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Original Research Article

Assessment of Health Risk of Bromate in Ozonised Bottled and Sachet Water in Aba Metropolis, South Eastern Nigeria

Irogbeyi Longinus Amarachi[1*], Nweke Ifeoma Nneka[1], Akuodor Godwin Christian[2], Orji Chima Ernest[2], Ekenjoku John Azubuike[1], Ezejiofor, Tobias Innocent Ndubuisi[3], Cajetan Elo Ilo[2]

[1]Department of Pharmacology and Therapeutics, Abia State University, Uturu, Nigeria
[2]Department of Pharmacology and Therapeutics, Faculty of Medicine, NnamdiAzikiwe University, Nnewi Campus, Nigeria
[3]Department of Biotechnology, School of Biological Sciences, Federal University of Technology, Owerri, Nigeria

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***Corresponding author:** Irogbeyi, Longinus Amarachi

Abstract

The study was carried out to determine the bromate contents in popular commercially available different brands of bottled and sachet drinking water in Aba metropolis. To assess the health risk of bromate in ozonised bottled and sachet water in Aba metropolis, South Eastern Nigeria Bromate determination was done using spectrophotometric method after treatment of the samples and absorbance was measured at 530 nm. The mean concentration of $Br0_3^-$ in different brands of bottled water was found to be 4.09±0.44 µg/l (range: 3.48±0.50 – 4.98±0.79 µg/l). On the other hand, the mean concentration of bromate ion in sachet water was 5.07± 0.78 µg/l with range 3.15±0.26 – 6.33±0.78 µg/l. Correlation analysis showed that bromate formation was influenced by the presence of bromide ions. There was a high cancer risk assessment resulting from the ingestion of bromate in bottled and sachet water which could occur overtime while both the drinking water were safe from the chemical toxicity risk point of view.

Keywords: Bromate, Cancer risk, chemical toxicity risk, Bottled water, sachet water, Nigeria.

INTRODUCTION

Water Quality is determined by the concentration of biological, chemical and physical contaminants. A contaminant becomes a pollutant when it exceeds an acceptable concentration advised by WHO guidelines [1].Water quality standards have been developed to minimize known chemical and microbial risks.

Production of bottled and sachet water has become a local intervention in Nigeria where public drinking water supply is unreliable [2].This has resulted in people looking for alternative drinking water source sold in bottled and polythene sachet.

The sources of bottled and sachet water in Aba metropolis, Abia state, south east, Nigeria are mainly bore holes and well water. The common technique for preparation of bottled and sachet water is based on chlorination, ultra filtration, ozonisation methods, *etc*. which are itself the removal technique of bromide ion. In spite of applying the removal processes, trace quantities of bromide are found in water.

Bromate

Bromate is not commonly found in water, but it may be formed as a by-product of ozonation disinfection of drinking water and also as a contaminant introduced from treatment of water with concentrated hypochlorite [3, 4]. Thus, ozonation treatment of drinking water represents an important potential pathway of bromate formation. The drinking water disinfection processes of ozonation, and to a lesser extent, chlorination, can yield the bromate ion as an unintentional by-product of the disinfection reactions [5]. Ozonation has the desirable advantage of being able to control Cryptosporidium parvum [6]. Cryptosporidium is a zoonotic parasitic protozoan, and its oocysts are refractory to most disinfectant chemicals [7. It was found that bromate formation was affected by such water quality conditions as bromide concentration, pH, temperature, carbonate alkalinity, ultraviolet light (UVA), disinfectant concentration and time (mg/l-min) and transferred ozone dose, among other factors. It was noted that even water with lower concentrations of bromide can approach the U.S. EPA standard of 10 microgram/litre (µg/l) for bromate [8] at sufficient ozone concentrations and disinfection times. Formation of bromate and haloamines after exposure to sunlight had been reported earlier in seawater to which chlorinated waste water had been discharged [9].

The U.S environmental Protection Agency (EPA) and European Commission have established a regulatory maximum contaminant level (MCL) of 10µg/l bromate in drinking water [10]. Later, the European commission set a lower MCL of 3µg/l bromate for natural mineral waters and spring waters treated by ozonation (11). The same value was proposed by the Drinking Water Commission European Union. More recently, WHO has proposed a guideline of <0.5µg/l [4].

The following equations show the pathway by which bromide (Br^-) is oxidized by ozone to bromate (BrO_3^-) through the intermediate formation of hypobromite (OBr^-). These equations also show that ozone does not oxidize hypobromous acid (HOBr) to bromate. Since increased acid (H_3O^+) will favor the formation of hypobromous acid, this suggests that ozonation at a low pH will tend to minimize bromate formation [12].

$Br^- + O_3 + H_2O \longrightarrow HOBr + O_2 + OH^-$
$HOBr + H_20 \longrightarrow H_30+ + 0Br^-$
$OBr^- + 2O_3 \longrightarrow BrO_3– + 2O_2$
$HOBr + O_3 \longrightarrow$ No Reaction

Guidelines Values

Under the 1986 EPA guidelines for Carcinogen Risk Assessment [13] on the basis of adequate evidence of carcinogenicity in male and female rats, bromate was classified as a probable human carcinogen by the oral route of exposure. Data on the carcinogenicity of bromate via the inhalation route are inadequate for an assessment of its human carcinogenic potential. The IPCS [14] value of 0.1 µg/kg of body weight per day for a 10^{-5} excess lifetime cancer risk level was based on an increased incidence of renal tumours in male rats given potassium bromate in drinking-water for 2 years using the same study (15). The upper-bound estimate of the cancer potency for bromate is 0.19 per mg/kg of body weight per day. The concentrations in drinking water associated with upper-bound excess lifetime cancer risks of 10^{-4}, 10^{-5} and 10^{-6} are 20, 2 and 0.2 µg/l, respectively [16]. Both the World Health Organization (WHO) and the U.S. Environmental Protection Agency (EPA) have judged bromate as a potential carcinogen, even at very low µg/l levels. The U.S. EPA has estimated a potential cancer risk of 1 × 10–4 (1 in 104) for a lifetime exposure to drinking water containing bromate at 5 µg/L and recently issued new rules that require public water supplies to control previously unregulated microbes (e.g., cryptosporidium and giardia) and cancer-causing Disinfection Bye Products (DBPs) in finished drinking water. The U.S. EPA Maximum Contaminant Level Goal (MCLG) for bromate in drinking water is set at zero, based on carcinogenicity. The Maximum Contaminant Level (MCL) is set at 10 ppb, based on the Practical Quantification Limit (PQL) [3].

MATERIALS AND METHODS

Sample Collection and preparation

Bottled and sachet water samples were purchased from the different designated areas that make up Aba metropolis, namely Aba North, Aba South and part of Osisioma. The number of bottled and sachet water used was 35 and 55 respectively of different brands purchased in triplicates all were written ozonised. The collected bottled and sachet water samples were filtered through 0.45 µ filter paper, acidified with 0.01M of nitric acid and stored in a pre-cleaned plastic bottle of 500 ml capacity.

Analytical Technique of Bromate Content of Water

Bromate content of bottled and sachet water samples was quantitatively analysed using previously reported method [17]. Drinking water samples were passed through a column of strong cationic resin, converted to the Na^+ form by treatment with saturated Nacl solution. Before use, the resin was washed with deionized water. The first 3ml of sample eluted from the column were discarded and then 25ml of sample were added with 1.5ml of 0.1M Hcl, 1.25ml of citrate buffer solution and 0.2ml of colour reagent. After 30 min the absorbance was measured at 530nm. Blank samples in deionized water were treated in the same manner without passing through the cationic resin.

Analytical Technique of Bromide Content of Water

Procedure: Into a $50cm^3$ water sample containing 0.005 – 1.0mg bromide were added $10cm^3$ buffer solution and (dropwise) $5cm^3$ hypochlorite reagent solution. The mixture was boiled for 10 minutes.

Then $2.5cm^3$ of sodium formate solution was added and the sample boiled further for 5 min. When it was cooled down it was transferred quantitatively into a $100cm^3$ volumetric flask. $15cm^3$ rosaniline solution was added and the mixture was homogenised. Three minutes, $25cm^3$ t-butyl alcohol-water solvent mixture (specific density $0.8g/cm^3$) is added and the flask is filled to the mark. The absorbance is measured. Reagent is made in the same way, substituting the sample with distilled water and the absorbance difference between the sample and blank is used for evaluation. A calibration curve is prepared, plotting the absorbance measured against standard solution.

Risk Assessment

The excess cancer risk due to ingestion of bromate in bottled and sachet water was evaluated based on the general USEPA standard method (18).

Methodology of Excess Cancer Risk Assessment

The individual excess cancer risk (IECR) as defined in USEPA, (18) can be defined by the following expression;

$IECR = UR_o \times C_{bw}$ -------- (equation (1)

Where UR_o is the risk factor expressed as $(Uq.L^{-1})^{-1}$ due to ingestion of drinking water and the considered toxicological values by US EPA of inorganic bromate for the cancer risk calculation at the case-study area is *UR*0= 2 × 10–5 (μg·L–1)–1.Cbw giving the estimated concentration of bromate in bottled water and sachet water expressed as $uq.L^{-1}$.

Methodology of Chemical Risk Assessment

To evaluate the hazard quotient for bromate, the chemical toxicity risk as life time average daily dose (LADD) was estimated with the help of equation 3 [18, 19, 20] and was compared to the reference dose (RfD) of 0.372 q/kg/day which is calculated on the basis of maximum acceptable level of bromate (10µq/l) in drinking water per guideline of US EPA [13]. Here the water ingestion rate was set as $2L.day^{-1}$ which is similar to the upper-bound level of adult daily intake recommended by USEPA [21], 365 for exposure frequency US EPA [20], 54.5 years for total exposure duration i.e the average all Nigeria life expectancy for both males and females [22], 19893 days for average time and 60.7kg for body weight [23]. The hazard quotient (HQ) and chemical toxicity risk (LADD) was calculated through ingestion of bottled and sachet water by the following formula:

$$HQ = \frac{LADD}{RfD} \qquad \text{(equation 2)}$$

$$LADD\ (\mu g/kg/day) = \frac{Ci \times IR \times EF \times LE}{BW \times AT} \qquad \text{(equation 3)}$$

Ci = Concentration of bromate in bottled water (µg/l
IR = Ingestion rate (L/day)
EF =Exposure frequency (days/year)
LE = Life expectancy (years)
AT = Average Time (days)
BW = Body Weight (kg)
RfD = Reference Dose ($\mu g.kg^{-1}.day^{-1}$)
LADD = Lifetime average daily dose, ($\mu g.kg^{-1}.day^{-1}$))

STATISTICAL ANALYSIS

The results collected in this study area were expressed as mean ± SD. Results were compared using the one way ANOVA analysis and independent sample test. Statistical analysis was performed using SPSS (Version 20) and (Software version 8.1) At 5% significant level, the calculated probability value was found to be lower than the tabulated value.

RESULTS AND DISCUSSION

Parameters used to assess cancer risk and LADD in bottled and sachet water

The bromate distribution can be assumed as a normal distribution. Ingestion rate of drinking water, total exposure duration and average time were considered as constant input values shown in table [1].

Bromate and Bromide levels in Bottled and Sachet water

The mean concentrations of BrO_3^- and Br^- in different brands of packaged bottled water samples in Aba metropolis were found to be 4.09±0.44 µg/l (range: 3.48 ± 0.50 - 4.98 ± 0.79 µg/l) and 9.11 ± 1.86 µg/l (range:6.51 ± 0.69 - 11.45 ± 0.82 µg/l) respectively. On the other hand, the mean values of BrO_3^- and Br^- in different brands of packaged sachet water samples were expressed as follows; 5.07 ± 0.78 µg/l (range: 3.15 ± 0.26 - 6.33 ± 0.78 µg/l) and 10.90 ± 1.0 µg/l (range:8.20 ± 0.79 – 12.37± 0.91 µg/l) respectively. The level of BrO_3^- content in bottled water found in this study was quite lower than the one cited in literatures in other country India with range (6 - 65 µg/l) (16). A wide margin of difference was obtained in Canada with the BrO_3^- range of 4.3 – 37.3 µg/l (20) coupled with a study in Los Angeles which has a wider margin of difference of BrO_3 content of 60 - 90 µg/l [24]. No work has been reported so far on bromate level in sachet water in the country or outside of the country where it may be neglected.

The mean value of BrO_3^- in sachet water (5.07±0.78 µg/l) was higher than the mean value of 4.09±0.44 µg/l of BrO_3^- found in bottled water in this study. It is noteworthy that the International Bottled Water Association (IBWA) based on USEPA has set a self- regulatory limit for bromate in bottled water of 10 µg/L whereas the World Health Organization (WHO) have set a guideline value of 25 µg/L which is under review and the proposed new guideline value is 10 µg/L [16]. The mean ratio of measured BrO_3^-/Br^- in bottled and sachet water in this study was found to be 0.48±0.03µg/l and 0.46±0.02µg/l respectively and these ratios are below the predicted ratios of 1.6, because it is derived that 62.5% (6.25µg/l) of bromide in bottled water is needed to convert into bromate upon ozonation to exceed the minimum contamination level of 10µg/l [16].

The mean values of bromate formation against predicted concentration in bottled and sachet water were 28.73% and 29.11% respectively. These values were in agreement with the predicted concentration of 62.5% because none of the values of bromate ion concentration found in this study was above 10 μg/l.

The measured bromate and bromide concentrations, their ratios and PH values in bottled and sachet water of various locations and consequently risks (Excess cancer risk and chemical toxicity risk) due to ingestion were shown in Table 2 and 3 respectively.

In the Ph range of 7-8, Haag and Hoigne [25] reported that only 1-10% of hypobromous acid (HOBr) total (in the form of hypobromite ion) takes part in reactions with molecular ozone and that the formation of hypobromous acid is very slow and does not contribute significantly to bromate formation.

This report confirmed the observation made in this study with the mean Ph value of 7.30 ± 0.14 and the range of 7.10± 0.10 – 7.7±0.59 in bottled water. The reduction in bromate level may be because of not favouring the formation of intermediate species as hypobromite (OBr). This was also found in Indian bottled water which was slightly alkaline and varied within narrow range of 7.1-7.3 [16]. However, the slight increase in bromate level found in sachet water may be as a result of Ph range of 7.3±0.10 – 8.5±0.03 with mean value of 7.7 ± 0.32 which was more alkaline.

Correlations

Pearson co-efficient of correlation (scatter plot) was used to establish a correlation of bromate and bromide contents in bottled and sachet water which showed a fairly high degree of correlation in fig1 and 2 respectively. This implied that bromate contents in bottled and sachet water were much influenced and controlled by bromide content.

Figure 3 was the scatter plot showing the relationship between bromate ion and Ph value in bottled water which showed a low degree of correlation. This implied that bromate content in bottled water was not influenced by the Ph of the samples in this study.

The same condition applied in figure 4 showing the relationship between bromate ion and Ph value in sachet water indicating that the effect of Ph was insignificant.

Table-1: Parameters used to assess cancer risk and LADD in bottled and sachet water

Parameters	Bottled water	Sachet water	Distribution	References
Bromate Levels (ug/I)	4.09±0.44	5.07±0.78	Normal	This study
IR (I/day)	2	2	-	USEPA, 1991
BW (kg)	60.7	60.7	Normal	Walpole et.al 2012
EF (day/year)	365	365	Triangular	USEPA, 1991
LE (years)	54.5	54.5	-	www.worldlife Expectancy, 2015

USEPA – United State, Environmental Protection Agency, EF Exposure Frequency
LE – Life Expectancy

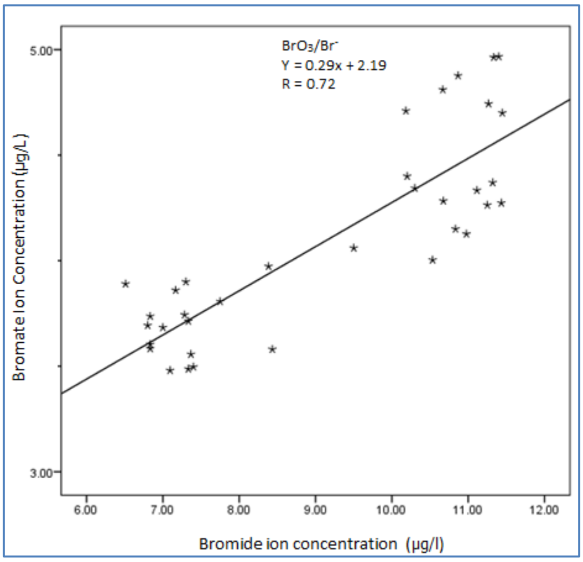

Fig-1: Scatter plot showing the relationship between Bromate and Bromide ions in bottled water

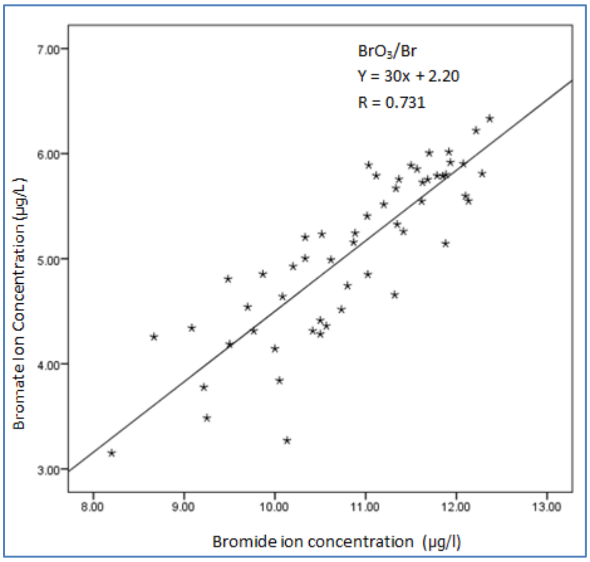

Fig-2: Scatter plot showing the relationship between bromate and Bromide ions in sachet water

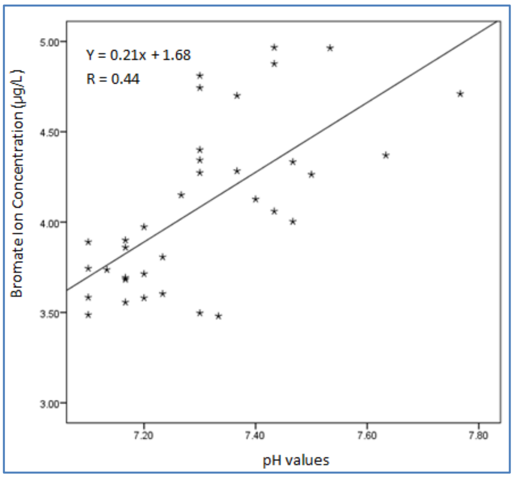

Fig-3: Scatter plot showing the relationship between Bromate and pH value in bottled water

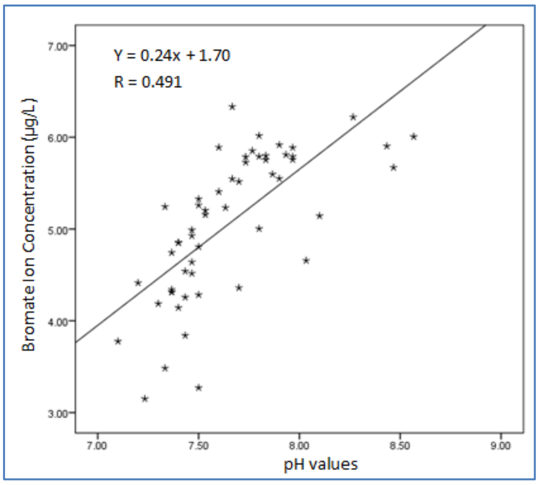

Fig-4.4: Scatter plot showing the relationship between Bromate and pH value in sachet water

Table-2: Showing measured Bromate, Bromide concentration, their ratios, percentage formation of bromate against predicted value and PH in bottled water of various regions of Aba metropolis and consequently risks (excess cancer risk and chemical toxicity risk) due to ingestion

Bottled water	Location	Measured conc, of BrO_3- (µg/L)	Measured conc. of Br^- (µg/L)	Measured BrO_3- con/ Measured Br-conc.	pH	% Formation BrO_3	Cancer Risk ($x10^{-4}$)	LADD	HQ (Hazard quotient)
BW-1	Aba North	4.70	11.45	0.41	7.37	25.66	0.80	0.148	0.4
BW-2		4.33	11.11	0.39	7.47	24.36	0.80	0.137	0.4
BW-3		3.89	6.51	0.60	7.10	37.35	0.60	0.122	0.3
BW-4		4.71	10.18	0.46	7.77	28.92	0.80	0.149	0.4
BW-5		4.26	11.25	0.38	7.50	23.67	0.80	0.135	0.4
BW-6		3.48	7.09	0.49	7.33	30.68	0.60	0.110	0.3
BW-7		3.69	6.80	0.54	7.17	33.92	0.60	0.117	0.3
BW-8		4.37	11.32	0.39	7.63	24.13	0.80	0.138	0.4
BW-9		4.96	11.33	0.44	7.53	27.36	0.80	0.157	0.4
BW-10		3.81	7.75	0.49	7.23	30.73	0,60	0.120	0.3
BW-11		3.97	8.38	0.47	7.20	29.61	0.60	0.125	0.3
BW-12		3.50	7.40	0.47	7.30	29.56	0.60	0.111	0.3
BW-13		4.74	11.27	0.42	7.30	26.29	0.80	0.150	0.4
BW-14		4.27	11.43	0.37	7.30	23.35	0.80	0.135	0.4
BW-15		3.60	6.83	0.53	7.23	32.94	0.80	0.114	0.3
BW-16	Aba South	4.06	9.50	0.43	7.43	26.71	0.60	0.128	0.3
BW-17		4.81	10.6	0.45	7.30	28.17	0.80	0.152	0.4
BW-18		3.58	8.43	0.42	7.20	26.54	0.60	0.113	0.3
BW-19		3.90	7.30	0.53	7.17	33.39	0.60	0.123	0.3
BW-20		3.74	6.83	0.55	7.13	34.22	0.60	0.118	0.3
BW-21		4.13	10.98	0.38	7.40	23.51	0.60	0.130	0.3
BW-22		3.56	7.37	0.48	7.17	30.19	0.60	0.112	0.3
BW-23		4.00	10.53	0.38	7.47	23.74	0.60	0.126	0.3
BW-24		4.88	10.87	0.45	7.43	28.06	0.80	0.154	0.4
BW-25		3.86	7.17	0.54	7.17	33.65	0.60	0.122	0.3
BW-26	Osisioma	4.28	10.67	0.40	7.37	25.07	0.80	0.135	0.4
BW-27		3.74	7.28	0.51	7.10	32.11	0.60	0.118	0.3
BW-28		3.58	6.83	0.52	7.10	32.76	0.60	0.113	0.3
BW-29		4.34	10.30	0.42	7.30	26.33	0.80	0.137	0.4
BW-30		3.71	7.33	0.51	7.20	31.63	0.60	0.117	0.3
BW-31		3.68	7.00	0.53	7.17	32.86	0.60	0.116	0.3
BW-32		4.15	10.83	0.38	7.27	23.95	0.80	0.131	0.4
BW-33		4.97	11.40	0.44	7.43	27.25	0.80	0.157	0.4
BW-34		4.40	10.20	0.43	7.30	26.96	0.80	0.139	0.4
BW-35		3.49	7.33	0.48	7.10	29.76	0.60	0.110	0.3

Table-3: Showing measured Bromate, Bromide concentration, their ratios, percentage formation of bromate against predicted value and PH in sachet water of various regions of Aba metropolis and consequently risks (Cancer risk and chemical toxicity risk) due to ingestion

Sachet water code	Locations	Measured conc. of BrO_3^- (g/L	Measured conc. Of Br^- (g/L	Measured BrO_3^- conc./measured Br^- conc.	ph	% formation of BrO_3^-	Cancer Risk (x10^{-4}	LADD	HQ Hazard
SW-1	Aba North	5.16	10.87	0.47	7.5	29.67	0.80	0.163	0.4
SW-2		4.74	10.80	0.44	7.4	27.43	0.80	0.150	0.4
SW-3		4.19	9.50	0.44	7.3	27.57	0.80	0.132	0.4
SW-4		5.52	11.20	0.49	7.7	30.80	1.00	0.174	0.5
SW-5		5.89	11.03	0.53	7.6	33.37	1.00	0.186	0.5
SW-6		6.33	12.37	0.51	7.7	31.98	1.00	0.200	0.5
SW-7		5.79	11.12	0.52	7.8	32.54	1.00	0.183	0.5
SW-8		4.66	11.32	0.41	8.0	25.73	0.80	0.147	0.4
SW-9		5.67	11.33	0.50	8.5	31.28	1.00	0.179	0.5
SW-10		6.01	11.70	0.51	8.6	32.10	1.00	0.190	0.5
SW-11		4.26	8.67	0.49	7.4	30.71	0.80	0.135	0.4
SW-12		5.80	11.89	0.49	7.8	30.49	1.00	0.183	0.5
SW-13		5.55	11.62.	0.48	7.7	29.85	1.00	0.175	0.5
SW-14		5.79	11.79	0.49	8.0	30.69	1.00	0.183	0.5
SW-15		5.92	11.93	0.50	7.9	31.01	1.00	0.187	0.5
SW-16		4.34	9.08	0.48	7.7	29.87	0.80	0.137	0.4
SW-17		6.22	12.22	0.50	8.3	31.81	1.00	0.197	0.5
SW-18		4.81	9.48	0.51	7.5	31.71	0.80	0.152	0.4
SW-19		5.60	12.10	0.46	7.9	28.93	1.00	0.177	0.5
SW-20		4.54	9.70	0.47	7.4	29.25	0.80	0.143	0.4
SW-21		5.41	11.02	0.49	7.6	30.68	1.00	0.171	0.5
SW-22		5.79	11.85	0.49	7.7	30.54	1.00	0.183	0.5
SW-23		5.21	10.33	0.50	7.5	31.52	0.80	0.165	0.4
SW-24		6.02	11.92	0.51	7.8	31.56	1.00	0.190	0.5
SW-25		4.93	10.20	0.48	7.5	30.21	0.80	0.156	0.4
SW-26	Aba South	5.73	11.63	0.49	7.7	30.79	1.00	0.181	0.5
SW-27		4.86	9.87	0.49	7.4	30.78	0.80	0.154	0.4
SW-28		5.89	11.50	0.51	8.0	32.01	1.00	0.186	0.5
SW-29		5.76	11.68	0.49	7.8	30.82	1.00	0.182	0.5
SW-30		5.24	10.52	0.50	7.0	31.13	0.80	0.166	0.4
SW-31		5.86	11.57	0.51	7.8	31.66	1.00	0.185	0.5
SW-32		4.32	9.77	0.44	7.4	27.64	0.80	0.136	0.4
SW-33		4.99	10.62	0.47	7.5	29.37	0.80	0.158	0.4
SW-34		5.33	11.35	0.47	7.5	29.35	1.00	0.168	0.5
SW-35		4.41	10.50.	0.42	7.2	26.25	0.80	0.139	0.4
SW-36		3.78	9.22	0.41	7.1	25.62	0.60	0.119	0.3
SW-37		5.24	10.88	0.48	7.3	30.10	0.80	0.166	0.4
SW-38		5.76	11.37	0.51	8.0	31.66	1.00	0.182	0.5
SW-39		4.85	11.02	0.44	7.4	27.51	0.80	0.153	0.4
SW-40	Osisioma	5.55	12.13	0.46	7.9	28.60	1.00	0.175	0.5
SW-41		5.81	12.28	0.47	7.9	29.57	1.00	0.184	0.5
SW-42		4.31	10.42	0.41	7.4	25.85	0.80	0.136	0.4
SW-43		4.14	10.00	0.41	7.4	25.88	0.80	0.131	0.4
SW-44		5.00	10.33	0.48	7.8	30.25	0.80	0.158	0.4
SW-45		3.84	10.05	0.38	7.4	23.88	0.60	0.121	0.3
SW-46		4.36	10.57	0.41	7.7	25.78	0.80	0.138	0.4
SW-47		5.26	11.42	0.46	7.5	28.79	0.80	0.166	0.4
SW-48		3.27	10.13	0.32	7.5	20.18	0.60	0.103	0.3
SW-49		5.90	12.08	0.49	8.4	30.53	1.00	0.186	0.5
SW-50		4.28	10.50	0.41	7.5	25.48	0.80	0.135	0.4
SW-51		4.64	10.08	0.44	7.5	28.77	0.80	0.147	0.4
SW-52		5.14	11.88	0.43	8.1	27.64	0.80	0.162	0.4
SW-53		3.48	9.25	0.38	7.3	23.51	0.60	0.110	0.3
SW-54		3.15	8.20	0.38	7.2	24.00	0.60	0.100	0.3
SW-55		4.52	10.73	0.42	7.5	26.33	0.80	0.143	0.4

Risk Assessment due to Oral Ingestion of Bromate in Bottled and Sachet Water

The individual excess cancer risk due to ingestion of bromate in bottled and sachet water at an average of 2L/day over the lifetime expectancy of 54.5 years for a Nigerian adult was observed to be in the range of 6 x 10^{-5} - 7x10^{-5} with mean value of 6.91 x 10^{-5} and mean value of 9.0 x10^{-5} in the range of 6.0 x 10^{-5} - 1.0 x 10^{-4} respectively. The values showed about one order of magnitude lower than the mean value of 2.24x10^{-4} found in Indian bottled water [16]. All the values were higher than the maximum acceptable level (2x10^{-5}) as per guidelines of USEPA [26]. This implied that people in this region were exposed to high cancer risk resulting from the overtime ingestion of bromate in bottled and sachet water. The sachet water, however, has more risk assessment than the bottled water from the values found in this study. Evaluation of chemical toxicity risk through bottled and sachet water ingestion produced hazard quotient (HQ) values of 0.35 and 0.43 respectively derived from the mean LADD of 0.129 in bottled water and the mean LADD of 0.160 in sachet water compared with the reference dose (RfD) of 0.372µg /kg/day shown in table [2, 3]. The values were found to be lower than the value of 1.01 found in Indian bottled water [16]. In accordance with the standard EPA method, if the HQ exceeds one, there is a chance that non-carcinogenic effects may occur with the probability which tends to increase as the HQ increases [27]. It therefore showed from this study that people in this region were safe from the chemical toxicity risk assessment point of view.

CONCLUSION

This study was carried out to assess the health risk involved in drinking bottled and sachet water treated with ozone as a means of water purification in Aba metropolis, Nigeria. It was realised that a carcinogenic substance bromate formed as a disinfection bye - product depends to a large extent on the level of bromide present and ozone dose. This underlined the importance of the central water regulatory authority in the country to set up standard measures that will reduce the effects of such factors like bromide, Ph, temperature and ozone dose which lead to bromate formation above the acceptable level.

Limitation of Study

The study did not involve the use of high technology equipments such as ion chromatography for more accurate and reliable results.

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Conflict of Interest

The authors declare no conflict of interest in the course of conducting this study.

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