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Impact of Total Organic Carbon on Trihalomethane Formation in Treated Water of Saidabad Water Treatment Plant and along the Distribution System

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Abstract: **Role of Total organic carbon in trihalomethane formation in the treated water of Saidabad Water Treatment Plant (SWTP) was investigated during the months of November 2014 to June 2015. Total organic carbon (TOC) concentration of the incoming raw water varied seasonally with amount ranging from 20.52mg/L –40.69mg/L in drier months (November-February) which later decreased to 8.30mg/L –15.02mg/L in wet season (April-June). A significant increase was also observed in trihalomethane concentrations in dry months at the SWTP outlet, with the highest concentration level of 145.80 µg/L being recorded in January. Based on this trend, a site-specific positive correlation (r = 0.526) was found between raw water TOC and treated water THM using Pearson Method of Correlation. THM in the distribution system also followed this seasonal pattern and the concentration levels of trihalomethanes increased with increasing distance from the treatment plant. A low but definite correlation was found between distance and formation of THM (r = 0.257). In the six locations selected in Dhaka city, total trihalomethane concentration in the tap water ranged from 28.52 µg/L to 191.17 µg/L. In most cases, the concentration levels obtained in drier months were higher than the maximum permissible limits of 80µg/L set by United States Environmental Protection Agency (USEPA).**

***Key Words*— distribution system, total organic carbon, treated water, trihalomethane.**

I. INTRODUCTION

Due to excessive urbanization, today's rapidly growing cities are facing challenges to ensure safe potable water at the nearest possible outlets for their citizens. To meet the increasing demand, Dhaka Water Supply and Sewage Authority (DWASA) commissioned Saidabad Water Treatment Plant (SWTP) in July 2002, to treat surface water from Sitalakhya river and supply the treated water in the city through water mains of aggregated length of about 200km. The principal raw water quality problem at SWTP is the high concentration of ammonia, algae and organic matter, particularly during the dry season (December to March) (IWM and BUET, 2004). Natural organic matter is difficult to measure, so total organic carbon (TOC) is usually measured instead, since it is the primary ingredient of organic matter. When this raw water, rich in organic content, is disinfected with chlorine to kill harmful pathogens, a number of carcinogenic/genotoxic disinfection byproducts (DBPs) are produced including trihalomethanes (THMs), halogenated phenols, chlorinated furones, aldehydes and halogenated acetic acids (HAAs) [1]. As a result, THM and other DBPs have been detected in variable concentration in different parts of the treatment system and along the distribution pipeline. Parameters found to affect THM formation rate and concentration are raw water pH and TOC concentration, precursor source and concentration, chlorine dose, and chlorine contact (reaction) time, temperature and season, residual chlorine, bromide level etc. [2]. The relationship between THM concentration and distance from treatment plant has been a factor of interest as it is an indirect way of measuring the effect of contact time between chlorine dosage and TOC [3]. The main goal of this paper is to analyze the seasonal variation of total organic carbon in the raw water of SWTP and to determine how it affects THM concentrations in the treated water. Special attention is also given to the variations in THM levels along the distribution system with increasing distance from the treatment plant.

II. MATERIALS AND METHOD

A. Sampling procedure

As part of this study, water samples were collected from Saidabad Water Treatment Plant during a span of November 2014 to June 2015, which included both dry and wet season. Samples were taken nearly at noon (between 11am to 1 pm) starting from raw water intake, water after pretreatment, chlorination, alum dose, roughing filtration and lastly treated water samples were collected from the tap located at the plant laboratory. To determine THM levels in the distribution system, six locations were selected in Dhaka city, with increasing distance from the treatment plant and water samples were collected directly from taps. The collection

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bottles were rinsed several times with distilled water. All samples were properly sealed and stored in the refrigerator at 4 °C before analysis.

B. Determination of TOC

TOC was determined using a TOC analyzer (SHIMADZU, Model TOC-ASI-5000A). Water samples were filtered, stored at 4 °C and were tested within 24 hours of collection. To observe gradual reduction of TOC, water samples collected from six different treatment levels (including raw and treated water) were analyzed and compared. The mechanism of TOC determination is as follows, the organic carbon in the water is oxidized to produce carbon di-oxide (CO2), which is then measured by a non-dispersive infrared detector.

C. Determination of THM in the treated water of SWTP

The treated water samples were tested for THM by THM PlusTM (HACH Method-10132, 0-200 ppb). In this method, the THM Plus reagents react to form a color in the solution which is directly proportional to the total amount of THM compounds in the sample. Test results are measured at 515 nm and report as ppb chloroform.

D. Determination of THM in the distribution system

Throughout the study, water samples were collected directly from the taps of six residential areas of Dhaka city with incremental distance from the SWTP once a month. The water was turned on and the system allowed to flush, to avoid contamination of sample by any kind of dust/impurities inside of the pipes.

III. RESULTS AND DISCUSSION

A. Assessment of TOC variation in the waters of SWTP

Significant variation of TOC has been observed during the study period specially between the dry (November-February) and wet season (March-June) in the raw water of SWTP (Fig. 1). During drier months TOC values vary between 35-52 mg/L, whereas in rainy season they vary from 15-25 mg/L. High concentrations of ammonia, organic matter and algae in the raw water during dry season [4] contribute to increase the TOC concentrations. The reduced value of TOC in the wet months can be attributed to better water quality due to rainfall and freshwater inflow from upstream. Ambient temperature can also be a distinct factor for different TOC levels in the water [5], but as temperature was not measured at site, this relationship could not be investigated.

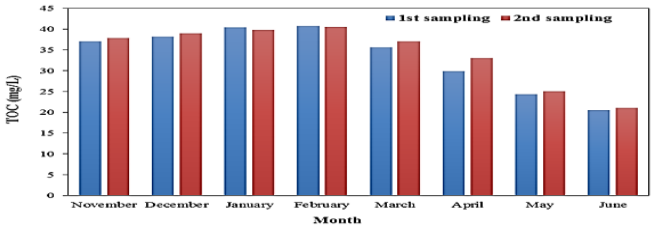

Fig. 1: Variation of concentration levels of TOC in raw water of SWTP.

Table I: Relationship of TOC with raw water quality parameters and THM concentration of treated water

TOC concentration with independent variable	Pearson *r*	THM concentration with independent variable	Pearson *r*
COD	0.381	Raw water TOC	0.526
BOD	0.218	Distance from treatment plant	0.257
Ammonia	0.494	Residual chlorine	-0.319

Variation of other water quality parameters, such as BOD5, COD and ammonia was also investigated to develop site-specific relation to raw water TOC of SWTP (Table I). Using Pearson method of correlation, TOC showed a positive relation with COD (r = 0.381) and ammonia (r = 0.494). BOD5 was also found to have a low but positive relation (r = 0.218), although very high BOD5/COD to TOC ratios were found in almost all the samples collected during the monitoring period. This indicates that the raw water of SWTP contains organic compounds that are easily oxidized. TOC concentrations were also measured along the treatment system to observe how much of raw water TOC is transformed to form THM in the treated water. Samples were collected from the following locations- after pretreatment (pH adjustment with lime), after pre-chlorination, after alum coagulation and after roughing filtration where water are flowed over the filter beds. TOC concentration gradually decreased along the treatment process. The percentage reduction of TOC values from raw water to treated water varied between 20-35% during the study period. In almost all cases, reduced TOC levels were observed immediately after chlorination and alum coagulation. This can be linked to the oxidation of organic carbon through addition of chlorine or removal of organic matter due to coagulation process.

B. Impact of TOC on THM formation at SWTP outlet

Many researchers have agreed that presence of natural organic matter as precursor in raw water is the primary factor affecting

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THM levels [6]. TOC was found to be a useful estimator in measuring precursor concentration. Fig. 2 shows the relation between raw water TOC and treated water THM concentration (measured as chloroform, CHCl3 mg/L) at SWTP. It indicates a linear increase in CHCl3 concentration with increase in TOC level of raw water. Using Pearson correlation method, a substantial relationship was obtained between TOC and THM formation (r = 0.526). According to Singer et al. [7], reaction rates of THM formation also increases with increasing TOC concentrations. Another parameter which showed a reverse relationship with THM formation is residual chlorine. Since THMs are a result of reaction between organic matter in water and chlorine used for disinfection, residual chlorine amount decreased with increasing THM concentration.

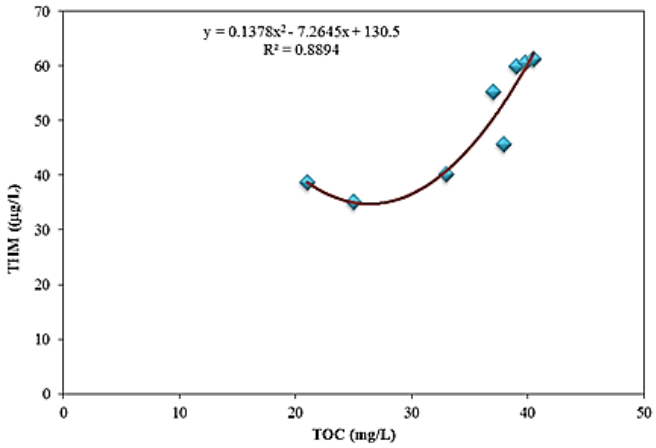

Fig. 2: Effect of TOC level on THM concentration at WTP outlet

C. THM concentration in the distribution system at increasing distance from SWTP

As mentioned earlier, six locations within Dhaka metropolitan area were selected to predict THM concentration in the distribution pipeline. They are- (i) Tikatuli (distance from treatment plant- 2.95 km), (ii) Kamlapur Road (3.381 km), (iii) Polashi (5.55 km), (iv) New Eskaton Road (7.5 km), (v) Panthapath (8.85 km) and (vi) Asad Gate (11.9 km). THM concentrations in these locations also follow a seasonal pattern. Fig. 3 shows the variation of the predicted THM concentration in the distribution system of SWTP with distance from treatment plant. THM measured from the tap waters of these locations follows an increasing trend with the increase of distance from the treatment plant. Although some scientists [8] reported that the distance-THM correlation to be an inverse one, results of this study confirmed a low but definite positive relationship (r = 0.257). THM concentrations in the tap water ranged from 28.52 µg/L to 191.17 µg/L and in almost all samples, THMs concentration was higher in the downstream of the SWTP distribution system rather than the outlet pipe of the treatment plant. However, in some months, especially in the wet season, THM concentration decreased even though the distance from the treatment plant increased. This exception can be attributed to dilution duet to leakage of pipes and increased inflow or infiltration of stormwater during rainy season.

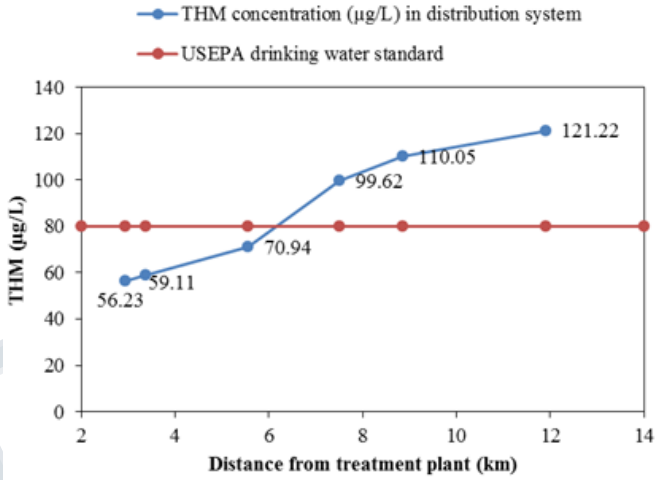

Fig. 3: Variation of tap water THM concentration with distance from treatment plant in the month of January

IV. CONCLUSION

Trihalomethanes were determined present in treated water and along the distribution system of SWTP and these THM concentrations were found to have a positive linear relationship with raw water TOC. Dry season (November-February) is the critical period for SWTP, as the incoming raw water is rich in organic matter and TOC values are as high as (40.5 mg/L). There is also a noticeable rise in the concentration of THMs in the dry season, ranging from 45.3 µg/L to 61.23 µg/L in the treated water at SWTP. THM concentrations increased with an increment in distance from the treatment plant. In some areas during drier months THM concentrations exceeded the standard value (80 µg/L) in (Panthapath and Asad Gate -in the months of January and February). Further study can be conducted taking into consideration the environment inside distribution pipes to evaluate other parameters, besides organic matter and residual chlorine, is responsible for THM formation in the distribution system.

V. ACKNOWLEDGEMENT

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