Assessment of Regulated Disinfection By-Products in Ahmadu Bello University Community Drinking Water Supply

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The Drinking water produced from the Ahmadu Bello University (ABU) water treatment plant was assessed for its quality in terms of its regulated disinfection by-products (DBPs) content between 2008 and 2010. There were highly significant differences in mean concentration levels of these DBPs in the stages of treatment and distribution of the drinking water (F=4.86** - THMs, F=4.93** - HAAs). The pattern of variation of the Trihalomethanes was varied among the regulated trihalomethanes (THMs) while that of the haloacetic acids was consistent, decreasing from after chlorination stage to house level. Only THMs are regulated under the Nigerian drinking water standard with a maximum contaminant level of 0.001 mg/l as against international limits of 0.080 mg/l (USEPA) and 0.10 mg/l (WHO, EU). Mean concentration levels at booster station storage tanks were 0.0013 mg/l (THMs) and 0.5934 mg/l HAAs while at house level mean levels were 0.0107 mg/l (THMs) and 0.4863 mg/l (HAAs). These values show that drinking water produced by the ABU water treatment plant is non-compliant with national standard, but is readily compliant with international standards - USEPA, WHO and EU. However in terms of haloacetic acids (HAAs) the treated water had higher than the maximum permissible limits for HAAs under any of the standards. This calls for more concerted effort in monitoring for these DBPs and reducing their levels in the treated water.

Introduction

Clean, healthy and secure drinking water is a fundamental human right. So declared the United Nations Committee on Economic, Cultural and Social Rights and adopted by the General Assembly of The United Nations in December, 2002. This is because water is indispensable for leading a healthy life in human dignity. It is also a prerequisite to the realisation of all other human rights and as such this right has been so infused (ENS, 2002). Associated with this, is the fact that drinking water is a fundamental requirement of the human body that cannot be replaced. Indeed water is vital to all living resources, plants and animals alike as well as an indispensable economic resource that plays a fundamental role in climate change (WISE, 2011)

The Ahmadu Bello University, Zaria, Nigeria is one of the foremost universities in Nigeria. It was established in 1962 as two campuses situated in a land area of about 7,000 hectares north and south of Zaria metropolis. The main campus which is the larger of these campuses is about three quarters of this total land area (ABU, 2012). The Ahmadu Bello University (ABU) drinking water treatment plant is in the main campus supplying drinking water to students, staff, their dependant families and some people from Samaru village.

The ABU water treatment plant was commissioned in 1981 when the Zaria municipal water supply was found to be incapable of meeting the drinking water needs of the Ahmadu Bello University community. This plant is a conventional single train, one disinfection segment water treatment plant. Raw water from the River Kubanni is impounded into a manmade reservoir to provide the source water for the treatment plant. The water treatment plant is located within the university premises at an elevation of 655 meter MSL on latitude 11^0 08′ 25.60″N and longitude 7^0 39′ 19.65″E. Raw water is abstracted by two low lift pumps and treated in five sand gravity filters, five bottom hopper type sedimentation tanks, one liming unit and one disinfecting unit to presently produce 4.8million litres/day. It also has a clear water well of 1,500 m^3 capacity, with three high lift pumps. Part of the treated water is sent to the booster station which has two tanks – concrete (capacity 110m^3) and steel tank (capacity 117m^3) for storage and distribution to houses on higher elevations. The other part is sent to the elevated tank near the University Senate building to supply most academic areas, students' hostels and some residential houses. At the moment, water is distributed intermittently to areas on high elevations from the booster station (Anon, 2004). It is part of the study to identify how far the treatment plant provides safe drinking water to the academic community by determining the levels of Disinfection by-Products (DBPs) that are regulated under national and international standards in the finished drinking water.

Disinfection by-Products (DBPs) are produced when the disinfectant in use during water treatment combines with dissolved organic matter or its intermediate product such as humus, fulvic acids, and amides in water. Among these DBPs are Trihalomethanes (THMs), Haloacetic acids (HAAs), Acetonitriles, Halo-ketones and volatile organic compounds (VOCs) (Stevens *et al*. 1989; USEPA 1990(a, and b); Cox, 1997; Clarke and Thurnau, 2001). By 1989, over 500 of these DBPs have been discovered with more being discovered by the day. At the moment, there are many drinking water quality regulations. Among these, are the American Safe Drinking Water Act (SDWA) of 1974 as modified up to 2001 (Amendment 66), 1980 EU Approved Drinking Water Directive (effective 1985) with its Integrated Disinfection Design Framework (IDDF) and the Nigerian Drinking Water Standards. These regulations identified DBPs as having carcinogenic and mutagenic effects and are therefore likely to be injurious to health (Cox, 1997; Hydes, 1999; Stevens *et al*, 1989; USEPA 1990a; 1990b; 2003, 2011a; 2011b; Lipscomb, 2000). Among these legislations, the America SDWA has most wide ranging documentation on these DBPs in drinking water. To date, only eleven of the known DBPs are statutorily regulated under the American SDWA as amended up to 2001 (Stevens *et al*, 1989; Owens, 2001). These regulated DBPs are four Trihalomethanes (THMs)–Trichloromethane (Chloroform), Bromodichloromethane, Tribromomethane (Bromoform), Dibromochloromethane; five Haloacetic Acids (HAAs)–Monochloroacetic Acid, Dichloroacetic acid, Trichloroacetic acid, Monobromoacetic acid, Dibromoacetic acid; Bromate and Chlorite. This study is limited to the regulated THMs and HAAs only in the drinking water produced by the treatment plant excluding bromate and chlorite since the treatment plant uses only chlorine (from calcium hypochlorite) as disinfectant instead of ozone or chlorine dioxide.

Materials and Method

a) Sampling

Two Hundred and fifty two samples were taken in duplicates longitudinally along the treatment and distribution system of the ABU water treatment works from the source water (Kubanni reservoir) to an elevated Household (in Area E Quarters). These samples were taken between 2008 and 2010. Simultaneously, samples were taken of the raw water, water after sedimentation, water after chlorination and water at the booster station. House level sample was taken from Area E House Number 20. Samples for Trihalomethanes and Haloacetic acid analyses were taken in 60 ml glass vials with quantities of de-chlorinating agent (ammonium chloride) and stored at temperature about -4^0C or less in ice filled jugs in accordance with USEPA method 551.1 (USEPA, 1995).

b) Analytical Method

Analyses of the water samples for the regulated disinfection by-products were in accordance with standard methods outlined in USEPA (1995) method 551.1 using Agilent Gas Chromatography calibrated with commercial standards supplied by Ultra Scientific Analytical Solutions, North Kingstown, USA. The results were later compared with national and international standards.

Results and Discussions

The results of the analyses for the regulated disinfection by-products in the water undergoing treatment and being distributed along the distribution mains to households (in elevated estates) are presented in Tables 1 and 2 as mean values.

Table 1: Mean Levels of Regulated Trihalomethanes 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
Trichloromethane (Chloroform)	BD	BD	BD	0.0027	0.0038
Tribromomethane (Bromoform)	BD	BD	0.0067	0.0078	0.0040
Dibromochloro-Methane	BD	BD	BD	BD	BD
Bromodichloro-Methane	BD	BD	BD	0.0026	0.0029
Total THMs	BD	BD	0.0067	000131	0.0107

BD – BELOW DETECTION

From Table 1 above, mean chloroform values were found to vary between below detectable limits for the raw water to the 0.0038 mg/l at household level. The below detection level for the raw water and of water after sedimentation is not surprising as disinfection is not undertaken at these stages of drinking water treatment. However the level after disinfection may be related to delayed reaction between the disinfectant and the dissolved organic matter or its fractions as DBP precursors until at storage in the booster station with fractions of the residual disinfectant (0.03mg/l residual chlorine). The increase in the mean chloroform level at household level is likely due to increase in the sulphate (24.5 to 42.0 mg/l) and total dissolved solids (55.0 to 66.0 mg/l) content from the booster station to household level. This is in agreement with earlier findings in literature (WHO, 2008). The maximum contaminant level prescribed by 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 booster station and at household level were correspondingly lower than the prescribed limits in these standards and as such the treated drinking water could be assumed to be safe.

Like the Trichloromethane (Chloroform), mean levels of Tribromomethane (Bromoform) 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 with mean value of 0.0067 mg/l of Tribromomethane were observed. This mean level increased to 0.0078 mg/l in the booster station, where it decreased to 0.0040 mg/l in the household water. The increase in the bromoform concentration in the booster station may be due to the increased levels total organic carbon (TOC) from 2.25 in the chlorinated water to 2.40 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 any 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 drinking water and during this study. However, bromodichloromethane was detected in the water treated and stored in the booster station with a mean concentration of 0.0026 mg/l. This mean concentration increased at household level to 0.0029 mg/l. This is similar to chloroform mean levels which increase may be due to increase in the sulphate (24.5 to 42.0 mg/l) and total dissolved solids (55.0 to 66.0 mg/l) content from the booster station to household level as had been reported in literature (WHO, 2008). The obtained mean concentration value for this regulated trihalomethane in the treated household drinking water (0.0029 mg/l) is considerably lower than the maximum permissible limit of the compound in the WHO standards for drinking water (0.06 mg/l) (WHO, 2008).

From this study, total Trihalomethanes (TTHMs) in the various treatment stages of ABU water treatment were found to vary highly significantly (F=4.86**). The highest concentration of 0.0131 mg/l was recorded 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 2.25 mg/l in water after chlorination to 2.40 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 (0.0131 as against 0.0067 mg/l in the water after chlorination). From the booster station mean concentration level decreased to 0.0107 mg/l. This lower household concentration level may be due to losses in the distribution system arising from frictional losses and flow characteristics as earlier observed by Stevens *et al* (1989); USEPA, (1997). In relation to standards, these concentration levels of 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; WHO, 2008).

Table 2: Mean Levels of Regulated Halo Acetic Acids (HAAs) 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
Dichloroacetic acid	BD	BD	0.3935	0.0033	0.0012
Trichloroacetic acid	BD	BD	1.0759	0.3858	0.3456
Monochloroacetic acid	BD	BD	0.1385	0.1253	0.0971
Monobromoacetic acid	BD	BD	0.0095	0.0052	0.0015
Dibromoacetic acid	BD	BD	0.2148	0.0738	0.0409
Total Haloacetic acids THAA5	BD	BD	1.8322	0.5934	0.4863

BD – BELOW DETECTION

From Table 2, the haloacetic acids (HAAs) were below detectable levels in water undergoing treatment before chlorination. This is not surprising as there is no disinfectant to combine with in forming the HAAs during these stages in water treatment. But after chlorination, the water samples recorded highest levels of the regulated haloacetic acids measured. This is not unconnected to the fact that it is at this stage that first and maximum reaction occur between the disinfectant and the relevant DBP precursors. All the measured HAAs were found to vary highly significantly (F=4.93**). Mean concentration levels after chlorination decreased to house level in the residential quarters. This is most likely due to frictional loses and flow characteristics as earlier observed by Stevens *et al*, 1998; USEPA, 1997. Among the regulated haloacetic acids measured trichloroacetic acid was highest in mean concentration with 1.0759 mg/l after chlorination and decreased to 0.3456 mg/l at house level which is significantly higher than the maximum contaminant level of 0.02mg/l in Stage 2 DBP Rule (USEPA, 2011a). Monobromoacetic acid was least with mean concentration of 0.0095 mg/l after chlorination that decreased to 0.015 mg/l at house level. Total regulated haloacetic acids (THAA5) ranged from 1.8322 after chlorination to 0.4863 mg/l at house level. Although not regulated by national drinking water standard, these mean concentrations are higher than permissible levels by the United States Stage 2 Disinfectants and Disinfection By-Products Rule of 0 060 mg/l (USEPA, 2011a).

Conclusion

From this assessment, the drinking water produced by ABU water works had mean concentration levels of regulated THMs which were considerably lower than those of regulated HAAs. By these THM concentrations the treated water did not meet the prevailing Nigerian drinking water standard even though it meets international (USEPA, EU and WHO) standards THM regulation. Against the background of partial functioning service laboratories in many of Nigeria's water treatment industry, the criteria for determining the national THM standard could be contested to lack objectivity and enforcement. However with respect to the regulated HAAs, mean concentration values of the finished drinking water were well above the maximum permissible limits in any of these standards even though these compounds are not regulated under the national standard. The finished drinking water produced from the ABU water treatment plant can be considered to be potentially capable of causing increased risk of cancer traceable to its HAAs content. It is therefore necessary that their levels in the drinking water need further and constant monitoring with concerted effort to minimize them. It is by so doing that wholesome and potable delivery will be ensured to the university community.

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