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Determination of Levels of Regulated and Emerging Trihalomethanes (THMs) Disinfection By-Products (DBPs) in a Community Drinking Water Supply

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Abstract

Ahmadu Bello University (ABU) drinking water treatment plant (ABUDWTP) uses calcium hypochlorite to supply chlorine in disinfecting drinking water supply to the university community. Between 2008 and 2010, 252 water samples were taken in duplicates along the treatment and distribution systems of ABUDWTP with ammonium chloride as de-chlorinating agent in accordance with United States Environmental Protection Agency (USEPA) Method 551.1. This was aimed at determining the concentrations of trihalomethanes (THMs) disinfection by-products (THM-DBPs) and the degree of wholesomeness of the drinking water supplied. The THM concentrations in the samples were analysed using Agilent Gas Chromatograph after preliminary extraction with methyl *tert*-butyl ether (MTBE). Samples' analyses identified six THMs - two additional to the regulated four. These are Dichlorobromomethane and 1,2-Dibromomethane here classified as emerging THM disinfection by-products (EmerTHM-DBPs). Measured total mean concentration of the regulated THMs (TRegTHM-DBPs) at house level was 1.0601E-02±1.6625E-05 mg/L as against 9.9704E-02±6.4706E-05 mg/L for total mean emerging THM-DBPs (TEmergTHM-DBPs). This TRegTHMs concentration indicates house level water is within acceptable limits of international standards despite being above the national permissible limit of 0.001 mg/L. Though not considered under exiting drinking water quality index TEmergTHM-DBPs were found to account for over 90% of gross THM-DBPs (GTTHM-DBPs) at each sampling stage. These TEmergTHM-DBPs could create health complications on consumers as they are either suspected carcinogens or recognised to increase the risk of carcinogenicity and mutagenicity in humans. Both are irritants of several body tissues and are implicated in several health abnormalities including reproductive and fertility disorders as well as liver and kidney damage. In view of these likely supplementary health burdens, this paper advocates additional stricter monitoring and control of these emerging THM-DBPs as they will most probably compound and increase the frontline of health challenges from chlorine disinfected ABU drinking water supply to its consumers.

Keywords: Trihalomethanes, Emerging disinfection by-products, drinking water, ABU Community

1. Introduction

Disinfection has been accepted and appreciated as an indispensable process in the treatment of drinking water. This is because it serves as the major barrier against the transmission of water borne diseases, the occurrence of which has been linked to many deaths in developing countries. In 1993 alone cholera outbreak in developing countries was of the magnitude of 950,000 reported cases with more than 9,000 deaths (Reiff, 1995). As a result, disinfection is considered the most important process in drinking water treatment and one of the major public health triumphs of the 20th century. Because of this, microbial safety has taken precedence over associated health risks of disinfecting drinking water in most developing countries (Reiff, 1995; Schoeny, 2010)

Water is very vital to all living resources plants and animals alike. It is a pre-condition for human, animal and plant life as well as an indispensable economic resource. Water also plays a fundamental role in climate regulation (WISE, 2011). Drinking water is a fundamental requirement of the human body that cannot be replaced. Potable drinking water primarily sourced from rainfall or from surface water sources like streams, rivers, lakes and springs has of recent become very limiting. There is also rapid eco-forest destruction and aggravated pollution of water resources in many world regions by microbial pathogens, nutrients and various categories of wastes especially from anthropogenic activities. This is also compounded by global climate change and incompatible human activities on the world's hydrosphere (UNU, 2001; Shaibu-Imodagbe, 2011). As a result, a range of water crisis in water quality and quantity are triggered (Postel, 2000). Of recent complex anthropogenic discharge of intricate waste products of the sophisticated human agricultural and industrial activities result in the deterioration of the quality and quantity of available surface and ground water resources, further compounding this crisis (Porter 2002). This makes water treatment an inevitable process of ensuring surface water suitability as potable drinking water.

In the disinfection process in water treatment, chlorine and other disinfectants react with organic matter or its intermediates such as humus, fulvic acids and amides that are dissolved in water. Subsequently, potentially harmful disinfection by-products (DBPs) are produced. Among these, the trihalomethanes (THMs) are the first group of DBPs to be recognized. This group of compounds have been implicated in liver and kidney defects, central nervous system problems and increased risk of carcinogenicity and mutagenicity as Class B carcinogens (USEPA, 1990). Four of these THMs are being regulated in drinking water. Among these, bromodichloromethane – $CHCl_2Br$ is known to be most toxic followed by dibromochloromethane – $CHClBr_2$ and tribromomethane – $CHBr_3$ while trichloromethane, – $CHCl_3$ is least toxic even though it is the most common and dominant compound of these regulated THMs in drinking water (WHO, 2005). Apart from these four regulated THMs, others are considered in this study as emerging trihalomethanes disinfection by-products (EmergTHM-DBPs).

In view of the fact the ABU community is a relatively enlightened community, it is expected that adequate and good quality drinking water will be highly appreciated and maintained. As such this study assesses the proportion of THMs in drinking water supply available to the community in view of the use of chlorine based disinfectant in drinking water treatment. These THMs, are susceptible to pH changes, levels of total dissolved organic carbon, and sulphates content of the drinking water medium through a direct relationship (WHO, 2008). These show that there is a need to document concentrations of these trihalomethane DBPs in drinking water. This will thus provide an understanding of the probable health related risks faced by those consuming the treated water and provide empirical basis for the managers of the treatment works to modify their drinking water treatment methods.

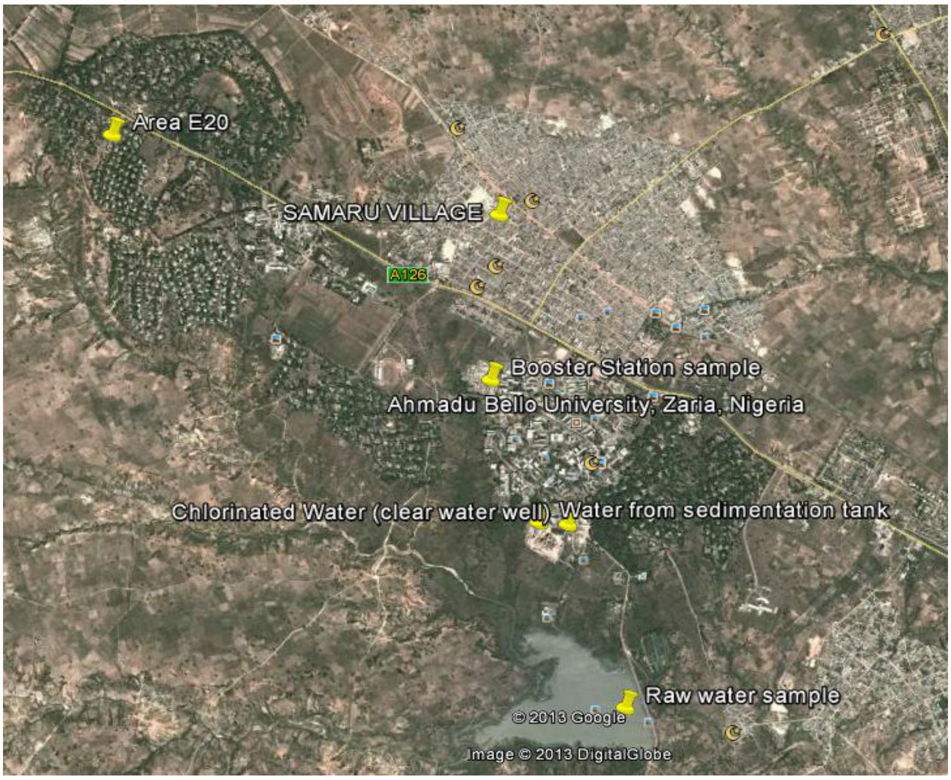
2. Materials and Methods

2.1 Materials

Materials used in the study include sixty millilitres (60-mL) screw cap glass vials equipped with cap fitted with PTFE septa which were washed thoroughly and dried ready for sampling. In addition, micro syringes of the capacities – 10 µL, 50 µL, 100 µL and 1000 µL were readied for solvent measurement, Glass Pipettes of 10 mL size and Pasteur pipette of about 23cm length were used to extract solvent while salts were weighed out on top loading balance. Others include ACS Grade ammonium chloride de-chlorinating agent, ACS Grade sodium sulphate muffle furnaced at 400^0C for a minimum of 30 minutes and Phosphate buffer prepared by mixing 1% ACS grade sodium phosphate dibasic and 99% ACS grade potassium phosphate monobasic salts. High purity grade MTBE was used as extractant and Agilent Gas Chromatograph (GC) Model 19091 – 413 calibrated with commercial standards for disinfection by-products supplied by Ultra Scientific Analytical Solutions, North Kingston, RI 02852-7723, USA with a Certificate of Quality Assurance was used to determine the DBPs in the sample extracts. All the reagents used were of analar grade.

2.2 Sampling

Two hundred and fifty two (252) samples were collected in duplicates longitudinally along the treatment and distribution system of the Ahmadu Bello University Drinking Water Treatment Plant (ABUDWTP). These samples were taken from the source (raw) water (Kubanni reservoir), the sedimentation tanks, after chlorination, at the booster station and at residential house level (Area E Quarters) (Fig 1).



11°09'12.54" N   7°39'08.97" E

Fig 1: Google Map Showing the Sampling points for the Assessment of THM - DBPs in Ahmadu Bello University Drinking Water Supply

Samples for trihalomethanes (THMs) analyses were taken in 60mL glass vials with weighed samples of ammonium chloride used as de-chlorinating agent. Care was taken to avoid overtopping or spilling of sampled water from the vials. The samples were subsequently stored at temperature of about 4 ^{0}C or less in ice filled jugs in accordance with USEPA method 551.1 (USEPA, 1995). In addition, five (5) duplicate samples were taken longitudinally along the treatment and distribution system of the ABUDWTP. These samples used for some physico-chemical analysis.

2.3 Methodology

Samples for physico-chemical analysis were first subjected to *in situ* (at sampling) measurement of their temperature with a thermometer. They were further subjected to chemical analyses for pH, conductivity, chlorides, total dissolved solids, total carbon, residual chlorine, nitrates, sulphates and phosphates in accordance with standard methods (APHA, 1998).

Analyses of the water samples for the THMs were in accordance with standard methods outlined in USEPA method 551.1 using Agilent Gas Chromatograph (USEPA, 1995). The results were assessed, and compared with national and international standards.

3. Results and Discussions

The results of the physico-chemical parameters as determined are presented in Tables 1 and 2 while those of the determined trihalomethanes are presented in Table 3.

Table 1: Sampled Water Temperature Variations during the Sampling Periods

Year	Jan-Feb (Peak Harmattan and Beginning of Hot Season)	March - May (Mid Hot Season)	June July (Onset of Rains)	August - Sept (Peak Rainy Season)	Nov. - Dec. (Beginning of Harmattan)
2008 (^{0}C)	12.3	21.8	22.8	22.8	18.1
2009 (^{0}C)	15.5	21.8	24.1	23.3	16.7
2010 (^{0}C)	15.8	22.6	23	22.8	18.2

Over the study period, the sampled water mean temperature values as obtained were relatively consistent with the five weather conditions over the periods. The months of June and July when the rains are beginning to set in in the study area recorded the highest water mean temperatures averaging 22.8 ^{0}C in 2008, 24.1 ^{0}C in 2009 and 23 ^{0}C in 2010. On the other hand the peak *harmattan* and beginning of the hot season (January and February) recorded the least mean water temperatures of 12.3 ^{0}C, 15.5 ^{0}C and 15.8 ^{0}C for 2008, 2009 and 2010 respectively. These values are reflections of mean daily temperature values of the study area during the period. Other results of analysed physical parameters are presented in Table 2. From this table, the measured pH values of the treated and distributed water ranged between weakly alkaline with pH 7.80±0.98 after chlorination and weakly acid with pH 6.70±0.51 at household level. These values are within international acceptable limits for drinking water of slightly acidic to slightly alkaline range of pH values. The increase in acidity towards house level could be due to the intermittent distribution of the produced drinking water. This practice favours biofilms generation and their subsequent decomposition creating intermediate products (Jakubovics, 1998; LeChevallier, 2000) with tendency to acidify the medium (Shaibu-Imodagbe, 2011).

Conductivity values of the treated water were 131.00±16.21 µS/cm @ 25 ^{0}C in samples after chlorination and 102.00±27.30 µS/cm @ 25 ^{0}C. These values are considerably lower than the maximum permitted level of 1000 µS/cm @ 25 ^{0}C under the prevailing national and international standards. Highest values were obtained after chlorination in the treatment stage probably due to the calcium hypochlorite used as a disinfectant and the peak content of chlorides at this stage of treatment. The treated water also had higher concentrations of chlorides (12.65±4.06 mg/L) than the distributed water at household level (0.5±0.087 mg/L). The variation in chlorides content may also not be unconnected with the disinfectant used at the treatment stage. This is despite the initial high values in the raw water (12.30±3.59 mg/L) which had been precipitated at the sedimentation tanks.

Table 2: Mean Concentration Levels of Physico-chemical Parameters as Measured in the Water Samples from the Treatment and Distribution Systems of the ABUDWTP (ABU Waterworks)

	Raw Water	Water after Sedimentation	Water after Chlorination	Booster Station Water	Household water
pH	7.8 ±1.34	7.60±1.00	7.80±0.98	8.00±1.01	6.70±0.51
Conductivity (µS/cm @ 25 ^{0}C)	83.52±14.75	102.50±25.60	131.00±16.24	121.00± 30.81	102.00±27.30
Chlorides (mg/L)	12.30±3.59	0.80±0.16	12.65±4.06	0.50±0.11	0.50±0.087
Total Dissolved Solids TDS (mg/L)	50.50±10.97	50.50±9.96	51.50±9.88	55.00±14.52	66.00±7.02
Total Organic Carbon TOC (mg/L)	6.57±0.92	4.30±1.73	2.30±0.31	2.40±0.31	2.30±0.28
Residual Chlorine (mg/L)	0.00	0.00	0.05±0.016	0.03±0.016	0.02±0.014
Nitrates (mg/L)	3.00±0.54	2.40±0.54	0.80±0.28	0.80±0.30	1.40±0.50
Sulphates (mg/L)	40.00±11.55	23.00±1.09	22.50±1.35	24.50±2.99	42.00±5.90
Phosphates (mg/L)	0.39±0.021	0.15±0.019	0.25±0.026	0.15±0.017	0.10±0.012

The total dissolved solids (TDS) ranged between 50.50±10.97 mg/L in the raw water sample to 66.00±7.02 mg/L in the treated household water sample. The higher TDS values were recorded during the distribution of the treated water than during the treatment stage. This lower value in the treatment stage may be due to the use of flocculating agents during treatment; while the upsurge in the TDS concentration levels during distribution could be due to the products of the mineralization of the intermediate products of decomposed biofilms in the distribution system. The proportion of total organic carbon in the raw water (6.57±0.92 mg/L) and the treated water (2.30±0.31 mg/L) and distributed water to household level (2.30±0.28 mg/L) exceeded the maximum total organic carbon levels of 4 mg/L for source water and 2 mg/L for treated water specified in the Disinfectants and Disinfection By-Products Rule of the USEPA (EPD, 2001). This may have implications for trihalomethane formation during the drinking water treatment and distribution. The mean concentrations of residual chlorine in the treatment and distribution system were found to vary from 0.05±0.016 mg/L in the samples after chlorination to 0.02±0.014 mg/L at household level. These low mean concentrations have implications for the safe delivery of wholesome and potable drinking water to the consuming community as these may indicate limited ability to maintain secondary disinfection in the distribution system. The mean nitrate concentrations decreased longitudinally along the treatment process from 3.00±0.54 mg/L in the raw water to 0.80±0.28 mg/L in the sample after chlorination but increased slightly to 1.40±0.5 mg/L at house level probably due to the biofilm growth, decomposition and mineralization as a result of intermittent water distribution. These values are considerably lower than the maximum contaminant limit of 50 mg/L allowed in national and international standards because of the risk of methaemoglobinanaemia. The concentrations of sulphates were found to decrease during the treatment process from 40.00±11.55 mg/L to 22.50±1.35 mg/L after chlorination but gradually increased to 42.00±5.90 mg/L at household level. This situation is most probably accounted for by the growth, decomposition and mineralization of biofilms generated in the distribution system due to intermittent water distribution. Despite this, these values are still within permissible limits under the national and international standards which range from 100 mg/L to 500 mg/L. The mean phosphate concentrations in the treatment and distribution stages progressively decreased from the raw water with 0.39±0.021 mg/L to house level water with 0.10±0.012 mg/L. This trend may be connected to the use of phosphates as essential nutrients for the growth and development of biofilms along the distribution system.

Table 3: Mean Concentration Levels of Trihalomethanes (THMs) as determined in Drinking water from Ahmadu Bello University (ABU) Water Treatment Plant

	Raw Water	Water after Sedimentation	Water after Chlorination	Booster Station Water	Household water
Regulated THMs DBPs (mg/L)					
Trichloromethane $CHCl_3$	BD	BD	BD	2.7068E-03 ±2.7476E-07	3.7703E-03 ±9.2954E-07
Tribromomethane $CHBr_3$	BD	BD	6.7297E-03 ±6.2606E-05	7.8324E-03 ±1.1855E-05	3.9843E-03 ±4.2909E-06
Dibromochloromethane $CHClBr_2$	BD	BD	BD	BD	BD
Bromodichloromethane CHCl2Br	BD	BD	BD	2.6007E-03 ±3.5978E-06	2.8459E-03 ±2.8459E-03
Sum of Regulated THM-DBPs (TRegTHM-DBPs)	**BD**	**BD**	**6.7297E-03 ±6.2607E-05**	**1.3140E-02 ±1.4614E-05**	**1.0601E-02 ±1.6625E-05**
Emerging THMs DBPs (mg/L)					
Dichlorobromomethane	BD	BD	4.3220E-01 ±8.2275E-05	BD	9.9704E-02 ±6.4706E-05
1,2-Dibromomethane	BD	BD	5.3446E-02 ±4.4597E-05	BD	BD
Sum of Emerging THM-DBPs – (TEmergTHM-DBPs)	**BD**	**BD**	**4.8564E-01 ±1.2685E-04**	**BD**	**9.9704E-02 6.4706E-05**
Grand Total THM-DBPs (GTTHMs)	**BD**	**BD**	**4.9237E-01 ±1.8089E-04**	**1.3140E-02 ±1.4614E-05**	**1.1031E-01 ±8.0564E-05**
% Emerging THM-DBPs of GTTHMs			**9.8633E+01**	**0.0000E+00**	**9.0390E+01**

BD = Below detection

Table 3 shows mean concentrations of trihalomethanes as determined for the water samples during the treatment and distribution stages of the Ahmadu Bello University community drinking water supply. The trichloromethane ($CHCl_3$) values were found to vary between below detectable limits for the raw water and sedimentation water samples and 3.7703E-03±9.2954E-07 mg/L at household level water sample. That trihalomethanes were not detected in the raw water and water after sedimentation is not surprising as disinfection is not undertaken during these stages of drinking water treatment. However the level after disinfection in the booster station may be related to delayed reaction between the residual disinfectant and the dissolved organic matter or its fractions as DBP precursors until at storage in the booster station (0.03±0.016 from 0.05±0.016 mg/L residual chlorine). The increase in the mean trichloromethane ($CHCl_3$) concentration at household level is likely due to increase in the sulphate (24.50±2.99 to 42.0±5.90 mg/L) and total dissolved solids (55.00±14.52 to 66.00±7.02 mg/L) content from the booster station to household level as well as the increase in acidity from the booster station to house level (from 8.00±1.01 to 6.70±0.51). This is in agreement with earlier reports in literature (WHO, 2008). The maximum contaminant level prescribed by the WHO, (2008) for this compound is 0.3 mg/L as against the maximum contaminant level goal of 0.07 mg/L under the USEPA standards. The mean values of the compound in the treated and distributed water to households as determined are correspondingly lower than the prescribed limits in these standards and as such the treated drinking water could be assumed to be safe for human consumption.

Like the trichloromethane, mean levels of tribromomethane were below detectable levels in the raw water and water after sedimentation due to the absence of a disinfectant in these stages of water treatment. But after chlorination, mean concentration of 6.7297E-03±6.2606E-05 mg/L of tribromomethane was observed.

This mean level increased to 7.8324E-03 ±1.1855E-05 mg/L in the booster station, where it decreased to 3.9843E-03±4.2909E-06 mg/L in the household water. The increase in the tribromomethane concentration in the booster station may be due to the increased levels of total organic carbon (TOC) from 2.30±0.31 mg/L in the chlorinated water to 2.40±0.31 mg/L), which would have provided more dissolved organic matter to react with the little quantity of residual chlorine (0.03 mg/L) to form more of the tribromomethane during storage in the booster station tanks. Like the trichloromethane, this observed mean level of tribromomethane is lower than the maximum contaminant level (0.1 mg/L) permitted by the WHO drinking water guidelines (2008). It is likely therefore that the Ahmadu Bello University treated drinking water does not pose serious risk to human health due to its content of tribromomethane.

Dibromochloromethane was neither detected in the source water nor in the Ahmadu Bello University treated and distributed drinking water during this study. However, bromodichloromethane was detected in the water treated and stored in the booster station with a mean concentration of 2.6007E-03±3.5978E-06 mg/L. This mean concentration increased at household level to 2.8459E-03±2.8459E-03 mg/L. Like trichloromethane ($CHCl_3$), the increase in mean concentration levels of dibromochloromethane may be most probably due to increase in acidity (pH from 8.00±1.01 to 6.70 ±0.51), sulphate content (from 24.50±2.99 to 42.00±5.90 mg/L) and total dissolved solids (from 55.00±14.52 to 66.00±7.02 mg/L) of the house level water from the booster station water samples This is consistent with other findings in literature (WHO, 2008).

The obtained TRegTHM-DBPs value for the treated house level drinking water (1.0601E-02±1.6625E-05 mg/L) is considerably lower than the maximum permissible limit of the compounds in the WHO and USEPA standards for drinking water (0.1 mg/L and 0.08 mg/L respectively) (USEPA, 1997; WHO, 2008; IEPA, 2011). From this study, TRegTHM-DBPs in the various treatment and distribution stages of ABU drinking water supply had the highest concentration of 1.3140E-02±1.4614E-05 mg/L during storage in the booster station tanks. This is likely connected to the development of biofilms due to fluctuations in the water levels in these tanks which caused increase in the total organic carbon content (from 2.30±0.31 mg/L in water after chlorination to 2.40±0.31 mg/L in the booster station water). This observation is similar to earlier reports by Jakubovicks, (1998) and LeChevallier, (2000). Such increased total organic carbon provides more dissolved organic matter as DBP precursor to generate more of the THMs during storage in the booster station tanks than after chlorination (1.3140E-02±1.4614E-05 mg/L as against 6.7143E-03±6.2606E-05 mg/L in the water after chlorination). From the booster station, the mean concentration level decreased to 1.0601E-02±1.6625E-05 mg/L in house level samples. This lower household concentration level may be due to losses in the distribution system arising from frictional losses and flow characteristics as had been noted earlier (Stevens *et al,* 1989; USEPA, 1997). In relation to standards, these TRegTHM-DBPs concentration levels in the finished drinking water (household and booster station) are well within permissible limits of the USEPA (0.080mg/L), WHO and EU (0.1 mg/L) but exceeded the maximum limit of 0.001 mg/L of the Nigerian Drinking Water Quality standard (SON. 2007).

Apart from the regulated THMs, this assessment identified two additional trihalomethanes in the treated water produced by the ABU water treatment plant during the study period. These are dichlorobromomethane and 1,2-dibromomethane which this study assesses as Emerging THM disinfection by-products (DBPs). Like the regulated THMs, these Emerging THM-DBPs were observed to be below detection levels in the raw water and sedimentation samples probably due to the same reasons of absence of disinfecting agent. Unlike the regulated THM-DBPs which recorded their highest concentrations at the booster station, the emerging THM-DBPs were of highest concentration in chlorinated water samples indicating a likely faster rate of formation. The proportion of the emerging THM-DBPs among the analysed THMs in the water samples during treatment and distribution ranged between over 90% in house water sample and 98% in chlorinated water. These Emerging THM-DBPs would definitely add on the THM burden of the community drinking water supply.

Traces of dichlorobromomethane were first noticed in water samples of treated drinking water after disinfection at mean concentration level of 4.3220E-01±8.2275E-05 mg/L. This concentration decreased to below detectable limit in the booster station but re-occurred in house level samples. The reason for this is not immediately established but the change in the reaction of the medium (from relatively neutral after disinfection to slightly basic in the booster station and subsequently weakly acid at house level) is suspected to contribute. This compound is a recognized carcinogen, a suspected toxicant of cardiovascular or blood, gastrointestinal or liver, kidney and neurological tissues (EPD, 2001; Cameo, 2014). Under toxic exposures it causes irritation of the skin, eyes, mucous membranes and the respiratory tract. It had also been reported to induce narcosis, nausea, dizziness and headache as well as liver and kidney damage in addition to nervous system breakdown. It is considered more hazardous than most chemicals in four out of nine hazard ranking systems (Scorecard, 2014; USEPA, 2014, WHO 2008)

1,2-dibromomethane (Dibromoethane or Ethylene Dibromide – USEPA, 2000) on the other hand was detected only in the treated drinking water after disinfection. Subsequently it was lost in the distribution system from the booster station to house level with concentration levels below detection. This is most probably due to the ready volatilization of the compound as had been reported in literature, most probably aided by warmer ambient temperatures (USEPA, 2004). Despite the absence of immediate threat to human health to consumers of the treated drinking water, its presence in the drinking water treatment poses health challenges. This is because the compound is probably mutagenic and a human carcinogen - a USEPA Category B2 classified carcinogen (USEPA, 2000). It is also reported to be responsible for reproductive and fertility abnormalities including morphological modification of sperm cells. Reports of tapered heads, abnormal tails and damage to sperm cells in testicles causing decrease in fertile sperm cells coupled with reduction in sperm viability under chronic exposures had been reported. Acute and short term exposures result in much reduced sperm velocity and quantity of semen. These are in addition to the irritation caused to the skin, the throat, eyes and the respiratory tracts (MEGS, 1999; USEPA, 2004; USEPA, 2014; WHO, 2008).

4. Conclusion

This study found Ahmadu Bello University treated drinking water to be USEPA and EU compliant with respect to the regulated THMs since the TRegTHM-DBPs values were lower than the MCL (maximum permissible levels) for the total Regulated THMs stipulated by both USEPA and EU (and WHO) standards of 0.08mg/L and 0.1 mg/L respectively. However, these TRegTHM-DBPs values were higher in all the treatment segments and finished water (at the Booster station and Household) than the Nigerian standard maximum permissible limit of the compounds (0.001 mg/L). In addition, this study identified additional trihalomethanes disinfection by-products (emerging THM-DBPs) in the treated drinking water which are known for their suspected and recognised carcinogenicity and genotoxicity. They are also known to cause narcosis, nausea, dizziness, headache, damage to the liver and kidney damage as well as central nervous breakdown. They also cause reproductive disruptions and irritations on the skin, the mucous membrane, the eyes and the respiratory tract. The proportions of these emerging THM-DBPs were found to account for over 90% of the concentrations of the grand total trihalomethanes (GTTTHMs) determined at each stages of the treatment and distribution system where they were observed. This adds to the health liability of THMs in the drinking water and hence a source of additional worries of the health impacts of consumers of the drinking water. As a result, a constant effort to minimise the concentration of these THM-DBPs in the treated water by reducing the DBP precursors, through source water protection from wastewater discharges from Samaru village and effluent from waste dump behind Ramat/ICSA hostels is urgently needed. Also, an uninterrupted flow of treated water in the booster station and distribution mains will control the growth of biofilms which add to the total organic carbon (TOC) when these decompose into the system.

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