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Predicting Trihalomethanes Formation Potential (THMFP) of a Drinking Water Source in a Mega City: A Case Study

Md. Serajuddin[1*], Md. Aktarul Islam Chowdhury[2], Md. Mahmudul Haque[3], Tanzir Ahmed Khan[4]

[1]Senior Specialist, Institute of Water Modelling, Dhaka, Bangladesh
[2]Professor, Department of Civil & Environmental Engineering (CEE), Shahjalal University of Science & Technology, Sylhet, Bangladesh
[3]Associate Specialist, Institute of Water Modelling, Dhaka, Bangladesh
[4]Water Supply Engineer, DOHWA Engineering Co., Ltd., Seoul, South Korea

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***Corresponding author:** Md. Serajuddin
Senior Specialist, Institute of Water Modelling, Dhaka, Bangladesh

Abstract | **Case Report**

Disinfection is a very important and indispensable water treatment process for drinking water safety, as it inactivates pathogens from drinking water. In this work, 27 selected empirical THM models of 18 scientists from literature are used to investigate their reliability in real situations through their application to the Dhaka surface water treatment plant (SWTP) in Bangladesh. For each of the water samples, namely, treated, pretreated, and raw the total trihalomethanes (TTHM) concentrations were predicted using each of the 27 models and, the percentage deviation of the predicted concentrations from the measured concentrations were calculated. Two thirds of the models underestimated the THM concentration values and rest one third overestimated the concentration, even among which 34 percent deviated more than +500 percent. It is quite important that the predicted highest value of THM is nearly 150,000 times higher than the minimum value obtained for the same sample of water and 90% of the models used in this study could not estimate the THM values nearer to the actual values as determined in the laboratory. The diversified predicted concentration of TTHM for a single sample of water, from the above mentioned 27 models indicate the complexity of THM formation and in developing universally applicable THM models that can be used with diverse array of specific natural water sources. It can be seen from the studied 27 models that no model has taken into consideration the presence and its influence of ammonia which is a common pollutant in the raw water of developing countries which is also prevalent in Dhaka's surface water during dry season. It may thus be concluded that independent THMs models should be developed to make accurate predictions for different regions.

Keywords: Drinking Water Disinfection, THMs Formation Potential, Mathematical Models, Ammonia, Chlorination.

1. INTRODUCTION

The consumption of safe drinking water that meets the highest quality standards is a priority for all humans. Besides, the physiological significance for life, water plays a major role in human pathology in the form of water borne diseases. These can be a result of the inadequate choice of water treatment which may not follow the main hygienic principles, sanitation techniques, and particularly disinfection (Durmishi *et al*., 2015). Chlorine and its compounds are the most commonly used disinfectants for water treatment. Chlorine's popularity is not only due to lower cost, but also to its higher oxidizing potential, which provides a minimum level of chlorine residual throughout the distribution system and protects against microbial recontamination (ACC, 2018).

Although several disinfectants and disinfection strategies are available for this purpose, chlorine remains the most effective and inexpensive disinfectant (Clark *et al*., 2001; Chowdhury *et al*., 2007). As importantly, only chlorine-based chemicals provide residual disinfectant levels that help control and reduce microbial (re)growth in the distribution system (WCC, 2008).

In the early 1970s, John Rook, a Dutch brewery chemist, and Bellar in the USA, Environmental Protection Agency (EPA) scientists, independently determined that drinking water chlorination could form a group of byproducts known as trihalomethanes (THMs), including (1) chloroform, (2) bromodichloromethane (BDCM), (3) dibromochloromethane (DBCM), and (4) tribromomethane (bromoform) (Rook *et al*., 1974; Bellar

et al., 1974). The sum of chloroform, BDCM, DBCM, and TBM concentrations is referred to as total trihalomethanes or TTHM (Durmishi *et al*., 2015). Based upon limited data, but concern that these chemicals might be carcinogenic to humans, EPA set the first regulatory limits for TTHM in 1979 with its Total Trihalomethane Rule (USEPA, 1979). Although all chemical disinfectants are known to form byproducts, the DBPs of chlorine disinfection of water are by far the most thoroughly studied (Hrudey *et al*., 2015; Li & Mitch, 2018). Cost-effective methods to reduce DBP formation are available and should be adopted where possible (ACC, 2018).

Although the THMs concentration in drinking water is generally relatively low, the fact that a perceived suspected carcinogen can be easily distributed through the public water supply system justifies the research on the formation and control of the THMs. In Bangladesh for example, certain conditions dictate the necessity of studying THMs, as the water sources are turbid rivers, enriched with organic pollutants, with high temperatures and where chlorine is the only disinfectant. All the above-mentioned factors indicate the high potential for the formation of THMs (Serajuddin *et al*., 2018b). A significant amount of research has been performed to characterize THMs formation and their associated health risks (Rodriguez *et al*., 2000 & 2002; Clark *et al*., 2001; Stevens *et al*., 1977; Engerholm & Amy, 1983; Amy *et al*., 1987; Black *et al*., 1996; Gang *et al*., 2002; Sohn *et al*., 2004; Rathbun, 1996; King *et al*., 2000).

Strong correlations were found among total organic carbon (TOC), dissolved organic carbon (DOC) and UV absorption capacity at 254 nm (UV_{254}). The study made by Chowdhury & Champagne, 2008, along with the past studies identified pH, temperature and reaction time as significant for THMs formation; however, some existing models ignored these parameters. Some models also considered concentration of bromine as significant for THMs formation (Heller-Grossman *et al*., 2001; Nokes *et al*., 1999; Oliver *et al*., 1979). The study made by Chowdhury & Champagne, 2008, recommends using one parameter from TOC, DOC and UV_{254} and chlorine dose, pH, temperature and reaction time for future modelling. Trihalomethanes in water supply systems have to be systematically monitored because they are perceived dangerous for human health. Measurement and detection of THMs and other disinfection-by-products requires advanced analytical instruments while purchase and preparation of the instruments is not possible for many water supply systems, so models for THMs formation potential (THMFP) prediction have been developed. Models allow to approximate the final concentration of trihalomethanes depending on changing quality of raw water and operational conditions, which implies the possibility of appropriate preventive actions undertaken by water supply systems managers. The predictive models may also be useful in finding maximal allowable concentration of trihalomethanes as well analysis of cancer risk caused by trihalomethanes. These models are also very useful in taking preventive measures to minimize the risk of occurrence of random events conducted to deterioration of the water quality intended for human consumption. Among the models, linear, non-linear and multiple regressions have been the mostly used models in water treatment facilities (Rezaei *et al*., 2014).

The cities in Bangladesh use chlorine as disinfectant for the drinking water, following worldwide guidelines and practices. Due to the perceived high health risks related to THMs resulting out of chlorination and like other developing countries, lack of access to advanced and expensive instruments for detecting THMs in all parts of the country, this study was conducted to assess THMs formation potential (anticipate the capacity and possibility of the THMs formation) in Dhaka drinking water system which draws water from the nearest river Sitalakhya, using several mathematical models developed elsewhere, and to ascertain applicability and efficacy of these different models in Dhaka's environment comparing adequacy to observed reality in a real drinking water treatment plant.

2. MATERIAL AND METHODS

2.1 Study Area

The study area is Dhaka the capital city of Bangladesh with a population of more than fifteen million located in the central part of Bangladesh. The city has a distinct monsoonal season, with an annual average temperature of 26°C and monthly means varying between 19°C in January and 29°C in May, sometimes reaching to 40°C. Approximately 87% of the annual average rainfall of 2,123 millimetres occurs between May and October. Dhaka is located at 23°42′N 90°22′E, on the banks of the Buriganga River and surrounded by other peripheral rivers. The largest treatment plant of the country is situated beside the river Sitalakhya in the eastern periphery of Dhaka city at Latitude 23°43'11.25"N and Longitude 90°26'14.25"E (Serajuddin, *et al*., 2018a). The water from this plant was collected and used for this study.

2.2 Water Sample Collection and Analysis

The largest drinking Water Treatment Plant of Dhaka which draws raw water from the Sitalakhya River was established and put into operation in 2002. It uses the conventional water treatment processes, with a unique biological pretreatment unit. To conduct this study three water samples from three stages of the water treatment plant were collected, namely, raw water at the intake of the plant, pretreated water at the exit of the biological pretreatment unit and treated water from the entry of the treated water reservoir, on November 07, 2019. The water samples were tested for a wide range of parameters including pH, ammonia, UV_{254}, TOC, DOC and bromide. Sample containers were dark amber glass sterile bottles with PTEF lined screw caps. The samples

were immediately cooled in an ice cooler and brought back to SWTP laboratory. The water was then filtered through a Whatman GF/F filter (Whatman Japan Ltd., Tokyo, Japan, nominal pore size 0.7 mm). Measurement of pH and Temperature was done using multimeter sens ION+ MM150 (HACH, USA). Ammonia concentration in this study was measured by USEPA approved Nessler method (HACH method 8038) using a DR-6000 UV-VIS spectrophotometer (HACH, USA). UV_{254} samples, after filtration, were analyzed using a DR-6000 UV-VIS spectrophotometer (HACH, USA). DIUF water was used as blank. TOC concentration was measured by using HACH method no.-10129 LR, Test 'N Tube™ Vials (0.3 to 20.0 mg/L) DR-6000 UV-VIS spectrophotometer (HACH, USA). After TOC measuring, Dissolved Organic carbon (DOC) was determined by acidifying the filtered samples, in which Inorganic Carbon (IC) converted into Carbonic acid (H2CO3), also known as dissolved inorganic carbon (DIC). DOC concentration was measured by using HACH method no.-10129 LR, Test 'N Tube™ Vials (0.3 to 20.0 mg/L) DR-6000 UV-VIS spectrophotometer (HACH, USA). Bromide was measured by HACH method no. 8016 DPD Method (0.05 - 4.50 mg/L Br2) using DR-6000 UV-VIS spectrophotometer (HACH, USA). Trihalomethane concentration was measured by HACH method no.-10132 THM Plus™ Method (10 - 600 µg/L CHCl3) using DR-6000 UV-VIS spectrophotometer (HACH, USA).

In drinking water, chloroform is always with the highest concentration, and often represented by more than 90% of the total concentration of THMs (Durmishi, 2013). In non-coastal zones area bromoform generally are not found where study depicted that amongst various THMs, the contribution of chloroform was highest (97.99 to 98.71%) (Mishra, 2016). In our study in absence of the facility to test the other three forms of THM only chloroform was measured and extra five percent was added to ascertain the TTHM. In the water under study the bromide concentration level was beyond the detectable limit, as such for the sake of calculation bromide concentration in all cases are assumed to be 0.05 mg/L. On the other hand, significant quantities of THMs form rapidly after chlorine addition (Chang *et al*., 1996), an extended reaction time can also contribute to increased levels of THMs in drinking water (Kim *et al*., 2002), with the rate of formation decreasing after the rapid reaction phase (Gang *et al*., 2002). Chang *et al*., (1996) reported that most of the THMs formation occurred within the first 8 hours of reaction time. Chang *et al*., (2001a) reported no significant increases in THMs beyond 48 hours of chlorination. It was also noted that the rates of THMs formation declined considerably after approximately 7 hours of initial reaction phase which correspond to the findings of Kim *et al*., (2003). In our study the chlorine contact time was assumed as 06 hours and applied to different models for prediction.

The water quality characteristics of the above mentioned three water samples as were ascertaining in the laboratory were then used to estimate THM formation potential at this WTP based on empirical relationships. The trihalomethane formation potential (THMFP) of a raw water source would indicate the maximum trihalomethanes (THMs) that are likely to be produced when chlorine reacts NOM present in the water (Rajamohan *et al*., 2012). Actually, Trihalomethane formation potential (THMFP or ΔTHMFP) is defined as the difference between the final TTHMT concentration and the initial TTHM0 concentration. If sample does not contain chlorine at the time of collection, TTHM0 will be close to zero and the term THMFP may be used. The term "THMFP" often has been equated to the final TTHM concentration, even if the sample had contained chlorine when collected. In this study THMFP has been used as the final TTHM.

27 Mathematical THMs prediction models derived from the literature has been used in the present study and were developed by 16 lead and their associates' scientists. The list of the scientist, the models and year of development are shown in Table 1. The parameters affecting the formation of THMs in these models include the amount of NOMs as DOC, TOC, UV_{254}, chlorine contact time, chlorine dose, residual chlorine, bromide concentration, temperature, and pH of water.

Table 1: The list of the scientist, the models and year of development

SN	Scientist	Model description	Year of develop-ment
1	Amy *et al*.,	$THM= 0.0031*(UV_{254}*TOC)^{0.44}*D^{0.409}*t^{0.265}*T^{1.06}*(pH-2.6)^{0.715}*(Br+1)^{0.0358}$	1987
2	Amy *et al*.,	$THM=0.00412*DOC^{1.1}*D^{0.152}*Br^{0.068}*T^{0.61}*pH^{1.6}*t^{0.26}$	1998
3	Al-Omari *et al*.,	$CHCL_3= 4.527*t^{0.127}*D^{0.595}*TOC^{0.596}*Br^{0.103}*pH^{0.66}$	2004
4	Chang *et al*.,	$THM= 12.72*TOC^{0.291}*t^{0.271}*D^{0.126}$ $THM= 108.8*TOC^{0.2466}*t^{0.2956}*D^{0.126}*UV_{254}{}^{0.9919}$ $THM= 131.75*t^{0.2931}*D^{0.1064}*UV_{254}{}^{1.075}$	1996
5	Harrington *et al*.,	$THM= 0.00309*(TOC*DOC)^{0.44}*D^{0.409}$ $CHCl_3= 0.00309*(TOC*DOC)^{0.44}*D^{0.409}*t^{0.265}*T^{1.06}*(pH-2.6)^{0.715}*(Br+1)^{0.03}$	1992
6	Hong *et al*.,	$THM= 10^{(-1.375)}*t^{0.258}*(D/DOC)^{0.194}*pH^{1.695}*T^{0.507}*Br^{0.218}$ $CHCl_3= 10^{-0.748}*t^{0.21}*(D/DOC)^{0.221}*pH^{1.374}*T^{0.532}*Br^{0.184}$	2007

7	Bayalla *et al*.,	$THM= 0.0001*D^{3.14}*pH^{1.56}*D^{0.69}*t^{0.175}$	2004
8	Malcom Pirnie Inc.	$CHCL_3=0.078*(TOC*UV_{254})^{0.616}*D^{0.391}*t^{1.15}*(pH-2.6)^{0.8}*(Br+1)^{-2.23}$	1992
9	Montgomery Waston	$CHCL_3=0.064*TOC^{0.329}*UV_{254}{}^{0.874}*(Br+0.01)^{0.404}*pH^{1.161}*D^{0.561}*t^{0.269}*T^{1.018}$	1993
10	Rathbun	$CHCl_3= 0.442*pH^2*D^{0.229}*DOC^{0.912}*Br^{(-0.116)}$ $THM= 14.6*(pH-3.8)^{1.01}*D^{0.206}*UV_{254}{}^{0.849}*t^{0.306}$	1996
11	Rodriguez *et al*.,	$THM= 0.044*DOC^{1.3}*t^{0.262}*pH^{1.149}*D^{0.277}*T^{0.968}$ $THM= 1.392*DOC^{1.092}*pH^{0.531}*T^{0.255}$	2000
12	Semerjian	$THMs^2= 17.31+10.52*D^2+259728.6*SUVA^2$ $THMs^2= 42.1+29.23*D^2+353375*UV_{254}{}^2$ $THMs^2= -471.11+0.48*t^2+1856.07*Br^2+404.38*D^2$	2008
13	Sohn *et al*.,	$THM= 3.296*DOC^{0.801}*D^{0.261}*Br^{0.223}*t^{0.264}$ $THM= 75.7*UV_{254}{}^{0.593}*D^{0.332}*Br^{0.06}*t^{0.264}$ $THM= 23.9*(DOC*UV_{254})^{0.403}*D^{0.225}*Br^{0.141}*t^{0.264}$	2001
14	Urano *et al*.,	$THM= 0.00082*(pH-2.8)*TOC*D^{0.5}*t^{0.36}$	1983/1987
15	Uyak *et al*.,	$THM= 0.0707*(D+3.2)^{1.314}*(pH-4)^{1.496}*(D-2.5)^{-0.197}*(SUVA+10)^{-0.724}$	2005
16	Yoon *et al*.,	$THMFP7=1875*UV_{254}$ $THMFP7=71.67*DOC$	2003
17	Zhu *et al*.,	$THM = 0.42*UV_{254}{}^{0.482}*D^{0.339}*J^{0.023}*T^{0.617}*pH^{1.609}*t^{0.26}$ $THM = 0.283*(DOC*UV_{254})^{0.421}*D^{0.145}*J^{0.041}*T^{0.614}*pH^{1.606}*t^{0.261}$	1995

Remarks: THM = total THMs (µg /L); t= reaction time (h); D = applied chlorine dose (mg/L); T = temperature (ºC); BR = j=bromide concentration (mg/L); TOC =Total organic carbon(mg/L); UV_{254} = UV absorbance (cm-1); PH = (pH–2.6) with 2.6 represented a statistically determined minimum pH at which THMs formation occurred; DOC=Dissolved organic carbon(mg/L); $CHCL_3$= Chloroform(mg/L)

3. RESULTS AND DISCUSSIONS

The laboratory analysis report of the collected three samples with some of the relevant water quality parameters are shown in Table 2.

Table 2: Status of water quality characteristics of the samples under test

Sample ID and date of sampling	**TOC**	**DOC**	**UV_{254}**	**pH**	**Total Cl_2 dose**	**Time**	**Br**	**Temp.**	**SUVA**	**NH_3-N**
Unit	**mg/L**	**mg/L**	**cm^{-1}**		**mg/L**	**hour**	**µg /L**	**ºC**	**L/mg.m**	**mg/L**
Raw water (Nov. 07, 2019)	22.63	8.2	0.1076	7.18	6.5	6.0	0.05	27.3	1.3122	2.0
Pre-treated Water (Nov. 07, 2019)	21.57	7.2	0.1012	7.13	6.5	6.0	0.05	27.5	1.4056	0.33
Treated Water (Nov. 07, 2019)	18.82	4.6	0.0568	6.75	6.0	6.0	0.05	29.2	1.2348	0.0

Chlorine was added to all the three samples to make the water chlorinated at the rate of 6.5 mg/L for raw and pretreated water and 6.00 mg/L for treated water. Treated water along with the chlorine dose was collected from the system and in the rest two sample chlorine was added in the laboratory and allowed for a contact time of 6.5 hours to get resulted THM concentration.

THM formation potential (THMFP) of Dhaka WTP was found based on a number of specific models as shown in Table 1, in the month of November of the year 2019. From the result as discussed below it is evident that THMFP of any given sample water collected from Dhaka surface water treatment plant (SWTP) within Dhaka city has wide range of variations for the same water sample as calculated by different models.

For each of the water samples, namely, treated, pretreated, and raw the TTHM concentrations were predicted using the 27 models of 16 lead and their associates scientists (Table 1) and, the percentage deviation of the predicted concentrations from the measured (observed) concentrations was calculated with the following equation:

[(Predicted - Observed)/Observed] x 100 (1)

Figure 1 illustrates the relative frequency of the percentage deviation between the predicted and observed concentrations for TTHMs, using Eq. 1. The cumulative relative frequency results indicate that for the treated water 63 percent of the predicted concentrations were negatively deviated from 0 to 100 percent and 22 percent were positively deviated from 0 to 500 percent, rest 15 percent were deviated more than +500 percent.

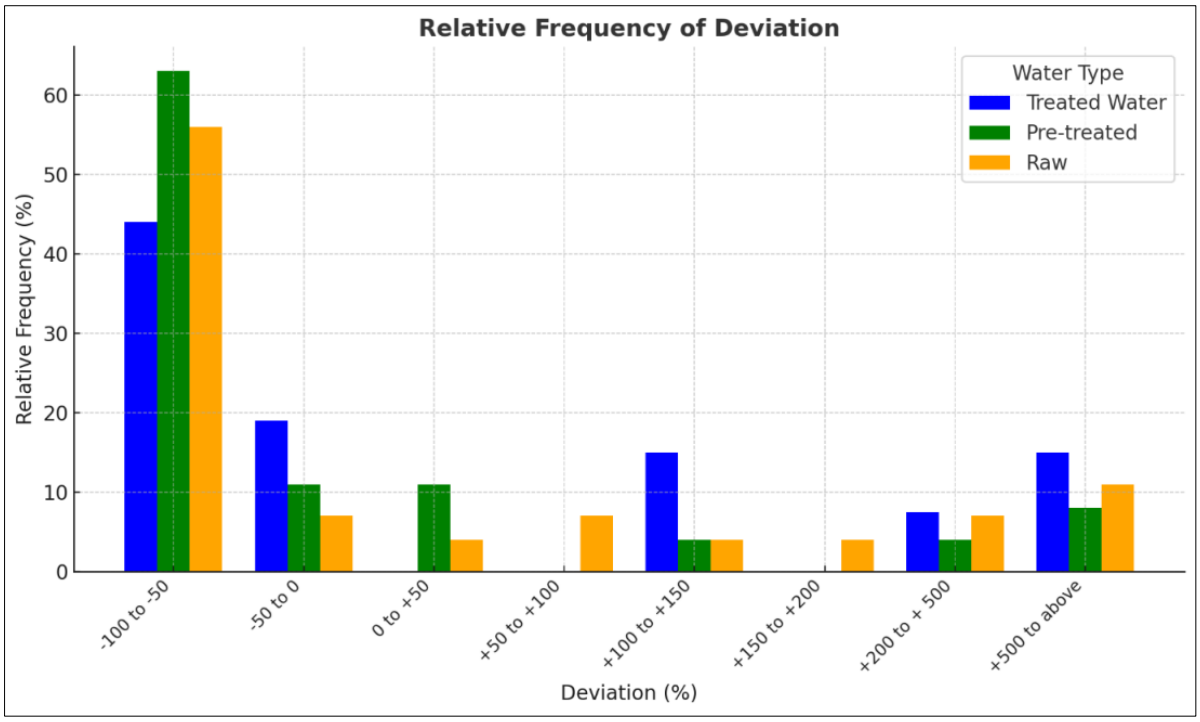

Figure 1: Relative frequency of percentage deviation between predicted and observed TTHM concentrations

For the pretreated water, 74 percent of the predicted concentrations were negatively deviated from 0 to 100 percent and 19 percent were positively deviated from 0 to 500 percent, rest 8 percent were deviated more than +500 percent.

For the raw water 63 percent of the predicted concentrations were negatively deviated from 0 to 100 percent and 26 percent were positively deviated from 0 to 500 percent, rest 11 percent were deviated more than +500 percent.

Two third of the models underestimated the THM concentration values, rest one third overestimated the concentration among which 34 percent deviated more than +500 percent.

From the result it is evident that THMFP of Dhaka SWTP water as assessed by each of the above mentioned 27 models separately are widely different in values among themselves. For the treated water sample, the maximum and the minimum TTHMP values are respectively 5930.237µg/L and 0.045779 µg/L. For pretreated water the values are respectively 9792.44 µg/L and 0.0612 µg/L and for raw water those are 10685.85 µg/L and 0.06616 µg/L respectively. In all the cases that is for raw, pretreated and treated water samples the model developed by Mr. Zhu (1995) gives the highest values and the model developed by Mr. Harrington (1992) gives the minimum values. The model developed by Zhu is based on UV, chlorine dose, time, pH and temperature; and the model of Harrington is based on TOC, DOC and chlorine dose. It is quite important that the predicted highest value of THM is nearly 150,000 times higher than the minimum values obtained for the same sample of water. It is amazing to note that 90% models among the 27 models used in this study could not estimate the THM values nearer to the actual values as determined in the laboratory. Thus, it is a concern that if it is tried to estimate THMFP of Dhaka's water utilizing any of the mentioned models, in most of the cases, it will give a very high or very low value which might mislead the public.

In case of treated water, the maximum predicted value as ascertained by Zhu (1995, as cited in Suchona *et al*., 2015) UV based Model is 130k times greater than the minimum value ascertained by Harrington (1992, as cited in Chowdhury *et al*., 2009) TOC-DOC based Model. Out of the 27 predicted values of THMFP of the treated water 02 nos. are more than 5000µg/L, 08 nos. were more than 100 µg/L. The mean, median, and standard deviation are respectively 521, 33.58, and 1571 µg/L. The actual THM as determined in the laboratory is found to be 53 µg/L. Out of 27 predictions 09 number were more than the actual values and 18 numbers were less than the actual values.

Among the predicted values the nearest value to the determined value is 48.01 µg/L (91%) which is predicted by the Rodriguez *et al*., (2000) model based on DOC, pH and temperature. The other model developed by Rodriguez *et al*., in same year but considered more water quality parameters than the earlier one, namely time and chlorine dose, gives a predicted THMP value of 130.88 µg/L which is 2.72 times higher than the predicted value by the 1st model of Rodriguez. Searching the other nearer predicted values, we found that the model developed by Semerjian (2008, as cited in Chowdhury *et al*., 2009) based on UV_{254} gives a value of

47.27 µg/L which is very nearer to the actual one (89%). Thirdly the model developed by Chang *et al*., (1996) based on TOC, time and chlorine dose gives a value 42.68 µg/L which is also fairly nearer to the actual value (81%).

Similarly, in case of the pretreated water sample the maximum and the minimum predicted values of THMFP are found to be 9792.44 µg/L and 0.0611µg/L respectively as predicted by the model of Zhu (UV based, 1995) and Harrington (TOC, DOC, chlorine dose based, 1992). In case of pretreated water, the maximum predicted value as ascertained by Zhu (UV) Model is 160k times greater than the minimum value ascertained by Harrington Model. Out of the 27 predicted values of THMFP of the pretreated water 02 nos. are more than 5000µg/L. The mean, median, and standard deviation are respectively 787, 48.58 and 2418 µg/L. The actual THM as determined in the laboratory is found to be 209 µg/L. Out of 27 predictions 08 number were more than or nearer to the actual value and19 numbers were less than the actual value.

Among the predicted values of the pretreated water the nearest value to the determined value is 213.32 µg/L (102% of the actual) which is predicted by the Rodriguez *et al*., (2000) model based on DOC, temperature, pH, time and chlorine. The other model developed by Rodriguez *et al*., in same year but considered DOC, pH, Temperature as the basis, gives a predicted THMP value of 79 µg/L which is 2.69 times lower than the predicted value by the 1st model of Rodriguez. Searching the other nearer predicted values, we found that the model developed by Yoon (2000, as cited in Suchona *et al*., 2015) based on UVA, gives a value of 190 µg/L which is very nearer to the actual one (91%). Thirdly the model developed by Amy *et al*., (1987) based on UVA, TOC, time, temperature, pH, bromine concentration and chlorine dose gives a value 177.96 µg/L which is also fairly nearer to the actual value (85%).

Similarly, in case of the raw water sample the maximum and the minimum predicted values of THMFP are found to be 10685.55 µg/L and 0.06615 µg/L respectively as predicted by the model of Zhu (DOC*UV based, 1995) and Harrington (TOC, DOC, chlorine dose based, 1992).

In case of raw water, the maximum predicted value as ascertained by Zhu *et al*., (DOC*UV based, 1995) Model is 161k times greater than the minimum value ascertained by Harrington Model. Out of the 27 predicted values of THMFP of the raw water 02 nos. are more than 5000 µg/L. The mean, median, and standard deviation are respectively 838, 50.38 and 2584 µg/L. The actual THM as determined in the laboratory is found to be 113 µg/L. Out of 27 predictions 10 number were more than the actual values and 17 numbers were less than the actual values.

Among the predicted values of the raw water the nearer value to the determined value is 129 µg/L (108% of the actual) which is Semergian (2008) model based on time, bromine and chlorine dose. The other model developed by Semergian in the same year but considered UVA and SUVA as the basis, more water quality characteristics than the earlier one, namely time & chlorine dose, gives a predicted THMP value of 669 and 73 µg/L which is 5.18 and 1.77 times higher and lower respectively than the predicted value by the 1st model of Semerigian.

Searching the other nearer predicted values, we found that the model developed by Rodriguez *et al*., (2000) model based on DOC, pH and temperature gives a value of 92 µg/L which is also nearer to the actual one (77%). The other model developed by Rodriguez *et al*., in same year but considered more water quality parameters, namely time and chlorine dose give a predicted THMP value of 244 which is 2.05 times higher than the predicted value by the 1st model of Rodriguez.

4. CONCLUSION

The diversified predicted resulted concentration of TTHM for a single sample of water, ranging from almost zero to ten thousand units from the above mentioned 27 models indicate the complexity of THM formation and in developing THM prediction models. It appears that predictive models are closely related to the specific exploitation conditions as well as the quality of raw water i.e., site specific, which supplies the system, so probably it will be impossible to find out the model which will fit to all real water supply systems. There is a large diversity between models.

It can be seen from the studied 27 models that no model has taken into consideration the presence and its influence of ammonia which is common pollutant in the raw water of developing countries which is also prevalence in Dhaka's water during dry season. It is well known that when chlorine is added to water it reacts not only with the organic precursors of disinfection by-products but most of all it is the oxidant of other substances contained in the water. It is especially true in case of ammonia, when present in water with NOM, it reacts first with chlorine before with NOM and form chloramine thus retarding and reducing THM formation. It is evident from actual determined TTHM concentration values of raw water and pretreated water. In case of raw water, the most polluted sample (DOC = 8.2 mg/L) among the three tested, and contains 2.0 mg/L of ammonia but gives lesser THM (113mg/L) than pretreated water (THM = 209 mg/L) which contains lesser DOC (7.2 mg/L) and lesser ammonia that is 0.33 mg/L of ammonia than the raw water.

All research shows the complexity of THM formation which also makes it difficult to develop universally applicable models that can be used with diverse array of specific natural water sources. It may be

concluded that independent THMs models should be developed to make accurate predictions for different regions.

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