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ASSESSMENT OF WATER QUALITY AT CONSUMER LEVEL AND AT SOURCE IN DHAKA CITY

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ABSTRACT

The present study focuses on monitoring the chemical water quality at household level supplied by Dhaka WASA. In this study, five areas (Kallyanpur, Rampura, Malibagh, Baridhara and Uttara) have been selected to assess the water quality over a four-month period (October 2018 to February 2019). The water samples were analyzed for pH, EC, hardness, alkalinity, ammonia, nitrate, phosphate, total chlorine, free chlorine, and chloramines (mono-, di- and tri-chloramines). In order to assess surface water quality at source, data on treated water quality at the Saidabad Water Treatment Plant (SWTP) were collected for the year 2017. In order to assess groundwater quality at source, water samples collected from three deep tubewell (DTW) pump stations located at Bijaynagar, BUET West Palashi Campus and Rampura were analyzed. This study shows that characteristics of water received at consumer-level in different areas of Dhaka city vary significantly, primarily due to variation in the characteristics of DTW water and water supplied from the SWTP. The water samples collected from Rampura and Kallyanpur contained relatively high concentrations of ammonia, free and total chlorine, and chloramines; and concentration of these parameters increased with the progress of dry season (from October to February). This variation closely matches the characteristics of treated water as STWP. The water samples collected from Baridhara, Uttara and Malibagh shows similar chemical characteristics that did not vary significantly with time; groundwater appears to be the predominant source of supply in these areas. Complete lack of chlorine in supplied water in these areas is a concern.

Keywords: *Water quality, Dhaka WASA, Chemical characteristics, Ammonia, Chloramines.*

1. INTRODUCTION

Supply of safe water for drinking and other purposes in Dhaka city appears to be a major challenge nowadays due to escalated pollution of surface water and lowering of ground water level. At present, total population of the Dhaka city is around 18.24 million. This huge population needs a large volume of water for the purpose of drinking and domestic uses. The whole water supply system including collection, treatment and distribution of water is done by Dhaka WASA. The water supplied by Dhaka WASA comprises of both groundwater and treated surface water (primarily from Saidabad Water Treatment Plant, SWTP). Groundwater extracted from deep tubewells (DTW) and treated surface water are fed to the same distribution network that carries it to the consumers. The service area of Dhaka WASA covers more than 360 square km. At present, the service area of Dhaka WASA extends to Mirpur and Uttara in the North and to Narayanganj in the South. For better operation, maintenance, and customer care, the total service area of Dhaka WASA is divided into 11 geographic zones, which includes 10 zones in Dhaka city and 1 zone in Narayanganj. Depending on location, some consumers therefore receive primarily ground water, some receive predominantly groundwater, while others receive mixture of surface and groundwater. The quality of treated surface water at the SWTP depends on the quality of raw water drawn from the Sitalakhya rivers, which varies seasonally. The raw water quality deteriorates significantly in dry season, with very high concentrations of organic matter, ammonia, and dissolved solids. Chlorination carried out at the SWTP are likely to form chloramine due to reaction of chlorine with ammonia. Studies have demonstrated that excessive levels of free chlorine cause a negative impact on human health (Zheng, C. He & Q. He, 2015). Chloramines may cause immune system problem, respiratory problem, skin problem, digestive and gastric problem. That is why it is necessary to monitor the water quality at consumer level as well as at source. A variety of physical, chemical and biological transformations can happen once the water travels through a distribution system.

The overall objective of this study was to assess the quality of potable water at consumer level and at sources in Dhaka city. The specific objectives included: (i) Collection of the water samples from consumers in five different locations distributed over Dhaka city, and analysis of the water samples for selected parameters; (ii) Collection and analysis of groundwater samples from selected DWASA deep tubewell pumps in Dhaka; and (iii) Collection and analysis of water quality data from the Saidabad Water Treatment Plant (SWTP).

2. METHODOLOGY

2.1 The study area

In this study, water samples were collected from 5 different areas of Dhaka City, as listed in Table 1, and shown in Figure 1. These points were selected considering their location with respect to the Saidabad Water Treatment Plant (SWTP). Kallyanpur, Rampura and Malibagh were selected considering that these are located close to the SWTP and the water supplied to these areas are likely to have a significant fraction of water from the SWTP. Baridhara and Uttara were selected considering that these two areas are located away from the SWTP, and are likely to receive water primarily from local DTWs. Ground water samples were collected from 3 different Deep Tube wells in Dhaka City, as listed in Table 2.

Table 1: Location of Water sample collection zones

Collection point	Location	Address
1	Baridhara	Road#05, Baridhara, Diplomatic Zone, Dhaka
2	Uttara	Sector 14, Road 16, Uttara, Dhaka
3	Kallyanpur	Road#01, Kallyanpur, Dhaka
4	Malibagh	D.I.T Road, Malibagh, Dhaka.
5	Rampura	East Rampura Road, Dhaka

Table 2: Location of Deep Tubewell

DTW Identification	Location
1	Bijoynagar
2	BUET West Polashi Campus
3	Rampura

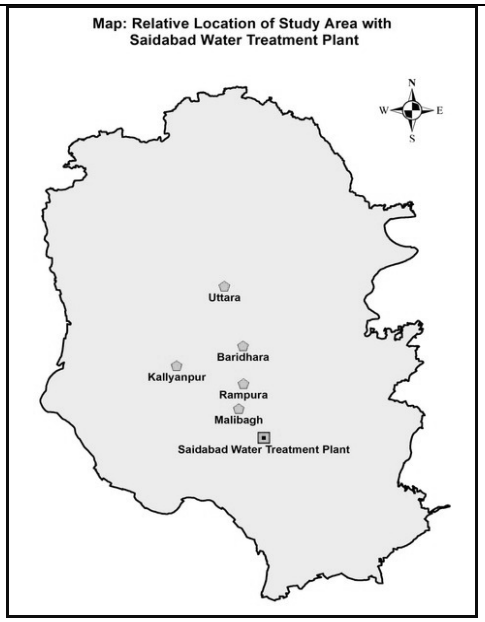

Figure 1: Study areas showing locations of sampling points and location of SWTP

2.2 Collection and Analysis of Water Samples

Water samples were collected from the five areas of Dhaka city roughly at one-week interval in order to monitor the water quality in a continuous manner. Table 3 shows the sampling schedule. All collected samples were transported to the laboratoy within 3 hours of collection, and tested immediately.

Table 3: Sampling and Testing schedule

Sampling cycle	Collection Point	Date of Sampling
1	Baridhara, Kallyanpur, Rampura	09 October, 2018
2	Baridhara, Uttara, Kallyanpur, Rampura	05 November, 2018
3	Baridhara, Uttara, Kallyanpur, Rampura	19 November, 2018
4	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	28 November, 2018
5	Baridhara, Kallyanpur, Malibagh, Rampura	12 December, 2018
6	Baridhara, Kallyanpur, Malibagh, Rampura	09 January, 2019
7	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	16 January, 2019
8	Baridhara, Malibagh, Rampura	23 January, 2019
9	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	12 February, 2019

All collected water samples were analyzed for a range of chemical parameters, including pH, electrical conductivity, alkalinity, hardness, ammonia, free chlorine and total chlorine, chloramines (mono, di and tri-chloramine), nitrate and phosphate. pH and EC were measured with a pH meter

(Hach) and EC meter (WTW), respecively. Ammonia was measured by the Nessler method, nitrate by the cadmium reduction method, phosphate by the molybdenum blue method using a spectrophotometer (Hach, DR 6000U). Free chlorine and mono-, di-, tri-chloramines were measured by DPD titrimetric method, following Standard Methods. N, N-diethyl-p-phenylenediamine (DPD) is used as an indicator in the titrimetric procedure with ferrous ammonium sulfate (FAS).All other parameters were measured followoing Standard Methods.

3. RESULTS AND DISCUSSION

3.1 Water Quality at Source

3.1.1 Saidabad water treatment plant (SWTP)

Dhaka WASA supplies 17% of its total supplied water from the SWTP. To evaluate the quality of treated water at SWTP, sever parameters – pH, electrical conductivity (EC), alkalinity, ammonia nitrate, and phosphate - were analyzed based on water quality data collected from Dhaka WASA for the year 2017. This section briefly describes the treated water quality at the SWTP.

The pH of the treated water at the SWTP varied over a narrow range. The maximum value was 7.65, while the minimum was 6.84. The EC measured at SWTP showed a seasonal variation. Relatively higher values were recorded from January to May, i.e., during the peak dry period. The recorded values exceed 1,000 μS/cm during February to April. Higher values of alkalinity were measured in January to mid of April (i.e. the dry season). The maximum alkalinity was recorded in March and the minimum alkalinity was recorded in November.

Figure 2 shows variation of ammonia concentration in treated water at the SWTP in 2017. The treated water contains high concentration of ammonia during the peak dry season (January to April). The maximum value, 12.8 mg/l, was recorded in February. Previous studies showed that the duration of ammonia contamination of the Sitalakhya River is extended and continues from December to April (Serajuddin, 2017). Ammonia concentrations recorded during January to March exceed the Bangladesh drinking water quality standard (0.5 mg/l) by a large margin. The elevated ammonia concentration in the treated water during the dry season coincides with high ammonium concentration in the water of the river Sitalakhya River (Mahbub, Nahar and Ahmed, 2011). Ammonia concentration in both raw water (from Sitalakhya River) and treated water at the SWTP drops sharply with the commencement of wet season.

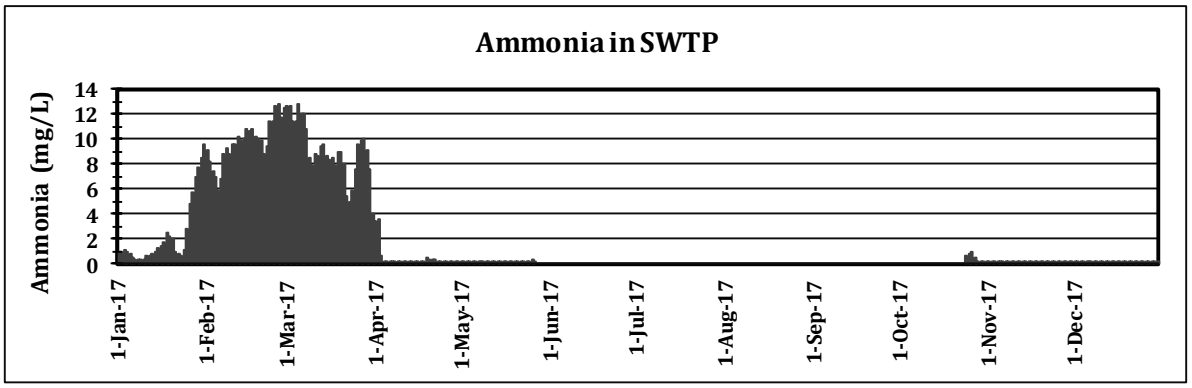

Figure 2: Variation of ammonia in treated water at SWTP in 2017

Higher nitrate concentrations were recorded in treated water as the SWTP from January to May (i.e., during dry season), followed by lower concentration during the wet season (June to October). Concentration of nitrate began to increase again from November, with the commencement of dry

season. Nitrate concentration exceeded the Bangladesh standard (10 mg/l) in March 2017. Microbial activities can get increased due to the presence of Ammonia and Nitrate (Rajala et al., 2015). Elevated concentration of ammonia can affect influenced turbidity, colour, taste, odor, alkalinity, TDS, etc. which are the aesthetic properties of treated water (Hossain, Begum, Fakhruddin & Khan, 2006). Phosphate concentration in treated water follows a trend similar to that of nitrate. High phosphate concentration exceeding the Bangladesh drinking water standard of 6 mg/l was recorded in February and March.

3.1.2 Deep Tube well Pump Stations

The pH value of the three groundwater samples were similar; pH ranged from 6.5 to 7.1. The TDS values lie in a narrow range (230 to 450 mg/l). The alkalinity of the groundwater samples ranged between 140 to 200 mg/l as $CaCO_3$. This values are significantly lower than the alkalinity values of treated water at the SWTP during the dry season. Hardness of the groundwater samples ranged from 104 mg/l (as $CaCO_3$) for the Rampura DTW to 264 mg/l (as $CaCO_3$) for the BUET Campus DTW. Chloride concentration of the groundwater samples ranged from 6 mg/l for the Rampura DTW to 80 mg/l for the BUET Campus DTW. Ammonia concentration ranged from 0.06 mg/l for the Rampura DTW to 0.26 mg/l for the BUET Campus DTW. Nitrate concentration ranged from 0.20 mg/l for the Rampura DTW to 1.4 mg/l for the Bijoynagar DTW, while phosphate concentration ranged from 0.40 mg/l for the BUET Campus DTW to 3.10 mg/l for Rampura DTW. Arsenic concentration in the groundwater samples were all below 2 ppb, well below the Bangladesh standard of 50 ppb. Iron concentrations in all groundwater samples were below the Bangladesh standard of 1.0 mg/l; only the Mn concentration of BUET DTW water exceed the Bangladesh standard of 0.1 mg/l. Very low chlorine (total) concentration, varying from 0.02 to 0.03 mg/l, was detected in the groundwater samples.

3.2 Water Quality at Consumers Level

As treated water from the SWTP gets mixed with extracted groundwater from DTW pump stations in the distribution network, water quality varies significantly at consumer level. Contamination of water may take place in the distribution system and/or in water tanks or reservoirs at household level (Mahbub et al. 2012). Among the areas from where water samples were collected, Rampura, Malibagh and Kallyanpur are located closer to the SWTP, and are likely to receive part of the water supply from the SWTP. On the other hand, Baridhara and Uttara are located far away from the STWO and receive water supply primarily from DTWs. The following section describes the water quality at consumer level, based on the results of analysis of the collected water samples.

pH: pH of water samples collected from Baridhara and Uttara lied in the range 6.8-7.55 and did not vary considerably over the study period. The peak pH was observed in January in both these areas. The average pH value of water samples collected from Kallyanpur frequently exceeded 7; the maximum value was recorded in November in this area. The pH of water samples collected from Rampura area varied over a wider range (6.8-7.84). Peak pH is recorded in the month of December.

Electrical Conductivity: The EC of water samples collected from Baridhara ranged between 293-342 μS/cm and increased slightly with the approach of dry season. The EC of water samples from Uttara remained within a very narrow range of 248-253 μS/cm throughout the study period. In the water samples collected from Kallyanpur, the EC showed a distinct elevation as the dry season approached, with a peak value of 926 μS/cm in February. In Malibagh, EC remained within a narrow range of 311-370 μS/cm. Similar to Kallyanpur, the EC showed an increasing trend from October to February for water samples from Rampura.

Alkalinity: The alkalinity values of water samples from Baridhara and Uttara were similar to those recorded for the DTW water samples. Also, the values were less than the average alkalinity (200 mg/L as $CaCO_3$) of treated water at SWTP. The alkalinity of water samples from Kallyanpur and Malibagh ranged between 150-200 mg/l as $CaCO_3$. The alkalinity of water samples from Rampura showed an increasing trend as dry season progressed from October (48 mg/l as $CaCO_3$) to February

(222 mg/l as$CaCO_3$). This variation shows a strong resemblance with the alkalinity values recorded at SWTP.

Hardness: The hardness of water samples of Baridhara ranges between 50-150 mg/l as $CaCO_3$ in 9 cycles of test; hardness of water samples collected from Uttara varied from 76 to 112 mg/l as $CaCO_3$. For water samples collected from Malibagh, hardness varied over a narrow range of 104 to 130 mg/l as $CaCO_3$. Hardness of water samples from Kallyanpur was a bit higher, and varied from 140 to 230 mg/l as $CaCO_3$. The hardness of water samples collected from Rampur varied from 82 to 296 mg/l as $CaCO_3$; it showed an increasing trend as dry season progressed from October to February.

Ammonia: Ammonia measured in Baridhara water samples were negligible, except for the two samples collected in November and December (see Fig. 3). In Uttara, ammonia concentration exceeded the drinking water quality standard (0.5 mg/l) in November; however, ammonia concentration became negligible (0.02 mg/l) during January-February. In the water samples from Kallyanpur, ammonia concentration was elevated drastically in February, reaching a value of 13 mg/l. A similar trend was observed for Rampura, where ammonia concentration reached a peak value of 12 mg/l in February. These peak values (at Kallyanpur and Rampura) are significantly higher than the groundwater ammonia concentration recorded in this study. On the other hand, these values are comparable to the high ammonia concentration in treated water at SWTP. This suggests that Kallyanpur and Rampura receive water mainly from the SWTP. The presence of ammonia induces objectionable odor at consumer level.

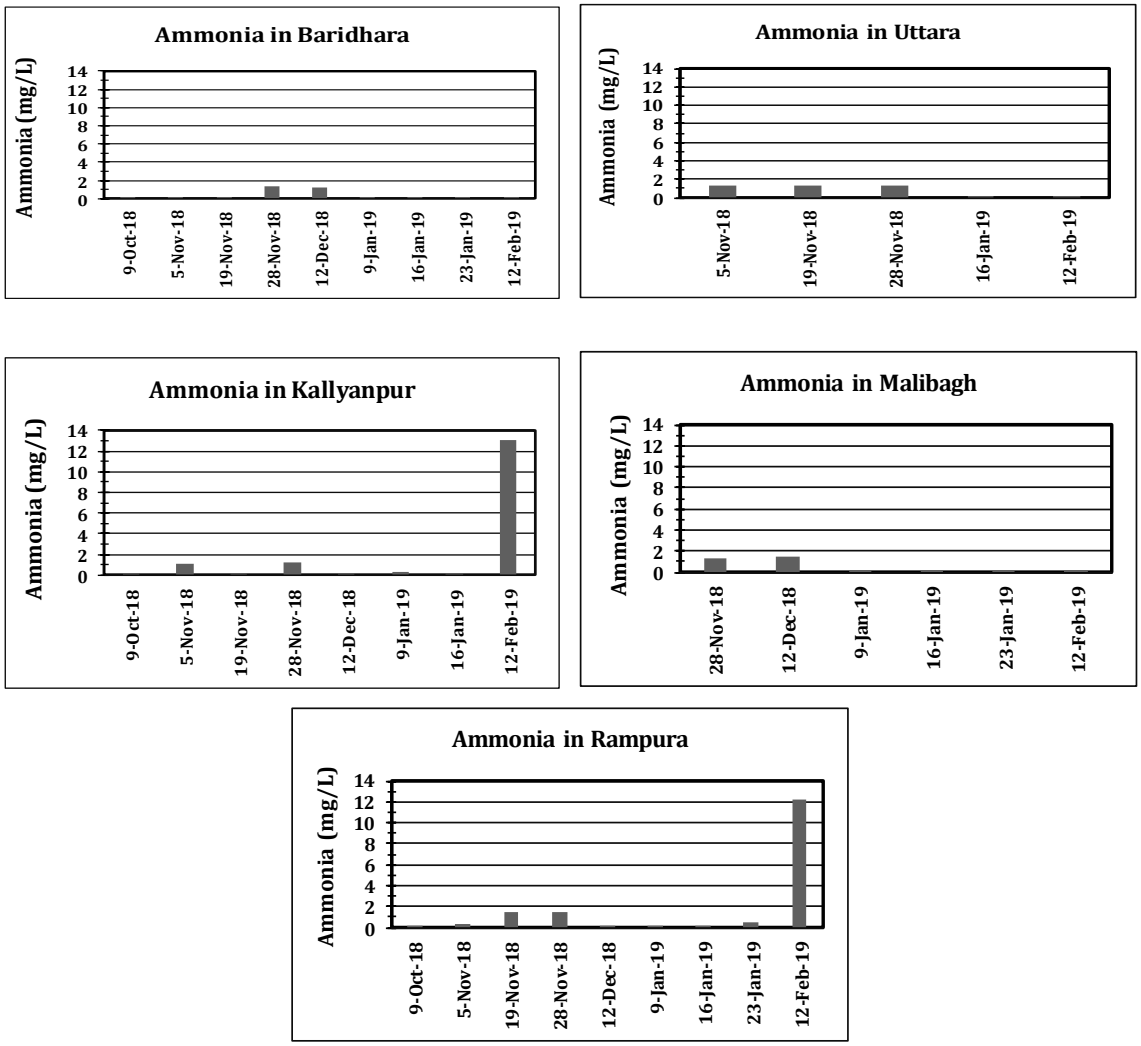

Figure 3: Variation of ammonia concentration in water samples collected from households in Baridhara, Uttara, Kallyanpur, Malibagh and Rampura

Nitrate: The nitrate concentration remained almost constant over test cycles in water samples collected from Baridhara, Uttara and Malibagh, ranging from 0.2 to 0.6 mg/l. Nitrate concentrations were relatively higher in water samples collected from Kallyanpur and Rampura. The highest concentration recorded for Kallyanpur was 4.4 mg/l. Nitrate concentrations varied from 2.5 to 3.8 mg/l for the water samples collected from Rampura.

Phosphate: Phosphate concentration in water samples from Baridhara varied over a narrow range of 4.0 to 4.5 mg/l, while in Uttara it varied from 4.3 to 10.5 mg/l. In Malibagh, phosphate concentrations in water samples varied over a wide range of 1.5 to 11.2 mg/l, while for water samples from Kallyanpur, it varied from 3.1 to 7.25 mg/l. Phosphate concentrations of Rampura water samples ranges from 0.05 to 5.9 mg/l during October to January; while in February, a very high concentration of 13.9 mg/ was recorded.

Free Chlorine: Virtually No free chlorine was detected in the water samples from Baridhara, Uttara and Malibagh. Free chlorine was detected in water samples from Kallyanpur and Rampura, areas that appear to receive water from the SWTP. Significant free chlorine was detected in the water samples collected from Kallyanpur, where it varied from below detection limit (in October) to 2.0 mg/l in January. In Rampura, free chlorine concentration varied from less than detection limit to 3.0 mg/l.

Total Chlorine: Like free chlorine, total chlorine concentration was low in water samples from Baridhara, Uttara and Malibagh; while it was higher for water samples collected from Kallyanpur and Rampura. In Kallyanpur, total chlorine varied from 0.07 to 4.02 mg/l; while in Rampura, it varied from less than detection limit to 3.0 mg/l.

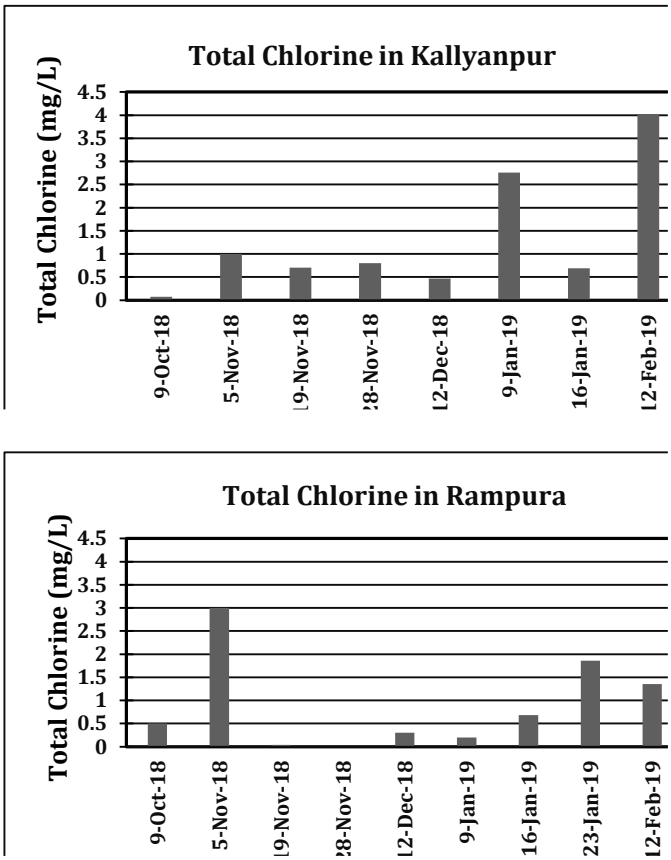

Figure 4: Variation of total chlorine in water samples collected from Kallyanpur and Rampura

Chloramines: Figure 5 shows chloramines concentration in water samples collected from households in different areas of Dhaka. Relatively low concentrations of chloramines were detected in water

samples from Baridhara and Uttara. Higher concentrations of chloramines were detected in water samples from Malibagh, Kallyanpur and Rampura. However, mono-chloramine, the species with strong disinfection power was detected in low concentrations in most water samples. In Malibagh, mono-chloramine was detected in three out of six water samples, and the concentration varied from 0.2 to 0.3 mg/l. In Kallyanpur water samples, mono-chloramine was detected in four test cycles; but high concentration (3.0 mg/l) was detected only in the water sample collected in February; in the other three samples chloramines varied from 0.05 to 0.20 mg/l. In Rampura, mono-chloramine was detected in three out of nine water samples, and the concentration varied from 0.05 mg/l (in October) to 1.5 mg/l (in February). It appears that chloramines concentrations increase with the increase in ammonia concentration in raw and treated water at the SWTP as dry season progresses.

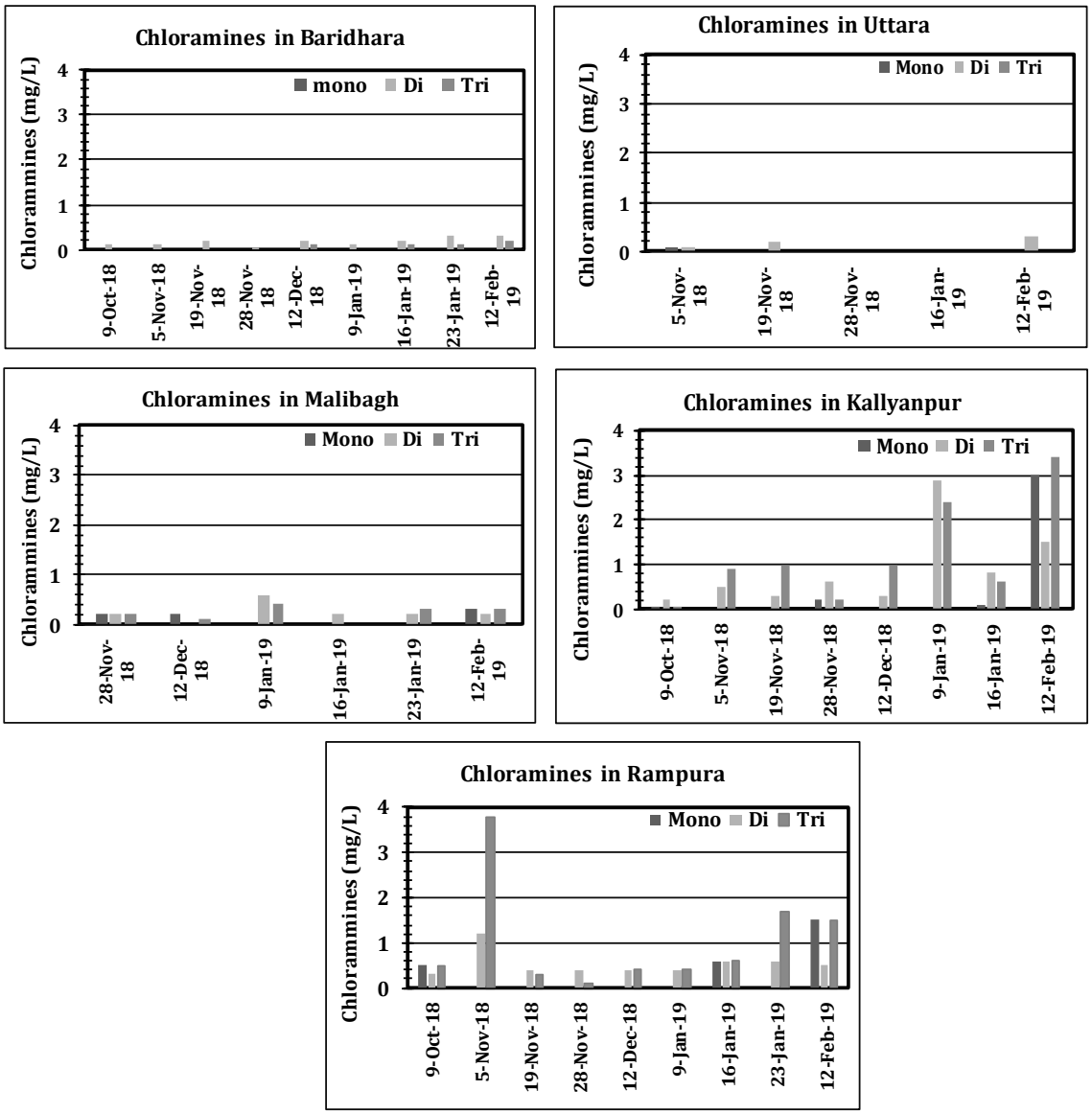

Figure 5: Variation of chloramines concentration in water samples collected from different areas of Dhaka city.

4. CONCLUSIONS

Results from this study suggest that water quality at source of water supply vary significantly. The quality of treated water at the SWTP vary significantly with season, and during the dry season the water is characterized by high concentrations of ammonia, nitrate, phosphate, as well as high concentrations of alkalinity, hardness and EC. On the other hand, the characteristics of groundwater

does not usually vary appreciably with season. While chlorination is regularly carried out at the SWTP and chlorine species are present in the treated water at the SWTP, virtually no free chlorine was detected in the water samples collected from three DTW pump stations in Dhaka. This suggests that chlorination is not carried out at theses DTW pump stations.

Results from this study clearly suggest that characteristics of water received at consumer-level in different areas of Dhaka city vary significantly. It appears that the main reason for this variation is the variation in the characteristics of DTW water and water supplied from the SWTP. Water samples collected from households at Rampura and Kallyanpur contained relatively high concentrations of ammonia, free and total chlorine, and chloramines; and concentration of these parameters increased with the progress of dry season (from October to February). This variation of characteristics of water (at consumer level) closely matches the characteristics of treated water as SWTP. This indicates that these two areas receive water predominantly from the SWTP. Very high concentrations of ammonia, exceeding Bangladesh drinking water standard, were detected in the water samples collected from Rampura and Kallyanpur. This possibly suggests inadequate treatment at the SWTP. The water samples collected from Baridhara, Uttara and Malibagh shows similar chemical characteristics as the major source for supplied water in these areas appear to be groundwater.

REFERENCES

Hossain, M. A., Begum, T., Fakhruddin, A. N. M., & Khan, S. I. (2006). Bacteriological and Physicochemical Analyses of the Raw and Treated Water of Saidabad Water Treatment Plant, Dhaka. Bangladesh Journal of Microbiology, 23(2), 133-136.

Mahbub, K. R., Nahar, A., Ahmed, M. M., & Chakraborty, A. (2011). Quality analysis of Dhaka WASA drinking water: Detection and Biochemical Characterization of the Isolates. Journal of Environmental Science and Natural Resources, 4(2), 41-49.

Rajala, P., Carpén, L., Vepsäläinen, M., Raulio, M., Sohlberg, E., & Bomberg, M. (2015). Microbially induced corrosion of carbon steel in deep groundwater environment. Frontiers in microbiology, 6, 647.

Serajuddin, M. (2017). Surface water quality susceptibility in drinking water treatment at Dhaka. Bangladesh. Journal of Biodiversity and Environmental Sciences (JBES), 11(1), 123-133.

Zheng, M., He, C., & He, Q. (2015). Fate of free chlorine in drinking water during distribution in premise plumbing. Ecotoxicology, 24(10), 2151-2155.