International Journal of Pure and Applied Science
Published by Cambridge Research and Publications
Vol. 21 No.9
June, 2021.

EFFECTS OF SOME GOITROGENS ON IODINE DISTRIBUTIONS IN PIPE-BORNE WATER, BOREHOLE WATER, AND WELL WATER OF SOKOTO STATE, NIGERIA

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ABSTRACT

Many chemicals and substances in drinking water are of public health concerns because of their potential to elicit health problems to users. A study was carried out in three zones of Sokoto State, Nigeria, to determine goitrogens and iodine distributions from different sources of drinking water in the state. Water iodine was measured using cerium IV reduction method. Goitrogens such as (Calcium, Magnesium, Nitrate, Chloride, and Fluoride) were evaluated using Atomic Absorption Spectrophotometry, while pH of the water was assessed using pH Metter. The revealed result for water iodine level was (5.2±0.01-9.5±0.1 µg/L). Antinutrients levels are: magnesium (7.3± 0.04-9.7±0.07 mg/L), calcium (8.2±1.05-9.8±1.32 mg/L), chloride (0.8±0.06-1.9±0.03 mg/L), fluoride (0.4±0.02-1.9±0.52 mg/L), and nitrate (1.7±0.06-3.9±0.01mg/L). The obtained pH was (6.24-6.65). Iodine levels differed among different water sources from all the three zones of the state but the difference was not significant ($p>0.05$). For chloride concentration, significant ($p<0.05$) difference in well water was observed between SCZ (1.1±0.01µg/L) and SEZ (1.7±0.03µg/L). Water iodine levels across the three zones of Sokoto State in different sources of drinking water were considerably lower than the recommended water iodine level of > 15 µg/L in drinking water according to the international standard. Therefore, analysis of iodine concentrations in different sources of drinking *water in the state will highlight more potential areas with low iodine tendency, as concentrations of iodine in water will inevitably reflect concentrations in soils, and food crops and hence overall dietary intake.*

Key word: *Nitrate, Calcium, magnesium, iodine, goitrogens, pH, water, and Sokoto State*

INTRODUCTION

The problems attached to the lack of portable and adequate water resources in Nigeria are endangering the health of about 40 million individuals (Wali *et al*., 2016; Adamu *et al*., 2019; Sarkingobir *et al*., 2020). Recently, World Bank (World Bank, 1990) suggests that it would cost in excess of US$ 109 a year to overhaul such problems if ground and surface water contamination and pollutions go unchecked (Richard and Ivanildo, 1997). In the long-term, the present level of environmental degradation instigates health problems from water-borne diseases for most of this population (Richard and Ivanildo, 1997). Many people are already affected by having to consume unsafe drinking water (Richard and Ivanildo, 1997).

Thus, water and food are the vital rudiments that all human beings require to survive. Thus, the kind of water and food a person takes determine his health status, whether such person will live long or not. Some water and foods that are found in our local communities can be very insalubrious to the health status of man due to the adverse effect they have to the normal functioning of the body system. Also, the water that we drink if not properly examined or taken care of contains some (chemicals) that can lead to the malfunctioning of some glands in our body (Enechi, *et al*,. 2013). Similarly, some water and foods consumed by man tends to suppress the functioning of the thyroid gland by interfering with the level of iodine in the body, which can, as a result, cause an enlargement of the thyroid gland called goiter.

Moreover, the water we drink can also be polluted or contaminated by some substances that cause inflammation of the thyroid gland. These substances contained in water and foods that promote the formation of goiter are called goitrogens (United Nations,1993; FAO/WHO,2006.; Vanderpas, 2006; Zimmermann *et al.*, 2008). Goitrogens suppress the functioning of the thyroid gland by interfering with the uptake of iodine, which as a result, lead to the enlargement of the thyroid, i.e. a goiter (United Nations, 1993; FAO/WHO,2006). Goitrogens can also induce hypothyroidism. In hypos, goitrogens can further depress thyroidal function and stimulate the growth of thyroid (goiter) (Enechi, *et al*,.2013). Parable, these goitrogens include foods, drugs and chemicals. Thus, goitrogens are important not just because they create goiter, but because they can interfere with the iodine metabolism in general. Moreover, since they are directly involved in thyroid hormone production and metabolism, they affect every part of the body (United Nations,1993; FAO/WHO,2006).

Certainly, iodine, water goitrogens, and goiter are interconnected. Iodine was initially unveiled in 1811 by Courtois and recognized as a new element by Gay-Lussac who named it "iode" (borrowed from Greek work "ioeides" meaning violet-colored) (Jenzer and Sadeghi, 2017). Iodine has a molecular weight of 126.9g/mol and belongs to non-metals particularly dubbed as halogens, which are highly electronegative. The property of high electronegativity gave iodine ability to be widely distributed in nature in order to attain octet configuration. It can be found in water, rock, soil, foods materials, and relations (Paz *et al*., 2018).

Iodine participates in the regulation of basal metabolic rate by thyroid hormones biosynthesis. 100-200 ug/day is required for this function of iodine. Deficiency of iodine spurs goiter, central nervous system disorders such as cretinism, mental retardation and relations. Iodine is essential in the synthesis of thyroid hormones in thyroid glands by iodination (formation of oxidized iodine species), iodization of iodine derivatives. Therein, the hormones T_3 and T_4 formed a conformation of twist-skewed fashion. The iodine is the most effective lipophilic substituent required to fix the twist-skewed confirmation of T3 and T4 hormones (Jenzer and Sadeghi, 2017).

Presently, iodine deficiency is a public health problem worldwide. More than, 1.5 billion people are suffering from goiter, cretinism and serious metabolic disorders such as hypothyreosis, myxedema coma, cardiac disorder, arrhythmia, catabolism, exopthalmia, infertility, pre-eclampsia, fatigue, infant death, low basal body temperature, weight gain, and mental disorders (Jenzer and Sadeghi, 2017; Umar *et al*., 2017; Andersen *et al*., 2009; Doku and Bortey, 2018; Paz *et al*., 2018).

Iodine level in water is important to determine the level of iodine, which is available for plants or animals, which is ultimately supplied to the food chain for human consumption. The rein, failure to provide adequate level of iodine will forsooth affect the iodine intake of plants and ultimately animals, and in turn leading to iodine deficiency disorders (Andersen *et al*., 2009; Lu *et al*., 2005). Water sources of iodine, more especially drinking water are due to geology, and other substances that are found in the water and are hell bent on interfering with the iodine level are goitrogens (Andersen *et al*., 2008; Lu *et al*., 2005; Jenzer and Sadeghi, 2017). Thus, scientific investigations aimed at determining the level of goitrogens and iodine in water are desirable. Therefore, this study was designed to investigate goitrogens and iodine distributions in different sources of drinking water in three zones of Sokoto State, Nigeria.

MATERIALS AND METHODS

Fifty milliliter of pipe borne water (PPW), borehole water (BW) and well water (WW) each from two communities of Sokoto Central Zone (SCZ), Sokoto Western Zone (SWZ) and Sokoto Eastern Zone (SEZ) were collected in a sterile plastic container and transported to Biochemistry general laboratory, stored at standard room temperature for less than three days before the analysis according to (Shin *et al.*, 2011). Analyses were done in triplicate.

Iodine estimation in (PPW, BW and WW) Fisher *et al.*, (1986).

Samples were collected in 10 test tubes, 1ml of each sample was pipetted into the 10 test tubes, 1ml of $H_3A_SO_3$ was dispensed into the test tubes, and was incubated for 10mins, then 1ml of Ce^{+4} was dispensed into the sample test tubes, and incubated for 20mins and absorbance was measured using spectrophotometer at the wavelength of 430nm. Standard curve on graph paper was used by plotting iodine concentration of each standard on the abscissa against its absorbance at the ordinate, the absorbance was used to extrapolate corresponding concentration from the curve.

pH determination in PPW, BW and WW.

Five mills (5mL) of samples were poured into 10 test tubes. The samples were stirred and allowed to stand for a minimum of one hour to allow the temperature to stabilize. Electrode(s) of the pH meter were immersed into the samples for

30 seconds to obtain good contact between the samples and the electrodes and the pH readings were taken.

Assessment of goitrogen factors in PPW, BW and WW (Greenberg *et al.*, 1992; Hauser, 2018).

Total metal analysis was obtained from the total of both dissolved and suspended metal ions. Triplicate of samples were run independently in each case to ensure high accuracy in the quantitative results. Results of metal analysis were reported as X ± 2σ in ppm units. Calibration of AAS was carried out using an external calibration curve. Difference between the mean obtained from the ANOVA were ascertained using Duncan's post hoc multiple range test. Results were expressed as means ± SD. Significant level was set at P < 0.05.

RESULTS

Iodine levels and some antinutrient factors from different sources of drinking water of the three zones of Sokoto State was shown in Table 1. Iodine level differed among different water sources in all the three zones of the state but the difference was not significant (p>0.05). For chloride concentration, significant (p<0.05) difference in well water was observed between SCZ (1.7±0.03µg/L) and SEZ (1.9±0.02µg/L).

Table 1: Iodine and Some Goitrogens That Affect Iodine Absorption, Bioavailability and Metabolism in Different Sources of Drinking Water in Three Zones of Sokoto State, Nigeria

	Sokoto Central Zone (SCZ)			**Sokoto Western Zone (SWZ)**			**Sokoto Eastern Zone (SEZ)**		
	Pipe-borne water (PBW)	Borehole water (BW)	Well water (WW)	Pipe-borne water (PBW)	Borehole water (BW)	Well water (WW)	Pipe-borne water (PBW)	Borehole water (BW)	Well water (WW)
Iodine (µg/L)	**9.5±0.01**	**6.9±0.01**	**6.5±0.01**	**8.5±0.03**	**7.2±0.04**	**6.4±0.05**	**7.2±0.01**	**6.5±0.01**	**5.2±0.01**
pH	6.49	6.65	6.37	6.35	6.45	6.56	6.42	6.24	6.34
Magnesium(mg/L)	Not detected	7.9±0.06	9.3±0.07	Not detected	7.3±0.04	9.7±0.07	Not detected	7.5±0.01	9.8.±0.07

Calcium (mg/L)	Not detected	8.7±1.07	9.8±1.32	Not detected	8.2±1.02	8.7±1.52	Not detected	8.2±1.05	9.5±1.10
Chloride (mg/L)	0.9±0.02	1.1±0.01	1.7±0.03*	0.7±0.02	1.8±0.01	1.9±0.03	0.8±0.06	1.0±0.01	1.9±0.02*
Fluoride (mg/L)	0.4±0.02	1.6±0.28	1.9±0.52	0.5±0.08	1.4±0.10	3.0±0.20	0.5±0.01	1.2±0.21	1.8±0.01
Nitrate (mg/L)	1.7±0.06	3.5±0.03	3.8±0.05	1.8±0.01	3.2±0.02	3.6±0.04	1.9±0.05	3.4±0.07	3.9±0.01

DISCUSSION

The results in table 1 revealed an iodine distribution which ranges from 5.2±0.01-9.5±0.1µg/L in the whole Sokoto state. Therein, the iodine level was comparatively higher from PBW, then BW, and lastly WW in all the zones of the state. This might be due to processing. The levels are in a descending order of processing, because processing of water reduces level of organic matter that could reduce the iodine availability in the sample water. The pH ranges from 6.24-6.65. Analyses indicated that, PB water have not shown any amount of magnesium(Mg) and calcium(Ca). This observation could be because of their processing through addition of alum to remove hardness which is mostly elicited by Mg and Ca. Thus, BW and WW had shown levels of Mg and Ca. The Mg distribution ranges from 7.3± 0.04-9.7±0.07 mg/L, while Ca ranges from 8.2±1.05-9.8±1.32 mg/L. Mg and Ca are the foremost causes of hardness in our water, which in turn cause wastage of soap and coloring on teeth, but has no significant health concern. On the other hand levels of the Mg and Ca in the Sokoto water are below excessive levels and could proffer health benefits to the users (WHO, 2011; Sengupta, 2013). Chloride and fluoride were detected with ranges of (0.8±0.06-1.9±0.03 mg/L) (0.4±0.02-1.9±0.52 mg/L) respectively. Their presence has been used as an indicator of contamination of this water due to anthropogenic sources. These findings are all below the Secondary Maximum Contamination Level (SMCL) and Maximum Contamination Level (MCL) respectively for chloride and fluoride (Minnesota Pollution Control Agency,1999). Fluoride below 1.5mg/l protects the teeth against decay, while above 1.6 mg/l could lead to health effects (Atia and Hoggui, 2013). The level found in Sokoto water cannot give detectable taste and is below the daily need humans, hence the distribution could not elicit health challenge (WHO,1996).

Nitrate distribution in Sokoto zones has a range of 1.7±0.06-3.9±0.01 mg/L. Also the concentrations increase from PBW down to the WW, which might be due to processing effect. Their presence could be attributed to agricultural habits of fertilizer application and human waste disposal (WHO, 2011; Zhou, 2015). Adults can take large amount of nitrate without health effects, but prolonged exposure could affect health due to formation of nitrosamines. Levels higher than 10mg/l affects babies below six months, and there is concern that nitrate could traverse the placenta to reach the fetus (Zhou, 2015; Colorado State University, 1997).

The results of this study in table 1 revealed that, water iodine distributions across the three zones of Sokoto State in three different sources of drinking water ranges from 5.2±0.01 to 9.5±0.1 μg/L, which is considerably lower than the Recommended Water Iodine level of > 15 μg/L in drinking water (Opinion on Scientific Committee on Food in the Tolerable Upper Intake level of Iodine in Brussels, 2002). The results had also shown that the pipe-born water(PBW) across all the zones was higher than the BHW and WW. This is in accordance with the findings of Lu *et al* (2005) and Andersen *et al*(2009), which echoed that processing of PBW is responsible for removal of many constituents such as the goitrogens that could reduce iodine content of the analyzed water samples.

Iodine concentrations in ground waters (and surface waters) largely lie in the range of 0.01–70 μg/L, depending on geographical location and geology factors of the soils (Johnson, 2003). Low iodine level in different sources of drinking water might be due to water 'hardness' which is defined by concentration of calcium and magnesium present in water. This study revealed the presence of these elements, therefore calcium and magnesium might be responsible for low iodine content in water. Ajayi *et al.*, (2015) reported that, calcium (Ca) and magnesium(mg) ions in water react strongly with iodine producing insoluble products to prevent its availability. Similarly, Johnson, (2003) reports that, Ca and Mg in water are suspected factors which result in low iodine in water. Likewise, it was reported that, high calcium in drinking water hinders iodine absorption in humans when it is consumed (Lin, 1991).

However, another susceptible reason for low iodine level in different sources of drinking water across the three zones of Sokoto State might be due to the presence of deposit of limestone in the State. Fuge and Long (1989) reported worst iodine deficiency in Derbyshire of UK where Carboniferous Limestone cropped out. Another potential factor that might have contributed to the low iodine levels in different sources of drinking water across the three zone of the State as also found in this study is the presence of fluoride in all the water samples. Mikhailets *et al.,* (1996) reported reduction of iodine-absorbing function in presence of fluoride in water. Tokar *et al.,* (1989) reported that presence of fluoride in water can impede Iodine pump, peroxidase reactions, coupling reactions, lysosomal hydrolysis and decrease peripheral conversion of T_4 to T_3 with increase Reverse T_3. This may be linked to low T_3 and T_4 with increased TSH. Pierre *et al.,* (1978) reported that fluoride reduces thyroid iodide concentration making iodine unavailable in humans who consumed such type of water. The reduction of iodine action by fluoride is achieved through competition. Chloride, fluoride, bromine and iodide ions are all halogens with strongest oxidative power and most reactive who compete with iodine in absorption, transportation and availability. In the biological system, such competition displaces iodine in cells leading to iodine deficiency. It is well established that iodine in position 5 of the thyroxine molecule is required for the bioactivity of both T_3 and T_4 and that other halogens can replace Iodine on that same position in T_3 and T_4 thus serving as a competitive inhibitor (Vobecky *et al.,* 1996).

Additionally, the high chloride concentration in the water as observed in this study might have enhanced the formation of perchlorates. As much as 35% of the chlorate found in a distribution system can be attributed to the type and performance of the chlorine dioxide generator (Vobecky *et al.,* 1996). If chlorite ion is present in water and is not removed, it will react with applied free chlorine to produce chlorate and chloride ions (WHO, 2005). Perchlorate is easily water soluble and ionizes, thus making the water pH less than seven. Additionally, low iodine levels in different source of drinking water in the study area can be attributed to the presence of nitrates as observed in the study. Nitrates are inhibitors of the sodium/iodine symporter (NIS) in the thyroid (Pearce and Braverman, 2009).

Forsooth, low iodine in water is a huge public health concern that could translate to low iodine intake in humans (Abebe *et al*., 2006). McClendon and Williams (1923) suggest that concentrations of less than 3–5 μg/l iodine in drinking water were goitrogenic. Coble *et al,*. (1968) reported that in populations inhabiting Egyptian oases, drinking water with concentrations of 7–18 μg/L led to low iodine, whilst concentrations of 44–100 µg/l did not. Mahedeva and Shanmuganathan (1967) found that low iodine areas in Sri Lanka had drinking-water iodine concentrations of 2.2–10.1 µg/L whilst with adequate iodine areas had 19.4–183 µg/L. They defined the local critical iodine concentration as 10µg/l. Smedley *et al.,* (1995) found iodine concentrations in ground waters from goitrous areas of the Upper East Region of Ghana in the range <1–10 µg/L (median 3.1 µg/L, most less than 6 µg/L). In tandem with the geographical location of Sokoto State, it is more prone to have iodine deficient water than coastal areas. Combination of these factors with additional nutritional factors greatly exaggerates the pattern of expected distributions of iodine level in different sources of water in the state. Therefore, analysis of iodine concentrations in different sources of drinking water in the state will highlight more potential areas with low iodine tendency, as concentrations of iodine in water will inevitably reflect concentrations in soils, and food crops and hence overall dietary intake (Abebe *et al*., 2006).

CONCLUSION

Water iodine levels across the three zones of Sokoto State, Nigeria from different sources of drinking water were lower than the recommended water iodine level of > 15 µg/L in drinking water according to the global recommendation. Therefore, study of iodine concentrations in different sources of drinking water in the state has provided a base-line data on potential areas with low iodine level. This study was therefore timely, relevant and important to the states and entire north western of Nigeria. However, the study recommended sensitization on portable and quality of water should be a public concern and stakeholders should provide water softeners to the communities.

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