IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)
e-ISSN: 2278-3008, p-ISSN:2319-7676. Volume 10, Issue 2 Ver. II (Mar -Apr. 2015), PP 22-25
www.iosrjournals.org

The Role of Water Goiterogens in the Persistence of Iodine Deficiency Disorders in Ekiti East Local Government Area, South Western Nigeria

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Abstract:
Background: *Total goiter rate (TGR) has remained persistently high in Ekiti East local government area, South West Nigeria despite the vigorous salt iodization policy of the Nigerian government, thus raising the question that other factors apart from dietary iodine could be responsible. This study was carried out to determine the possible role of water goitrogens in the area because some natural drinking water constituents have been linked with goitrogenesis in experimental animalsand human populations.*
Materials and Methods: *The communities in the study areathat have been established as goiter endemic from previous studies namely Ahon, Iworo, Iludofin, Ilasa and Isinbode were chosen for the study.Control samples were drawn from Ogijo village in Shagamu local government area of Ogun State, a region with similar socio-economic status but with low TGR as per previous studies. Ten water samples were randomly taken from wells and streams in each communityand were analyzed for Physio-chemical Properties, anion and cation concentrations. The water anions namely perchlorate, CN^- ,F^-, Cl^- , I^- ,NO_3^- , SO_4^{2-} and PO_4^{3-} were analysedusing the autoanalyser while the cationsCa, Mg, Mn, Fe,Zn,Cu,Cr, Co, Se, Vd, Pb, Ba and Si were determined using the atomic absorption methods of Tel and Rao.*
Results: *Results from the study showed that water samples from the goiter endemic region had significant increased water hardness, decreased electro conductivity and higher ions content compared with the control group. Fluoride, nitrate and chloride ions had higher concentrations in the endemic population $P<0.05$ compared with the control group.*
Conclusions: *It was therefore concluded that water goitrogens could play a major role in the persistence of IDD in Ekiti East local government. The use of water softeners and provision of portable water for the communities are recommended.*
Key words: *Total goiter rate, Water goitrogens.*

I. Introduction

Goitrogens are substances that are associated with impaired bioavailability of iodine even when there is sufficient iodine in the diet.[1]Goitrogens suppress the functions of the thyroid gland by interfering with iodine uptake, which then leads to the enlargement of the thyroid, that is, a goiter. Such antithyroidagents may enter into water and food thus becoming important environmental goitrogenic factors. [2] The roles of chemical constituents of drinking water in the etiology of endemic goiter have been established as far back as 1928[3] and also by Murray etal., in 1948[4]. Water goitrogens may be naturally occurring or due to pollution [1]. High calcium salts in water have been shown experimentally to cause goiter[5]. In field studies and surveys, high fluoride content of drinking water has been shown to be goitrogenic[2]. The role of water hardness in the prevalence of endemic goiter has long been established [6]. Ekiti East has been known as an endemic area for iodine deficiency disorders (IDD) since 1987[7]. Following the introduction of the mandatory salt iodization policy in 1994 by the Nigeria government, the Total Goiter Rate (TGR) in Ekiti East decreased from 38% in 1993 to 33.3% in 1998 while in other similar iodine deficient endemic areas, significant reductions in TGR ranging between 20-57% were recorded[8]. Even though Nigeria was commended by the International Committee for the Control of Iodine Deficiency Disorders (ICCIDD) for achieving 99% salt iodization in 2009, the recalcitrant high goiter rate in Ekitihas been highlighted as a problem[9]. The recent research work of Ajayi and Ogundahunsi also put the goiter rate in Ekiti East Local government area at 16.1%[10].The persistent high goiter rate despite iodine supplementation could only point to other factors besides dietary iodine in goitrogenesis. The identification of natural inhibitors of thyroid gland opened up a whole new concept of toxic dietary agents in the causation of the disease in contrast to deficiencies[8]. This study was designed to find out the roles of water goiterogens in the persistence of IDD in Ekiti East local government area despite iodine supplementation.The ethical approval to carry out the study was obtained fromEkiti State University Teaching Hospital, Ado-Ekiti, Nigeria.

II. Materials and Methods

Ahon, Iworo, Iludofin, Ilasa and Isinbodecommunities in Ekiti East local government area that have been established as goiter endemic from previous studies were chosen for the study[8,10].Ekiti East local government area lies $7^0 37 – 7^0\ 50^1$N of equator and $5^0\ 32^1$ - $5^0\ \ 50^1$ East of the Greenwich meridian. The landscape contains few hills and valleys. Control samples were drawn from Ogijo community in Ogun state, a place known to be of comparable socio-economic status andlowTGR as per previous studies[8]. The geographical coordinates of Ogijo are 6° 42' 0" North, 3° 31' 0" East.Drinking water samples were taken from the communities forgeochemical investigations.Ten water samples selected by random sampling were taken from wells and streams per community into clean two liter plastic bottles. The pH and temperatures were taken at the sites of collection. The water samples were transported back to the laboratory in coolers and refrigerated at 4^oC prior to analysis. Water conductivity, perchlorate, cyanide, nitrate, SO_4, iodine, fluoride and chloride were determined using the autoanalyser by the methods of Tel and Rao,1982[11].The cations(Ca, Mg, Mn, Fe, Zn, Cu, Cr, Co, Se, Vd, Pb, Ba and Si) in water were determined with the Atomic Absorption Spectrophotometer (AAS) Buck 205 model using the methods ofTel and Rao,1982[11]. Water hardness was calculated from the concentrations of calcium and magnesium ions obtained byAAS. Quality controls for the methods were established with certified samples.

III. Results

Table 1 shows thelevels ofphysico-chemical parameter and anions of the water samples. The pH of the water samples was not statistically different in all the communities including control. However, significant lower levels ofwater conductivity were observed in all the samples obtained from the goiter endemic communities compared with the control. Significant increases were also observed in calcium hardness, magnesium hardness and total hardness in the goiter endemic communities compared with the control. The results also showed that nitrate, sulphate, fluoride and chloride ions were significantly higher in Ekiti East communities compared with the control. In table 2, the results of cation concentrations of the water samples are shown. Significant increases were observed in calcium and magnesium ions in the goiter endemic communities compared with thecontrol while magnesium, vanadium and barium ions were significantly lower in the goiter communities compared with the control.

Table 1 Physio-chemical Properties and anion concentration of water samples Ekiti East and Controls(Mean ± SD)

	CONTROL	AHON	ILASA	ILUDOFIN	ISINBODE	IWORO
pH	$6.35±0.21^a$	$6.1±0.7^a$	$6.25±1.20^a$	$5.70±0.42^a$	$6.35±0.35^a$	$5.40±2.12^a$
Conductivity	$61.70±8.97^a$	$18.26±1.40^b$	$21.24±79^b$	$24.88±2.35^b$	$23.53±0.03^b$	$18.80±0.66^b$
Ca hard (ppm)	$7.17±0.51^a$	$60.34±24.41^b$	$65.35±3.38^b$	$47.53±18.66^b$	$41.18±11.72^b$	$56.52±23.02^b$
Mg hard (ppm)	$1.56±0.35^a$	$28.44±2.26^b$	$37.89±0.71^b$	$34.63±7.70^b$	$32.03±3.23^b$	$34.56±9.43^b$
Total hard (ppm)	$8.77±0.85^a$	$88.78±25.67^b$	$103.25±2.67^c$	$82.16±26.36^b$	$73.22±14.95^b$	$91.08±32.45^b$
Temp (ppm)	26.0±0.01	24.0±0.01	29.00±1.41	26.00±2.83	25.00±1.00	24.00±0.00
Perchlorate (ppm)	$0.34±0.03^a$	$0.10±0.01^b$	$0.08±0.01^b$	$0.09±0.01^b$	$0.11±0.02^b$	$0.10±0.03^b$
CN (ppm)	0.01±0.00	0.02±0.00	0.01±0.00	0.01±0.00	0.01±0.01	0.00±0.00
NO_3 (ppm)	$0.01±0.00^a$	$0.03±0.01^b$	$0.04±0.03^b$	$0.06±0.05^b$	$0.06±0.03^b$	$0.04±0.023^b$
$S0_4$ (ppm)	$0.01±0.00^a$	$0.03±0.01^b$	$0.05±0.03^a$	$0.04±0.01^b$	$0.03±0.01^b$	$0.06±0.02^b$
I_2 (ppm)	0.02±0.00	0.02±0.01	0.05±0.04	0.04±0.04	0.05±0.04	0.05±0.03
F (ppm)	$0.12±0.02^a$	$1.05±0.18^b$	$3.65±0.69^c$	$3.21±0.01^c$	$1.20±1.37^a$	$2.70±0.75^b$
Cl (ppm)	$2.28±0.48^a$	$10.79±0.08^b$	$10.07±0.47^b$	$10.24±2.62^b$	$10.92±1.69^b$	$11.27±1.70^b$
PO_4 (ppm)	$0.03±0.01^a$	$0.02±0.00^b$	$0.04±0.03^a$	$0.04±0.03^a$	$0.03±0.02^a$	$0.06±0.06^a$

Table 2 Cations Concentration In Water Samples From Ekiti East

	Control	Ahon	Ilasa	Iludofin	Isinbode	Iworo
Ca (ppm)	$2.87±0.02^a$	24.17 ± 9.78^b	26.17 ± 1.35^b	19.06 ± 7.47^b	16.49 ± 4.69^b	22.64 ± 9.22^b
Mg (ppm)	$0.38±0.08^a$	6.91 ± 0.55^b	9.20 ± 0.17^b	8.41 ± 1.87^b	7.78 ± 0.78^b	8.39 ± 2.29*
Mn (ppm)	$0.21±0.02^a$	0.09 ± 0.01^b	0.05 ± 0.01^c	0.08 ± 0.05^a	0.06 ± 0.01^b	0.06 ± 0.00^b
Fe (ppm)	$0.06±0.01^a$	0.12 ± 0.01^b	0.11 ± 0.01^b	0.08 ± 0.02^a	0.10 ± 0.01^a	0.05 ± 0.06^a
Zn (ppm)	$0.13±0.01^a$	$9 ± 0.10^a$	0.41 ± 0.13^a	0.49 ± 0.05^b	0.28 ± 0.20^a	0.37 ± 0.05^b
Cu (ppm)	$0.03±0.00^a$	0.07 ± 0.0^b	0.06 ± 0.01^b	0.06 ± 0.02^b	0.08 ± 0.02^b	0.07 ± 0.01^b
Cr (ppm)	0.01±0.00	0.01± 0.00	0.01± 0.00	0.01± 0.00	0.01± 0.00	0.01± 0.00
Co (ppm)	0.01±0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Se (ppm)	0.00±0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Vd (ppm)	$0.04±0.00^a$	0.00 ± 0.00^b	0.00 ± 0.00^b	0.00 ± 0.00^b	0.00 ± 0.00^b	0.00 ± 0.00^b
Pb (ppm)	0.00±0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Ba (ppm)	0.10±0.00 [a]	0.00± 0.00 [b]	0.00±0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]
Si (ppm)	0.02±0.01 [a]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]

IV. Discussion

The findings in this study showed that cations and anions concentrations are significantly increased in water samples from Ekiti East local government area compared with the control. Sulphate, nitrate, fluoride, chloride and phosphate ions were significantly increased while there were no significant changes in the iodine content. Water conductivity and the metallic ions of silicon, barium ,lead, vanadium and magnesium were significantly lower in the communities compared with the control.

Significantly increased water hardness as observed in this study could be related to the persistently high goiter rate observed in this region in previous studies[8,10]. Water hardness is a function of both the calcium and magnesium ion concentrations in a water sample[11]These findings supports the works of McCarrison, 1928[3], Murray et.al., 1948[4] and Sefner 1995[6]. It could be that calcium and magnesium ions especially when high in water reacts strongly with iodine producing insoluble products thus preventing itsbioavailability. In experimental animals, calcium salts have been shown to exacerbate goiter formation even when sufficient iodine is present in diet[5]. In field studies and surveys, water hardness has also be shown to contribute to goiter endemia[12,13,14]. High calcium in drinking water hinders iodine absorption[15]. Iodine deficiency may also be induced by fixation of iodine by calcium ions in soil yielding low concentrations in ground water and decreased efficiency of uptake[16].

It appears as if the increased ions in water as observed in this study prevent the bioavailability of iodine even when present in water. The fact that iodine concentration in water samples from both the goiter endemic communities and control were not statistically different is a pointer to this, and is in agreement with earlier reports[17]. Sulphates, nitrates, fluorides, chlorides, perchorates, cyanides and phosphates ions are known goitrogens from previous studies[18]. Nitrates are inhibitors of the sodium / iodine symporter (NIS) in the thyroid[19]. The inhibition potential of nitrate is much higher than perchlorates in the thyroid [20]. Higher sulphate ions concentrations in water samples have been associated with goiter prevalence[21]. High fluoride content of drinking water has been known for a long time as goitrogenic.[22,23,24]. Under experimental conditions, goiters develop in rats when fed with fluoride at high concentrations[24,25]. High fluoride concentration in iodine deficiency increases the rate of goiter formation in experimental animals. It also disrupts the pituitary- thyroid Hypothalamus axis leading to deranged thyroid function tests. The principle behind this observation is that high fluoride inhibits the action of deiodinase enzymes resulting in decreased plasma T_3 with normal or elevated T_4 and TSH[26]. Fluoride also mimics the action of the thyroid stimulating hormone (TSH).Starting in the 1930s and continuing through to the 1970s sodium fluoride was used to lower the activity of the thyroid gland for those suffering from hyperthyroidism (i.e. over active thyroid gland). Obviously if fluoride lowers the activity of an overactive thyroid gland, that effect could cause severe hypothyroidism in euthyroid individuals and those with underactive thyroid gland[27,28]. Moreover, Chloride, fluoride and iodide ions are all halogens with similar reaction patterns. Fluoride, bromide, and chloride in the body displace iodine in cells, leading to iodine deficiency. It is well established that iodine in position 5 of the thyronine 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[29].A scheme to explain the role of chloride in goiterogenesis can also be deduced as follows: Fluoride and bromide ions have been established as goiterogenic [30]. Bearing in mind that Chlorine is higher in the electrochemical series than iodine, it could also exert the same goiterogenic effect on iodine since its concentration in drinking water is more than ten fold compared with the control as seen in this study. It could be that chloride ions compete with iodine uptake by the thyroid cells. The high chloride level as seen in this study which is about ten times the control value may in part be responsible for the high ion content of the water samples. These observations agrees with previous findings [13,21] .

V. Conclusion:

Water Geochemistry seems to play a major role in goiterogenesis in EkitiEast Local Government area. It could have been one of the reasons while previous intervention roles have not completely eradicate goiter incidence in the region. The recommendation is therefore that water softeners be made available to the indigenes.Advocacy and enlightenment on water consumption should also be pursued and government should provide the communities with portable water.

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