fig.7 shows, viral burden has some proportion in the total DALYs. Virus, bacterial and protozoa burden has been found to be greater than the specified guideline value. The scenario of arsenical burden has been found to be less than both the guideline values.

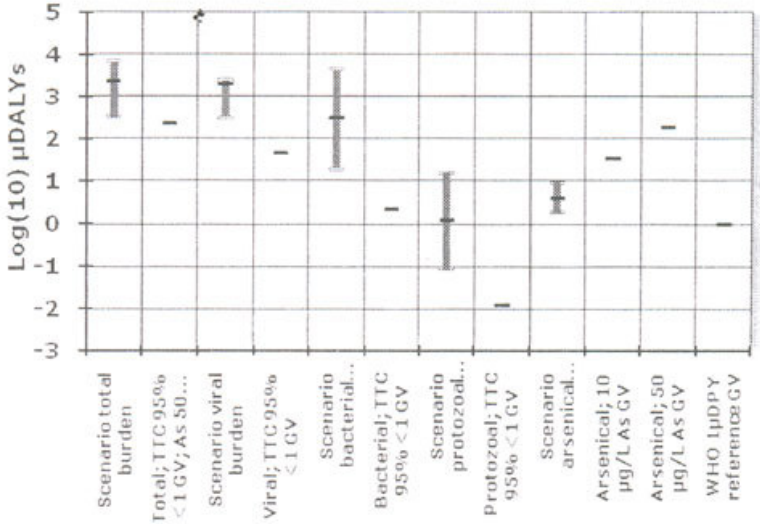

Figure 7. Assessment of disease burden of Residential Area 2.

Slum area 1: It can be seen from Fig. 8 shows both protozoal and bacterial burden has significant contribution to the total DALYs. Bacterial and protozoal burden has almost same contribution in total DALYs. So, the people living in slum area 1 are more susceptible to bacterial diseases than viral diseases. Arsenical burden has very narrow range and is less than the guideline value, although some data collected include water sample from tube well water. So the samples have been safe from the health risk due to arsenic.

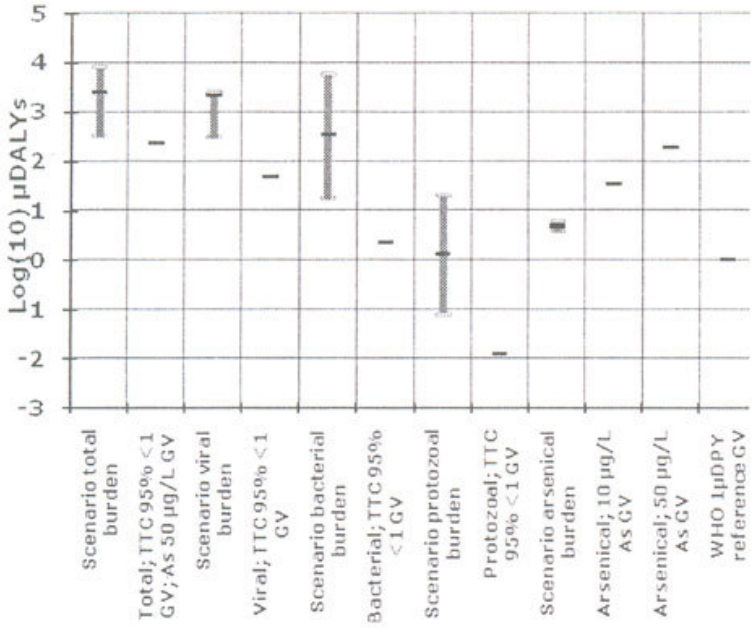

Figure 8. Assessment of disease burden of Slum Area 1.

Slum area 2: For this category, viral burden has the greater contribution to the total burden as compared to other category as shown in Fig. 9. So, people living in slum area 2 may be affected by viral diseases. The arsenical burden was well below all the guideline values. So the water samples have been safe from arsenical health hazard but pose some health risk due to microbial contamination.

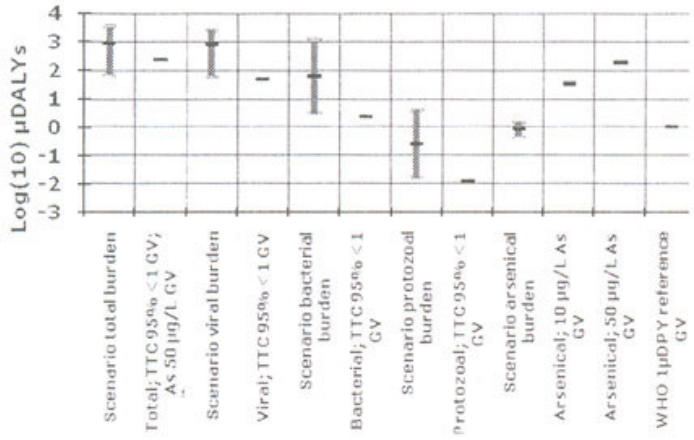

Figure 9. Assessment of disease burden of Slum Area 2.

Bottle Mineral Water: Protozoal and viral burden has greater contribution in the total DALY. Bacterial burden has a very negligible contribution in the total burden and has been lower than the guideline value. Arsenical burden has no contribution in the total DALY and has been much lower than the guideline value. So the water samples have been free from both risks.

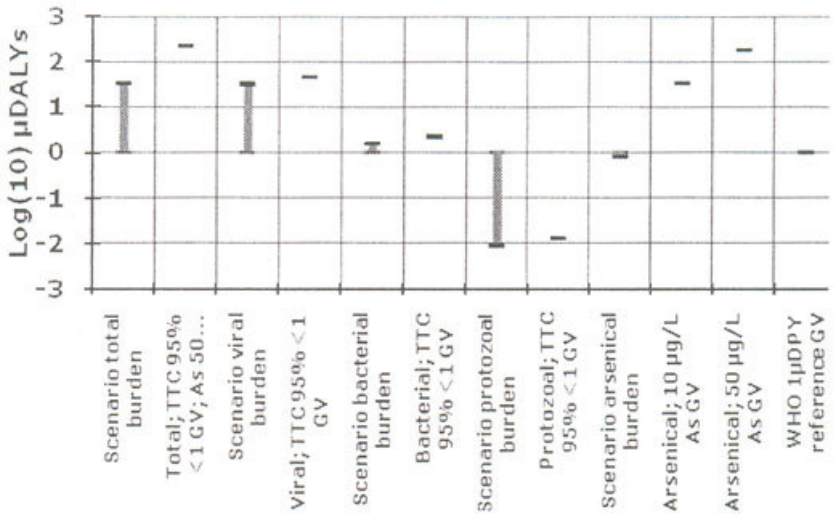

Figure 10. Assessment of disease burden of Bottle Mineral Water.

A summary of total microbial DALY is presented in Tab.1 which shows Microbial DALY has been found highest for slum area 1. Among the residential area the one located in Mohammadpur had been found more vulnerable.

Table 1. Comparison of Microbial DALY for different consumer categories

Area	Minimum (cfu/100 ml)	Maximum (cfu/100 ml)	Mean (cfu/100 ml)	Total Microbial DALY
Slum 1	20	160	61.6	2433.22
Residential -1	4	101	53	2361.95
Residential -2	4	65	27.6	1186.68
Bottle mineral water	0	0	0	0
Vending water	0	200	36.85	1723.36

Although the mean values of individual area and total microbial DALY showed higher concentration of FC in slum area (table 1) but comparison of the percent of samples greater than the indicated value versus FC count (fig. 3) showed that the most vulnerable area was residential area-2.

Conclusion And Recommendation

The important findings are as below:

- Except the bottle mineral water the microbial contamination has been found in all the samples. Although the highest magnitude of FC has been found in the slum areas but the percent of the samples greater than the indicated value VS FC count showed that the most vulnerable has been the residential areas.
- Water samples from vendors have showed higher concentration of fecal coliform even up to 200 per 100 ml. Many vendors supply water in crisis areas but vending water has been found unsafe for human consumption.
- The highest risk associated is due to microbial contamination as arsenic concentration in Dhaka water supply has been too low to cause hazard.
- It has been found that the slum dwellers consume inferior quality water as maximum value of FC was found in the slum area. They have lesser opportunities to improve their condition and they are at the highest risk.

The following are the recommendation for improving the water quality:

- Periodic estimation of some important parameters like bacterial load especially indicating fecal coliforms both at the source and at the consumers end must be carried out.
- Strong policy and law should be enforced to ensure the quality of the bottle mineral water and vending water.
- Urban poor deserve special attention as almost 25-30 % of the city population live in the slums and do not have the adequate access to the safe water.

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