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Quality Analysis of Drinking Water Provided for the Readymade Garment Workers in Dhaka, Bangladesh

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ABSTRACT: Readymade garment industries are the prominent economic sector for Bangladesh as well as scoping the huge working area for workers. But health condition of workers, drinking water quality, and proper maintenance of the environmental parameters are not well monitored. This study aims to assess the physio-chemical and bacteriological quality of drinking water provided for the garment workers in Dhaka. Ten garment industries were pre-selected for the water quality analysis and three drinking water samples from each industry were taken for further analysis. Physio-chemical parameters viz pH, TDS were measured by probe method and Total harness and Chloride of the water samples were measured by titrimetric method, respectively. Biological parameters viz Total coliforms, Fecal coliforms, Total aerobic bacteria count, Fecal streptococci, *Pseudomonas spp.,* and *Vibrio Cholerae* were determined through standard procedure. Results show that pH (6.7±0.05 to 7.4±0.20), TDS (126.2±8.42 to 217.9±3.60 mg/L), Total Hardness (92±7.07 to 275±21.22 mg/L), and Chloride (8.5±0.95 to 46.5±3.27 mg/L) are within the acceptable limit. Bacteriological results show that Total coliform ($1.05\times10^3\pm0.071\times10^3$ to $2.16\times10^3\pm0.084\times10^3$ CFU/100 ml), Fecal coliforms (145±2.828 to 249±21.213 CFU/100 ml), and Total aerobic bacteria count (2152.5±399.51 to 5540.5±185.97 CFU/100 ml) are higher than the standard limits. *Pseudomonas spp.* was also present in all drinking water samples but Fecal streptococci and *Vibrio Cholerae* were absent in all water samples. Bacteriological analysis shows that sources of drinking water are contaminated and proper maintenance and screening facilities should be improved.

Keywords: biological parameters, contamination, physicochemical parameters.

INTRODUCTION

Readymade garment (RMG) industry is the principal sector in terms of achieving foreign currencies in Bangladesh. At present, 5001 garment industry are running in Bangladesh (EBP, 2012) and more than eighty percent of the foreign money is coming from RMG sector (Islam and Chowdhury, 2014). The readymade garment (RMG) sector of Bangladesh initiated its journey in the late 1970s and within a short time contributed a major role in the economy regarding export earnings, generation of employments, reduction of poverty, and women's empowering (Rahman and Hossain, 2010). Out of total four million workers working in RMG sector, 90% are female workers who come from rural areas (Islam and Chowdhury, 2014). Statistics show that since 2002 to 2014 the average export of readymade garment industry expanded significantly in Bangladesh. The reasons behind this are the increased quality of the products, benevolence of the companies to the buyers, and availability of the efficient and cheap labor (Islam and Chowdhury,

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2014). Although the contribution and dedication of the RMG workers of Bangladesh are enormous and undoubtedly immeasurable, their living, socio-economic, and socio-environmental conditions are quite vulnerable. They have to live hand to mouth and are incapable of maintaining their daily needs through their wages (Ahmed and Raihan, 2014).

The readymade garment workers in Bangladesh cannot imagine having minimum health care, medical facilities, hygienic residents, proper sanitation facilities, nutritious foods, and safe drinking water. Their working environmental condition is not good enough. The garment workers of Bangladesh work from early morning till evening in a congested area where there is absence of sufficient ventilation and as a result they are infected with different microbial diseases (Ahmed and Raihan, 2014). According to Nahar *et al*. (2010) the working style of the garment factories result in intense health effects of the workers and the health problems are headache, malnutrition, musculoskeletal pain, eye strain, less appetite, chest pain, fainting, diarrhea, jaundice, food poisoning, asthma, fungal infection, helminthiasis, dermatitis, etc. Housing, water, and sanitation are the key factors related to the socio-economic status of the garment workers (Islam and Chowdhury, 2014).

Unfortunately, in Bangladesh, the garment workers have relatively less access to this vital factors that result in different waterborne and sanitation absence's related diseases. The BBC online news (2013) reported that around 600 garment workers became ill by consuming contaminated drinking water supplied by the factory near the capital, Dhaka. As all the garment workers are very poor, they are unable to buy safe drinking water and use the factories supplied water. They often suffer from various intestinal diseases. The present study was conducted to assess the quality of drinking water supplied for readymade garment workers near Dhaka city, the capital of Bangladesh, by determining some physio-chemical parameters and microbiological status of the supplied water as a case study.

METHODOLOGY

Sample collection

Ten representative industries were selected for the drinking water sources from Dhaka city (Fig. 1) and three water samples were collected from each industry for the water quality analysis. Drinking water samples were collected from the drinking water sources of industries through a pre-washed, poly-propylene bottles followed by standard procedure (APHA, 2012).

Analysis of physio-chemical parameters

The pH of all water samples was determined using pH meter (Ecosce Eutech, model no. 6, Singapore). TDS of all water samples was determined by HANNA, HI-8734 Romania branded meter. Total hardness was measured of the water by EDTA complexometry titration method (Eaton *et al*., 1995). Chloride of the water samples was measured by the titrimetric method followed by Clarke (1950).

Determination of biological parameters

Membrane filters (MF) method described by Noble et al. (2003) was strictly followed; 100 ml of each water sample was filtered through sterile membrane which retained the bacteria on its surface. The membrane was removed aseptically and placed on a MacConkey medium that was then incubated at 37°C for 24 hrs. Coliform colonies (indicating fecal contamination) grow on the surface of the membrane. According to Momtaz *et al*. (2013) *Vibrio cholera* of the water samples were determined. Fecal streptococci was determined by membrane filtration method (Cohen and Shuval, 1973). Total aerobic bacteria was calculated by heterotrophic plate count method reported in Martin *et al*. (2004). *Pseudomonas spp.* was enumerated by the standard procedure of APHA (2012).

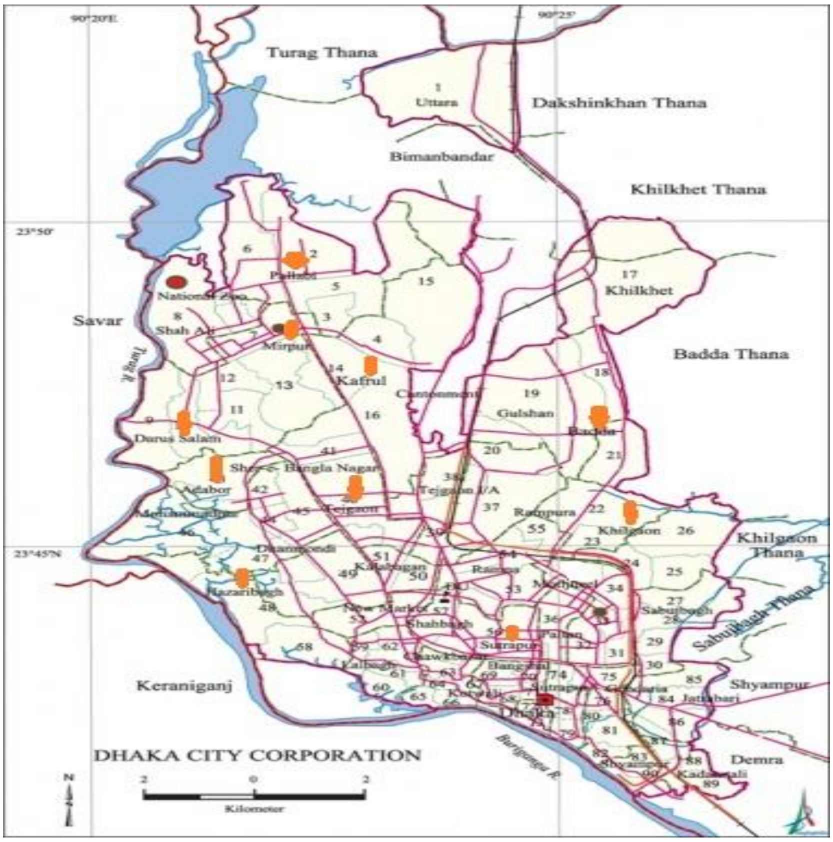

Fig. 1. Water sampling collection area in Dhaka city

RESULTS AND DISCUSSION

Physio-chemical characteristics of drinking water

pH values of all industries are shown in Table 1, showing that pH is in the range of 6.7±0.05 to 7.4±0.20. All the water sources maintain guideline pH value recommended by the DoE and WHO (Table 1). The pH values of all samples of supplied WASA water in Khulna were found in permissible range of 6.5-8.5 according to WHO (2006) recommended values with a varying range 6.76 to 7.78 (Fahmida *et al*., 2013). Zuthi *et al*. (2009) measured water quality parameters in CWASA's supply, 7.24 pH was reported in this study. Adhikary *et al*. (2013) studied the shallow groundwater quality of Khulna district, listed 7.8 pH in the range of guideline value. In coastal region of Bangladesh, higher pH level is reported in the drinking water (Islam *et al*. 2010). Sabrina *et al*. (2013) analyzed WASA supplied drinking water around Dhaka. They reported the pH range of 7.0 to 7.8 in their studied water samples. Rasul and Jahan (2010) studied the drinking water sources of Rajshahi City, Bangladesh and got a positive result regarding pH value.

Dhingra *et al*. (2014) studied the quality status of potable water of Jaipur, India and found the pH range in the guideline values**.** Okodoma *et al*. (2014) analyzed the potable water in Nigeria for 4 consecutive years. They found the pH range in between 6.25-7.25. In Cameroon, pH range was found 5.9 to 7.9, deviation found compared to WHO guidelines (Sorlini *et al*., 2013). In Ethiopia, tap water samples had mean pH value around neutrality (pH= 7.85) ranging between 7.4 and 8.14. (Yasin *et al*., 2015). In Greece, pH value of groundwater was 7.45 in the range of WHO guidelines (Papaioannou *et al*., 2010). Memon *et al*. (2011) analyzed drinking water quality of Pakistan. They found the pH in range of 7.90 to 9.90, higher than the guideline values. The pH values were between 5.1 and 6.9 in supplied drinking water in Cameroon conducted by Temgoua (2011). Das *et al*. (2014) studied the physio-chemical parameters of Tripura, India, and reported the higher level than the standard level. In Ghana, Nkansah *et al*. (2010) studied quality of water from Hand-Dug Wells and found the pH value in range of 6.0-7.0. In Haryana, India, pH range was 6.0-8.0 in drinking water supply, studied by Rout and Sharma (2011). In Badan city, Pakistan, mean pH value found 8.28 in drinking water supply reported in Ahmed *et al*. (2013). In Pakistan, pH range was found in the range of 7.0-7.5 listed by Mohsin *et al*. (2013). Bohara (2015) calculated the drinking water in Nepal and the pH range within the limit.

To determine the dissolved solid contents in any water source TDS is a significant parameter. TDS range was 126.2±8.42 to 217.9±3.60 mg/L (Table 1), revealing that the TDS of drinking water sources are below the DoE and WHO guidelines (Table 1). Several studies have been conducted in Bangladesh. Adhikary *et al*. (2013) studied the supplied water of Khulna city corporation, Bangladesh, and found 1043 mg/L in the water samples. In Chittagong regions, 710.87 mg/L TDS was found (Zuthi *et al*., 2009). Range of TDS value was 210 to 1870 mg/L in Khulna WASA of Bangladesh (Fahmida *et al*., 2013). TDS in drinking water at academic institutions of Tangail Municipality was 194 mg/L (Sultana *et al*. 2013). Dhingra *et al*. (2014) studied the potable water in India and reported 82 to 117 mg/L in the analyzed samples. Several studies were carried out in India and found 138.82 to 490.81 mg/L, 127 to 1034 mg/L, 31 to 1128 mg/L, respectively reported by Rout and Sharma (2011), Shah *et al*. (2012), and Shrivastava *et al*. (2015). Range of TDS value was 290 to 595 mg/L and mean value 438.50 mg/L in Pakistan reported by Mohsin *et al*. (2013) and Ahmed *et al*. (2013), respectively. In Nigeria, Oluyemi *et al*. (2010) analyzed local Government water sources and reported 37.80 to 622.50 mg/L TDS whereas in Cameroon 300 mg/L TDS was listed (Emile Temgoua, 2011).

Table 1. Physio-chemical and Biological parameters of supplied drinking water of Readymade Garment industries, Dhaka

Sample ID	pH	TDS (mg/l)	Chloride (mg/l)	Total Hardness (mg/l)	Total coliforms (CFU/100 ml)	Fecal coliforms (CFU/100 ml)	Total aerobic bacteria count (CFU/100 ml)	Fecal streptococci (CFU/ 100 ml)	Pseudomonas spp.	Vibrio Cholerae
IW-1	6.7±0.05	136.5±5.30	8.5±0.95	92±7.07	$1.05\times 10^3 \pm 0.071\times 10^3$	224.5±50.20	5540.5±185.97	Nil	Present	Nil
IW-2	6.7±0.25	154.1±5.84	30.8±2.030	104±22.62	$1.5\times 10^3 \pm 0.050\times 10^3$	145±2.82	3488.5±167.59	Nil	Present	Nil
IW-3	7.0±0.10	171.±9.95	23.9±1.42	160±14.15	$2\times 10^3 \pm 1.061\times 10^3$	170.5±10.60	4493±45.25	Nil	Present	Nil
IW-4	6.7±0.21	126.2±8.42	26.7±0.36	195±77.78	$2.125\times 10^3 \pm 0.530\times 10^3$	168.5±26.16	3179.5±311.84	Nil	Present	Nil
IW-5	7.2±0.10	154.3±21.0	46.5±3.27	120±28.28	$1.125\times 10^3 \pm 0.007\times 10^3$	199±48.08	4467.5±140.71	Nil	Present	Nil
IW-6	7.4±0.21	179.6±1.70	28.8±3.67	202.5±31.82	$1.39\times 10^3 \pm 0.212\times 10^3$	180±14.15	2152.5±399.51	Nil	Present	Nil
IW-7	6.9±0.05	204.1±9.55	27.8±0.89	266±1.45	$2.16\times 10^3 \pm 0.084\times 10^3$	201±28.28	3282±73.54	Nil	Present	Nil
IW-8	6.8±0.05	217.9±3.60	35.6±2.30	256±15.55	$1.395\times 10^3 \pm 0.078\times 10^3$	249±21.21	4284.5±51.61	Nil	Present	Nil
IW-9	7.4±0.20	139.3±4.40	28.7±6.75	275±21.22	$1.275\times 10^3 \pm 0.388\times 10^3$	203.5±33.23	3061.5±259.50	Nil	Present	Nil
IW-10	6.8±0.15	144.7±1.58	23.1±0.75	265±7.07	$1.48\times 10^3 \pm 0.113\times 10^3$	146.5±4.94	5315.5±198.60	Nil	Present	Nil
DoE standard	6.5-8.5	1000	150-600	200-500	0	0	-	0	-	-
WHO standard	6.5-8.5	1000	150-600	200-500	0	0	-	0	Absent	Absent

Total hardness range was 92±7.07 to 275±21.22 mg/L found in the drinking water sources of industries (Table 1). Water sources of industries including IW-1 to IW-5 are deviated from the guideline values but IW-6 to IW-10 is in the guideline range (Table 1). Total hardness in Chittagong areas was found 68 mg/L (Mamun *et al*., 2015). Zuthi *et al*. (2009) also reported the hardness value as 8384 mg/L. Haydar *et al*. (2009) analyzed the drinking water quality of Pakistan and listed the hardness value in range of 117 to 230 mg/L. Shah *et al*. (2012) reported the hardness value 464 mg/L in India. Several studies were conducted in Nigeria by Chinedu *et al*. (2011), and Okomoda *et al*. (2014). Chloride contents of the samples are determined and maximum 46.5±3.27mg/L was found in IW-5, minimum 8.5±0.95 found in IW-1 (Table 1), lower than the standard limit (Table 1).

Biological characteristics of drinking water

Total coliform was found $1.05\times10^3\pm0.071\times10^3$ to $2.16\times10^3\pm0.084\times10^3$ CFU/100 ml in different garment industries of Dhaka city (Table 1). Total coliform act as an indicator denotes that disease organisms may present in the water, whereas low total coliform suspects low disease organism and high coliform counts result in higher probability of diseases. In this study, drinking water is vulnerable in terms of total coliforms as it is higher than the guideline values (Table 1). Microbiological study of supply water in Dhaka city showed that all the water sources were found to be contaminated with total coliform (Acharjee *et al*., 2011). Maximum 335 CFU/100 ml total coliform was found in supplied water of Khulna WASA of Bangladesh (Fahmida *et al*., 2013). Maximum 9.67 CFU/100 ml total coliform were found in Tap water reported by Yasin *et al*., (2015). Islam *et al*., (2010) studied the bacteriological safety assessment of municipal tap water and quality of bottle Water in Dhaka City and found maximum 47 CFU/100 ml in mineral water, 1100 CFU/100 ml in filtered, water and 1100 CFU/100 ml in municipal tap water, respectively. Khan *et al*. (1992) studied bacteriological profile of bottled water sold in Bangladesh and also found the total coliform in the water samples. Jolly *et al*. (2013) also studied the current status on bacteriological quality of drinking water of the Jahangirnagar University Campus, Dhaka, Bangladesh, and found the total coliform to be 1.52×10^2 CFU/100 ml in their supplied water.

Ahmed *et al*. (2013b) discussed the risk assessment of total and fecal coliform bacteria from drinking water supply of Badin City, Pakistan. They reported 164.33 CFU/100 ml in drinking water. The results of the bacteriological analysis of drinking water from Mt Darwin exposed that most drinking water sources are contaminated with coliforms (Zvidzai *et al*., 2007). On the other hand, for the quality of drinking water of Kalama region in Egypt, 30% of water sample from public tap water was contaminated with coliform bacteria (Ennayat *et al*., 1988). Bohara (2015) enlisted that 58% water samples are contaminated by total coliforms in Nepal region. Another study of the quality of tap drinking water in Quebec City of Canada showed that 36 and 28% of water samples were contaminated by at least one coliform or indicator bacterium and or at least one pathogenic bacterium (Levesque *et al*., 1994). Several studies also reported coliform presence in their sampled water (Malick *et al*., 1998; Chatterjee *et al*., 2006; Sadeghi *et al*., 2007). Total coliform is not a health threat in itself, it is used to indicate whether other potentially harmful bacteria may be present (USEPA, 2015).

The consumption of drinking water contaminated with pathogenic microbes of fecal origin is a significant risk to human health in the developing world (Davies-Colley *et al*., 2001). Results show that highest fecal coliforms was found in IW-9

(249±21.21CFU/100 ml) and lowest was 145±2.82 CFU/100 ml in IW-2, indicating that there is a greater risk of pathogen present. Sabrina *et al*. (2013) conducted a work regarding fecal coliform count in water of different areas in Dhaka city. They found 2.8×10^3 CFU/100 ml in Basabo, 36 CFU/100 ml in Elephant road, 1.6×10^2 CFU/100 ml in Hazaribagh, Dhaka, respectively. Acharjee *et al*. (2013) assessed bacterial proliferation in municipal water supplied in Mirpur locality of Dhaka City and found fecal coliform in range of 0 to 9.7×10^2 CFU/100 ml. Fecal coliform in the drinking water sources of Jahangirnagar University areas showed that the range of fecal coliform bacteria was 0 to 2 CFU/100 ml (academic building), 0 to 44 CFU/100 ml (student dormitories), and 0 to 20 CFU/100 ml (food shops) (Jolly *et al*., 2013). Shahriyar *et al*. (1994) stated a fecal coliform ranging from 0.03 to 30 CFU/100 ml of locally produced bottled water and 0 to 10 CFU/100 ml of bottled water sold in Bangladesh (Khan *et al*., 1992). Shahidul *et al*. (2014) examined the fecal coliform in the tap water from different restaurants in Dhaka city and also found fecal coliform ranging 0 to 24 CFU/100 ml.

Ahmed *et al*. (2013b) studied the drinking water supply of Badin City, Pakistan, and reported mean 44.45 CFU/100 fecal coliform in the supplied water. Fecal coliform Contamination of drinking water in broiler farms in Iran also indicated the positive result of fecal coliform in water sources (Jafari *et al*., 2006). Amaral *et al*. (1995) assessed the water sources in rural areas and showed that 90% of the water samples from wells and 100% of the samples originated from springs had bacteria indicative of fecal pollution. Fecal coliform levels of surface water 1185 MPN colonies/100 ml was found in Ghana (Omari and Yeboah-Manu, 2012). Goan *et al*. (1992) examined water samples collected from 105 wells of 65 flocks in the United States and reported that fecal coliforms were present in 43% of the samples. Fecal coliform, indicating the occurrence of fecal pollution that could be due to free access of wild and domestic animals to the superficial water sources, disposal of animal excreta and dead carcasses, and even the drainage of human's sewage from the rural villages. Although the superficial water sources are more subjected to fecal contamination, the underground water is also susceptible to this type of pollution (Amaral, 2004). Another important bacteriological analysis shows that total aerobic bacteria count ranging to 2152.5±399.515 to 5540.5±185.969 CFU/100 ml in the drinking water sources (Table 1). In this study, fecal streptococci and *Vibrio Cholerae* was also determined. Results show that there is no occurrence in these water sources and free of contamination of them.

Pseudomonas spp. causes specific health risk to the specific host. All the drinking water sources confirm their presence in the water (Table 1). WHO guideline state that *Pseudomonas spp.* should be absent from drinking water. *Pseudomonas* was also found in drinking water sources of roadside restaurants in Dhaka city (Moniruzzaman *et al*., 2011). Islam *et al*. (2010) carried out the bacteriological safety assessment of municipal tap water and quality of bottle water in Dhaka City. They found microorganisms in tap water comprised *Escherichia coli spp.* (60%), *Klebsiella spp.* (40%), *Enterobacter spp.* (20%), and *Pseudomonas spp*. (70%). Chowdhury *et al*. (2014) analyzed the microbiological quality of Chittagong regions and found the pseudomonas in the deep and shallow tube well water. Ahmed *et al*. (2013c) conducted their research about the microbiological study of drinking water consumed by the habitants of different areas of the Dhaka metropolitan area and results showed that *pseudomonas* was present in the water. They discussed the fecal indicators and bacterial pathogens in bottled water from Dhaka, Bangladesh and found positive presence of *pseudomonas.*

Positive result of their existence in drinking water also enlisted in Omezuruike *et al*. (2008), Chan *et al*. (2007), Venkatesan *et al*. (2014), and Penna *et al*. (2002). Traistaru (2011) conducted a comparative study of the microbial quality of the water cooler dispenser and tap water. He stated that *pseudomonas* was commonly associated with tap water. The range of infections caused by *Pseudomonas spp.* is narrow and related to specific changes in the defense and immune status of the host (Hardalo and Edberg, 1997). *Pseudomonas spp.* like *P. aeruginosa* can cause a wide range of infections and is a leading cause of illness in immune compromised individuals. It can be a serious pathogen in hospitals (Dembry *et al*., 1998). *P. aeruginosa* is also a foremost pathogen in burn and cystic fibrosis (CF) patients and origins a high mortality rate in both populations (Molina *et al*., 1991; Pollack, 1995).

CONCLUSION

This study was conducted in different garment industries with a view to provide a water quality status of supplied drinking water and results show that physio-chemical parameters are within the acceptance limit. In terms of biological analysis, the water quality is not satisfactory because Total coliforms and fecal coliforms are present in the drinking water. *Pseudomonas spp.* was present in all water samples. Though fecal streptococci and *Vibrio Cholerae* were absent in all water samples, overall drinking water quality is not satisfactory. It is being hereby suggested for the regular disinfections, maintenances, and supervisions of water sources, and regular biological assessment of all water sources for drinking should be conducted. Moreover, the authority must pay attention to the regular maintenance of water tank cleaning and should be strict in overall environmental condition of garment industries.

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