International Journal of Advanced Biochemistry Research 2023; 7(1): 44-50

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2023; 7(1): 44-50
www.biochemjournal.com
Received: 02-11-2022
Accepted: 07-12-2022

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Health risk assessment, water quality indices and reproductive hormone profile among Abakpa citizens in Enugu metropolis

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DOI: https://doi.org/10.33545/26174693.2023.v7.i1a.164

Abstract
Numerous substances has been attributed to elicit endocrine-disruption and may potentially affect healthy reproductive functions. This study was carried out to determine the health risk assessment, water quality indices and reproductive hormone profile among citizens of Abakpa in Enugu metropolis. Ten (10) water sampling points comprising of wells and streams were analyzed for chemical properties such BOD, COD, DO, pH, TSS, TDS, Total Hardness, and Alkalinity and Heavy metal composition such as Zinc (Zn), Lead (Pb), Chromium (Cr), Cadmium (Cd) and Mercury (Hg) using the American Public Health Association's (APHA) guidelines and Atomic absorption spectrophotometer (AAS) respectively. Five (5) blood samples comprising males and females was collected across the sampling areas and assayed for reproductive hormone profile such as Testosterone, Follicle Stimulating Hormone, Progesterone, Prolactin, Estradiol and the enzyme Aromatase was using the ELISA kit method. The result of chemical properties such as TSS, TDS, COD, Total hardness and Alkalinity were all within World Health Organization (WHO) stipulated limits, whereas DO, BOD and pH were higher than WHO limits across all sampling points from the sampling area. Some parameters showed significance difference while some sample did not at different sampling locations at 95% confidence level. The result of heavy metals showed very high concentrations of analyzed metals with Hg present in five water samples from Abakpa at concentrations ranging from 0.01 to 1.96 ppm. Pb concentration ranged between 0.06-0.35 ppm; Zn 24.93- 33.65 ppm; Cr 0.00 – 0.23 ppm; Cd. 0.11 – 0.17 ppm across all sampling points. All the result of reproductive hormone showed lower concentration of testosterone in men (1.99 to 2.19 ng/ml) and high concentration in females (2.03 to 2.06 ng/ml) across all sampling points. The concentration of FSH was in the range of 0.67 to 0.77 ng/ml in males, while the level was between 0.71 to 0.83 ng/ml in female. Prolactin results was 3.49 to 3.86 ng/ml for males and 3.44 to 3.59 ng/ml in females. Estradiol levels were 8.48 to 9.54 ng/ml and 9.61 to 9.84 ng/ml for females and males respectively. However, progesterone level were between 34.08 to 37.45 ng/ml for females and 36.48 to 39.56 ng/ml. The aromatase enzyme was averagely below 4.0 Pmol/mg in both male and female. The risk assessment showed low risk exposure but mercury had high risk exposure tendencies of 16.333 when compared to other heavy metals from all samples. Consumption of water in sampled area's may pose a serious health challenge; high concentration of heavy metals could be attributed to the hormonal imbalance recorded in the research as most heavy metals is seen to reduce the expression and activity of 3β-HSD and 17β-HSD, which could be facilitated by high acidic nature of the water. Thus, interfering with steroidogenesis. Therefore, continuous monitoring of water quality in Abakpa in Enugu metropolis is highly recommended in order to ensure the health safety of humans living in such environment.

Keywords: Risk assessment, endocrine disruptors, heavy metals, water quality, and hormones

Introduction

Presently, accessible of quality water has been a major threat to residents of Enugu State, Nigeria. As reported by Premium Times newspaper in March, 2021, residents of Independence Layout, Community Layout in Trans Ekulu, Achara Layout and Emene in Enugu state were faced with acute water scarcity. However, Enugu State known for its coal deposits, and mining activities, which represents sources of pollution and decline of water quality, resulting to the contamination of water aquifers, which provides portable domestic water for the residents.

Industrialization and urbanization of Enugu metropolis have turned most of the mining sites into residential areas, with boreholes, hand-dug wells, springs, etc. as the main sources of water for consumption. The negative effects of coal mining activities are of great concern, as the acidification of aquifers results from heavy metal pollution from coal mining operations (Cui *et al*., 2011) [10]. Kaushal (2012) [12] described coal mining as activities that degrade soil, surface water and groundwater. It is more difficult to handle coal when burnt than crude oil or natural gas. The toxic pollutants present in coal are released into the air, water and soil during combustion. Correspondingly, areas previously known/used mainly for coal mining and abandoned for some time are sources of water pollution (Cui *et al*., 2011) [10]. Some of the pollutants is known to cause cancer, while others are known to interfere with fertility (Keating, 2001) [18] through disruption or interference with endocrine functions.

Furthermore, recent studies has expressed non-identifiable source of endocrine related challenges such as hormonal imbalance Endocrine disrupting chemicals (EDCs) are a diverse group of exogenous compounds that have been found to interfere with the endocrine system and produce adverse health effects in exposed individuals or their offspring (Gore *et al*., 2015; Sidorkiewicz *et al*., 2017) [16, 30]. Plasticizers, heavy metals, flame retardants, fungicides, pesticides, medicines, and even naturally occurring compounds like phytoestrogens are all known to affect the endocrine system (Yan *et al*., 2010) [35]. Endogenous hormones are dampened, blocked, or their activities potentiated by these and other EDCs through a variety of direct and indirect pathways. They may, for example, agonize or antagonize hormone receptors, disrupt hormone production, or change the number of hormone receptors (Gore *et al*., 2015) [16].

Materials and Methods

All materials and reagents used for this research were of analytical standard.

Methodology

Sample collection and Preservation

Water Samples

Water samples (10) were collected from 6 wells and 4 streams using a half litre transparent bottle across the 5 sampling points *viz*: Abapka, Trans ekulu, New haven, Obiagu and Iva valley, totalling 50 water samples in all.

Blood Samples

All samples were collected in compliance with ethical standard for care and use of human blood samples, as approved by the Faculty of Pure and Applied Sciences, Federal University Wukari, Nigeria. Blood samples were collected by venipuncture sampling method with the aid of a phlebotomist. About 3-5 ml of blood samples were collected from seven individuals comprising of 4 females and 3 males not below 20 years of age and have lived not less than 15 years in each sampling zone. The samples were carefully introduced into EDTA containers having anticoagulant and be labelled accordingly. The blood samples were centrifuged for 5 minutes at a speed of 5000 revolution per minute. The plasma were collected and refrigerated at -20oC in the laboratory and subsequently used for the assay.

Assay procedure

Fifty (50) coated wells in the holder were secured, about 50 µl of standards, samples, and controls were dispensed into appropriate wells. Subsequently, 100 µl of enzyme conjugate reagent were dispensed into each well, and thoroughly mixed for 30 seconds. The mixture was incubated at room temperature (18-22 °C) for about 60 minutes. The incubated mixture was afterwards removed by emptying the plate contents into a waste container. The microtiter wells were rinsed and emptied severally for 5 consecutive times with washing buffer (1X). The wells were sharply struck onto absorbent paper or paper towels to remove all residual water droplets. Furthermore, 100 µl of 5'-Tetramethylbenzidine (TMB) solution were dispensed into each well and gently mixed for 5 seconds. The mixtures were incubated at room temperature for 20 minutes. The reaction was halted by the addition of 100 µl stop solution to each well and gently mixed for 30 seconds. It is important to make sure that all the blue colour changed to yellow colour completely, the optical density was read with the microtiter well reader at 450 nm within 15 min.

Determination of water quality

Determination of chemical properties of water Total of 50 water samples (comprising of wells and streams) were collected from five different locations at Enugu (Trans-Ekulu, Abakpa, New haven, Obiagu, and Iva valley) ranging in depth between 20 and 120 m below ground level. The chemical parameters used for the water quality assessments in the study included; pH, dissolved oxygen content (DOC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solute (TDS), total suspended solids, total hardness, total alkalinity. All the analyses were carried out according to guidelines of APHA, (2012); Bartram and Balance (1996) [7].

Determination of Heavy Metals

About 100 ml of sample was transferred into a conical flask in fume cupboard, and 5 mL of conc. HNO3 was added and placed on a heating mantle and cautiously evaporate to less than 20 ml, making sure that sample does not boil. The mixture was allowed to cool and the flask wall was rinsed and washed with a distilled water. Furthermore, 5 ml of conc. HNO_3 was added and the flask was covered with a watch glass and returned to the heating mantle. Heating continued until digestion is completed. It was cooled, and flask was washed down with water. The solution was filtered and the filtrate was then transferred to a 100 mL volumetric flask built up to the required concentration with distilled water before being used for analysis (Radojovenic and Bashkin, 2006) [27].

Heavy Metal Estimation

Heavy metals was estimated by the use of an Atomic Absorption Spectrophotometer model 6650F using a modified standard method of AOAC (2006). The sample solutions in the sample bottles were analyzed for the concentration of the individual elements. Each element has specific cathode discharge lamp and this lamp was used to determine a particular element. Discharge lamp emits radiation at a wavelength specific for each element being assayed. This specificity can be obtained only from a pure sample of the element that is excited electrically to produce an arc spectrum on that element. The heavy metals analyzed were: Lead (Pb), Chromium (Cr), Mercury (Hg), Zinc (Zn), and Cadmium (Cd).

Statistical analysis

Statistical analysis was carried out using the Statistical

Package for Social Sciences (SPSS) version 23. The results were expressed as mean±standard deviation in all parameters and the statistical difference was determined by Analysis of variance (ANOVA) at 95% confidence interval and Duncan multiple comparison test at $p<0.05$.

Results

Physicochemical properties of water samples from Abakpa, Enugu

The result of chemical properties of water sampled from Abakpa in Enugu metropolis is given in Table 1 all expressed in mg/L. The result showed that Total suspended solid (TSS) ranged between 0.85±0.020 - 4.86±0.06 mg/L. The lowest TSS value was obtained in sample A5 (0.85±0.020 mg/L) while the highest was obtained from sampling point A2 (4.86±0.06 mg/L). There is no statistically significant difference ($p>0.05$) in all sampling points except sampling points A2 and A10. The result of Total dissolved solid (TDS) shows that sampling point A2 has the lowest TDS value of 0.44±0.02 mg/L and sampling point A1 has the highest 1.33±0.01 mg/L TDS value. There is no statistically significant difference ($p>0.05$) in all sampling points except sampling points A1 and A3. The result of Chemical Oxygen Demand (COD) showed the highest and lowest sampling points to be A6 (6.70±0.09 mg/L) and A9 (4.60±0.07 mg/L) respectively. Sampling points A2, A4 and A9 shows no difference ($p>0.05$) but statistically significantly differs from other sampling points at $p<0.05$. Biological Oxygen Demand (BOD) as seen in table 1, the result were all within the range of 4.00 and 6.00 across all sampling points. All sampling points depicted no statistical difference ($p>0.05$) except points A4 and A7, which did not show any statistically significant difference between each other at $p>0.05$. A narrow range pH level were observed analysed samples between 4.20±0.01 mg/L – 5.78±0.47 mg/L representing sampling points A2 and A6 as lowest and highest respectively. Sampling points A (1, 2, 5 and 8) are not statistically different ($p>0.05$) but show statistically significant difference between sampling points A (3, 4, 6, 7, 9, and 10) at $p<0.05$. 59 The result also showed that Total hardness (TH) ranged between 21.48±0.55 mg/L - 34.20±0.51 mg/L mg/L. The lowest TH were recorded in sampling point A1 (21.48±0.55 mg/L), while sampling point A5 (34.20±0.51 mg/L) ranked the highest. At $p<0.05$, sampling points A4 and A5 are statistically significant difference across all sampling points. Alkalinity of water samples as seen in table 1, showed a wide margin range between the lowest value 6.15±0.47 in sampling point A3 and the highest value 64.91±1.06 recorded in sampling point A7 when compared to other analyzed parameters. There is no statistically significant difference ($p>0.05$) between sampling points except sampling points A7 and A8

Table 1: Physicochemical properties of water samples sourced from Abakpa, Enugu

Samples	Parameters (mg/L)							
	TSS	TDS	COD	BOD	DO	pH	T. Hardness	Alkalinity
A1 WL	1.63±0.03^{b}	1.33±0.01^{b}	6.30±0.03^{c}	4.33±0.02^{a}	6.39±0.02^{b}	4.73±0.00^{a}	21.48±0.55^{a}	7.18±0.29^{b}
A2 WL	4.86±0.06^{c}	0.44±0.02^{a}	4.80±0.02^{a}	4.10±0.15^{a}	6.92±0.07^{c}	4.20±0.01^{a}	30.80±0.46^{b}	7.24±0.22^{b}
A3 ST	1.14±0.01^{ab}	1.11±0.01^{b}	5.77±0.12^{b}	4.50±0.06^{a}	5.58±0.20^{a}	5.09±0.21^{b}	31.51±0.19^{bc}	6.15±0.47^{a}
A4 ST	0.88±0.01^{a}	0.77±0.00^{a}	4.73±0.07^{a}	5.20±0.20^{b}	6.25±0.06^{b}	5.72±0.83^{b}	32.54±0.52^{c}	8.19±0.19^{b}
A5 ST	0.85±0.02^{a}	0.73±0.01^{a}	6.10±0.10^{c}	4.30±0.06^{a}	7.70±0.03^{c}	4.49±0.63^{a}	34.20±0.51^{c}	6.90±0.47^{a}
A6 WL	1.14±0.02^{ab}	1.04±0.02^{a}	6.70±0.09^{c}	4.70±0.04^{a}	6.53±0.06^{b}	5.78±0.47^{b}	30.19±0.11^{b}	7.40±0.49^{b}
A7 ST	0.94±0.01^{a}	0.78±0.04^{a}	6.50±0.20^{c}	5.40±0.03^{b}	6.00±0.05^{b}	5.18±0.37^{b}	28.73±0.52^{ab}	64.91±1.06^{c}
A8 WL	1.06±0.03^{ab}	0.83±0.01^{a}	6.50±0.14^{c}	4.40±0.01^{a}	6.68±0.10^{b}	4.65±0.52^{a}	30.04±0.61^{b}	63.79±0.58^{c}
A9 WL	1.33±0.03^{ab}	0.89±0.00^{a}	4.60±0.07^{a}	4.70±0.03^{a}	6.06±0.04^{b}	5.07±0.31^{b}	28.48±0.16^{ab}	7.70±0.50^{b}
A10 WL	3.07±0.01^{c}	0.93±0.01^{a}	5.40±0.04^{b}	4.60±0.02^{a}	6.55±0.02^{b}	5.13±0.27^{b}	25.26±0.27^{a}	6.53±0.57^{a}
WHO (2011/2022) Limit	1000	500	10	3	5	6.5-9.5	500	150

Results are expressed in mean±standard deviation of triplet determination. Results with same alphabet superscript shows no significant difference while results with different alphabet superscript within the row shows statistically significant difference at $p<0.05$. TSS = Total Suspended Solid, TDS = Total dissolved solid, COD = Chemical Oxygen Demand, BOD = Biological Oxygen Demand, DO = Dissolved Oxygen, PH = Total alkalinity and T. Hardness = Total hardness

Key: Sample points A1 to A10 represents: Ejindu, Ugwuagor, Nike Lake, Amuri, Atani, Obinagu, Ikem, Amansea, Osakwe streets respectively. WL: Well and ST: Stream

Heavy Metals of Water Samples from Abakpa, Enugu

Table 2, shows the result of heavy metal of water samples from Abakpa, Enugu. The result shows that Zinc has the highest concentration ranging from 22.38±0.02 – 33.65±0.01. The lowest value was recorded in sampling point A3 (22.38±0.02) while the highest was recorded in sampling point (33.65±0.01). No statistically significant difference exist amongst sampling points A (4 and 6) at $p>0.05$. Lead result showed that sampling point A5 (0.06±0.01) and sampling point A7 (0.35±0.30) recorded lowest and highest lead levels respectively. At $p<0.05$ sampling point A7 showed statistically significant difference across all sampling points except sampling points A6 and A8. As seen on table 2, Chromium result revealed highest concentration in sampling point A5 (0.23±0.01) and lowest chromium concentration in sampling point A9 (0.03±0.00) with no detectable levels across sampling points A1, A2 and A8. There is no statistically significant difference ($p>0.05$) across all sampling points except sampling points A4 and A5 at $p<0.05$. The result of cadmium as seen in the table 2 below, showed that cadmium concentration ranged between 0.11±0.00 - 0.17±0.00 which represents the lowest and highest concentrations. At $p>0.05$, no statistically significance difference exist across all samples. Mercury was not detectable at some sampling points *viz*: A4, A5, A6 and A9 while recording the lowest concentration at sampling point A3 (0.01±0.00) and highest concentration at sampling point A1 (1.96±0.06). Statistically significant difference exist between only sampling point A1 and all other sampling points at $p<0.05$.

Table 2: Heavy metals of water samples sourced from Abakpa, Enugu

Samples	Parameters (ppm)				
	Zinc	Lead	Chromium	Cadmium	Mercury
A1 WL	33.65±0.01[c]	0.25±0.19[b]	ND	0.11±0.00[a]	1.96±0.06[b]
A2 WL	24.93±0.06[a]	0.15±0.05[a]	ND	0.17±0.00[a]	0.03±0.00[a]
A3 ST	22.38±0.02[a]	0.15±0.01[a]	0.06±0.01[a]	0.12±0.00[a]	0.01±0.00[a]
A4 ST	25.81±0.07[ab]	0.23±0.00[b]	0.17±0.01[b]	0.13±0.00[a]	ND
A5 ST	27.62±0.04[b]	0.06±0.01[a]	0.23±0.01[b]	0.11±0.00[a]	ND
A6 WL	25.93±0.05[ab]	0.28±0.01[bc]	0.06±0.00[a]	0.13±0.00[a]	ND
A7 ST	30.34±0.07[c]	0.35±0.30[c]	0.03±0.00[a]	0.13±0.00[a]	ND
A8 WL	31.25±0.04[c]	0.29±0.01[bc]	ND	0.12±0.00[a]	0.02±0.00[a]
A9 WL	32.58±0.04[c]	0.17±0.01[a]	0.03±0.00[a]	0.13±0.00[a]	ND
A10 WL	30.59±0.05[c]	0.11±0.01[a]	0.05±0.00[a]	0.11±0.00[a]	0.02±0.00[a]

Results are expressed in mean±standard deviation of triplet determination. Results with same alphabet superscript shows no significant difference while results with different alphabet superscript within the row shows significant difference at $p<0.05$.

WHO permissible limit for analyzed heavy metals in drinking water in PMM: Zinc: 3.0; Lead: 0.01; Chromium: 0.05; Cadmium: 0.005; Mercury: 0.002(WHO, 2006; 2011). Standard Organization of Nigeria (SON) limit for the metal are as follows respectively: 3; 0.01; 0.05; 0.003; 0.001 (SON, 2007).

Key: Sample points A1 to A10 represents: Ejindu, Ugwuagor, Nike Lake, Amuri, Atani, Obinagu, Ikem, Amansea, Osakwe streets respectively. WL: Well and ST: Stream.

Reproductive Hormone Profile from Abakpa Blood Samples

The result of the reproductive hormonal profile is seen in Table 3. Testosterone ranged between 1.99±0.31 - 2.19±0.22 ng/ml. No Statistically significant difference was seen across both male and female samples at $p>0.05$. The result of FSH shows that sample A3 (F) has the highest FSH value (0.83±0.18 ng/ml) while sample A5 (M) has the lowest FSH value (0.67±0.08 ng/ml). At $p>0.05$, both male and female samples depicts no statistically significant difference. Progesterone ranked between 34.08±0.63 - 39.48±1.01 ng/ml, which was the lowest and highest levels at samples A1 (F) and A4 (M). Samples A1 is statistically significantly different across all samples at $p<0.05$.

The level of prolactin as seen in the result, has the highest value on sample A2 (37.45±0.40 ng/ml) and lowest value on A3 (3.44±0.28 ng/ml). No statistically significant difference exist across all samples at $p>0.05$. Estradiol has all values moderately above 8 ng/ml and below 10 ng/ml, having 8.48±0.90 ng/ml and 9.84±0.55 ng/ml as lowest and highest in samples A1(F) and A4 (M) respectively. At $p>0.05$, no statistically significant difference exists. The result of the enzyme aromatase revealed concentrations ranging between 3.05±0.36 - 3.30±0.16 ng/ml. Sample A1 (F) had the lowest aromatase level as A5 (M) has the highest concentration. There is no traceable statistically significant difference across all samples at $p>0.05$.

Table 3: Reproductive hormone profile from Abakpa blood samples, Enugu

Samples	Parameters (ng/ml)					
	Test	FSH	Prog	PROL	ESTR	Arom (Pmol/mg)
A1 (F)	2.06±0.25[a]	0.71±0.17[a]	34.08±0.63[a]	3.59±0.14[a]	8.48±0.90[a]	3.05±0.36[a]
A2 (F)	2.05±0.26[a]	0.74±0.11[a]	37.45±0.15[b]	3.59±0.40[a]	9.54±0.96[a]	3.25±0.23[a]
A3 (F)	2.03±0.40[a]	0.83±0.18[a]	37.36±0.82[b]	3.44±0.28[a]	8.53±0.76[a]	3.26±0.32[a]
A4 (M)	1.99±0.31[a]	0.77±0.09[a]	39.56±0.90[c]	3.49±0.15[a]	9.84±0.55[a]	3.17±0.15[a]
A5 (M)	2.19±0.22[a]	0.67±0.08[a]	36.48±1.01[b]	3.86±0.64[a]	9.61±0.90[a]	3.30±0.16[a]

Results are expressed in mean±standard deviation of triplet determination. Results with same alphabet superscript shows no significant difference while results with different alphabet superscript within the row shows significant difference at $p<0.05$, (M): represents Male while (F): Female.

Normal levels of the hormones in male and female respectively: Test.: 3-10 ng/ml and 0.15-0.7 ng/ml; FSH: 1.81-14.94 ng/ml; Prol.: <20 ng/ml and <25 ng/ml for non-pregnant and 80-400 ng/ml for pregnant female. Progesterone and Estradiol varies with respect to menstrual cycle and pregnancy phases

Table 5: Risk assessment of Zn in water samples

Samples		Zn		
	CONC	EDI	ADI	HQ
A1	33.65	0.561	3	0.187
A2	24.93	0.416	3	0.139
A3	22.38	0.373	3	0.124
A4	25.81	0.430	3	0.143
A5	27.62	0.460	3	0.153
A6	25.93	0.432	3	0.144
A7	30.34	0.506	3	0.169
A8	31.25	0.521	3	0.174
A9	32.58	0.543	3	0.181
A10	30.59	0.510	3	0.170

Table 6: Risk assessment of Pb in water samples

Samples		Pb		
	CONC	EDI	ADI	HQ
A1	0.25	0.003	0.01	0.250
A2	0.15	0.003	0.01	0.250
A3	0.15	0.004	0.01	0.383
A4	0.23	0.001	0.01	0.100
A5	0.06	0.005	0.01	0.467
A6	0.28	0.006	0.01	0.583
A7	0.35	0.005	0.01	0.483
A8	0.29	0.003	0.01	0.283
A9	0.17	0.002	0.01	0.183
A10	0.11	0.000	0.01	0.000

Table 7: Risk assessment of Cr in water samples

Samples		Cr		
	CONC	EDI	ADI	HQ
A1	0	0.000	0.05	0.000
A2	0	0.000	0.05	0.000
A3	0.06	0.001	0.05	0.020
A4	0.17	0.003	0.05	0.057
A5	0.23	0.004	0.05	0.077
A6	0.06	0.001	0.05	0.020
A7	0.03	0.001	0.05	0.010
A8	0	0.000	0.05	0.000
A9	0.03	0.001	0.05	0.010
A10	0.05	0.001	0.05	0.017

Table 8: Risk assessment of Cd in water samples

Samples		Cd		
	CONC	EDI	ADI	HQ
A1	0.11	0.002	0.005	0.367
A2	0.17	0.003	0.005	0.567
A3	0.12	0.002	0.005	0.400
A4	0.13	0.002	0.005	0.433
A5	0.11	0.002	0.005	0.367
A6	0.13	0.002	0.005	0.433
A7	0.13	0.002	0.005	0.433
A8	0.12	0.002	0.005	0.400
A9	0.13	0.002	0.005	0.433
A10	0.11	0.002	0.005	0.367

Table 9: Risk assessment of Hg in water samples

Samples		Hg		
	CONC	EDI	ADI	HQ
A1	1.96	0.033	0.002	16.333
A2	0.03	0.001	0.002	0.250
A3	0.01	0.000	0.002	0.083
A4	ND	ND	0.002	ND
A5	ND	ND	0.002	ND
A6	ND	ND	0.002	ND
A7	ND	ND	0.002	ND
A8	0.02	0.000	0.002	0.167
A9	ND	ND	0.002	ND
A10	0.02	0.000	0.002	0.167

Key ADI Accetable Daily Intake; EDI Estimated Daily Intake; HQ Hazard Qoutent

Note: HQ >1 Is Considered To Be Highly Risky and HQ <1 Is Less Risky

Discussion

Enugu metropolis is faced with many problems including water scarcity due to suspected pollution by coal constituents which might have leached into aquifers. These constituents are suspected to have effects on hormonal profile of individuals who have dwelt within this location for some length of time. Recently, there are increase report in the National dallies and other publications on the perceived increase in reproductive infertility and hormonal fluctuation among residents (PTN, 2021). The possible leaches of coal constituents into aquifers consumed by Enugu residents geared on focusing this research on evaluating the chemical properties of water, heavy metal contamination on fifty sampling points from the five sampling areas and the reproductive hormones profile of citizens within Abakpa in Enugu metropolitan city.

The result of physicochemical properties of water sourced from Abakpa revealed numerous chemical parameters in their order as seen in Table 2. All analysed parameters such as Total suspended solid (TSS), Chemical oxygen demand (COD), Total dissolved solids (TDS), pH, Total hardness (T. Hard), Dissolved Oxygen (DO), and Alkalinity were below WHO (2011, 2022) permissible limits TSS: 1000; TDS: 500; COD: 10; BOD: 3; DO: 5; ph: 6.5-9.5; T.Hard:500; Alkalinity: 150 all expressed in mg/L of all analyzed parameters except BOD, DO and pH. These research findings is not in agreement with a scientific research reported by Akpan *et al.* (2016) [2] while the result reported by Chinedu *et al.* (2011) [9] and Ken-Onukuba *et al.* (2021) [19] showed similarity on some parameters analysed on the same subject matter. The results of Mishra and Das (2017), showed similarities on BOD but contrasts with COD in analysed samples. This variation could be a result of differences in samples and study period used in the different researches. High levels of DO can speed up corrosion in pipe waters (Lomborg, 2003) [21]. This can in turn leach into the water as it passes through, depositing some compounds that might interfere with the water quality. The amount of dissolved oxygen (DO) required by aerobic biological organisms to break down organic material present in a given water sample at a given temperature over a certain time period is known as biochemical oxygen demand (BOD) (Sawyer *et al*., 2003) [28]. BOD, has been used in determining the rate of respiration in living beings and is used in the medical and pharmaceutical industries to measure the oxygen consumption of cell cultures (Liu and Mattiasson, 2002) [20]. All water samples in the five different locations, revealed pH lower than the recommended limit by WHO. This result varies slightly with the report of Ken-Onukuba *et al.* (2021) [19] from one of the sampling locations (Trans Ekulu). These differences could be a result of difference in sample collection points, season, and rate of industrial pollution within the sampling points (example mining effluents). The low pH recorded in the results signifies the acidic nature of water samples from these regions and could be a source of heavy metal contamination, thus posing health risk such as weakness, organ damage etc (Anyanwu *et al.*, 2018) [3]. Besides its direct health implications, water with a low pH can dissolve metal pipes over time due to its strong acidity, creating leaks and increasing the quantity of heavy metals in drinking supply (Belitz *et al.*, 2016) [8].

The results of heavy metals concentration in water samples sourced from Abakpa in Enugu state as shown in Table 3, showed the various analyzed metals in no special order such as Zinc, Chromium, Cadmium, Lead and Chromium in ppm. Zinc had the highest concentration ranging between 22.38 – 33.65 which was far above WHO and SON permissible limit in PMM: Zinc: 3.0, Lead: 0.01, Chromium: 0.05, Cadmium: 0.005; Mercury: 0.002 (WHO, 2006; 2011) [33]. Standard Organization of Nigeria (SON) limit for the metal are as follows respectively: 3, 0.01; 0.05, 0.003, 0.001 (SON, 2007) in drinking water. The result of Zinc in the present study contrast with the study of Oloche *et al.,* (2019) [25] at Odagbo, Kogi State. The disparity could be as a result of geographical differences and activities carried out in the different study areas. One of the most crucial trace elements in the body is zinc, which serves three key biological functions as a structural, regulatory, and catalytic ion. Despite that zinc is regarded to be non-toxic especially when consumed orally, It has been hypothesized that zinc supplementation at lower doses, closer to the RDA, interferes with the utilization of copper and iron and negatively affects HDL cholesterol levels (AREDS, 2002). The concentrations of lead and cadmium was high above both WHO and SON permissible limit in drinking water as seen in Table 3 (WHO, 2006; SON, 2007). The lowest and highest concentrations recorded in this present study were 0.06 and 0.35 respectively. Ferahtia, (2021) [14] reported a low concentration of lead in a study, which contrasts the present study. Lead is one of the most prevalent heavy metals, and because of its stability in contaminated areas and the intricacy of its biological toxicity mechanism, lead is particularly harmful to children and can induce mental retardation when it has an abnormal concentration in body fluid (Seema *et al*., 2013) [29]. Lead has the ability to inhibit or mimic the actions of calcium and to interact with proteins (Flora *et al*., 2006) [15].

The high concentration of mercury recorded in this study samples A1 and A2 which is far above the WHO and SON permissible limit in drinking water as reported in Table 3, (WHO, 2006; SON, 2007) is of very great concern. Ezeabasili *et al.* (2015) [13], result on mercury concentration falls within the range observed in the present study. Both in men and in women, mercury has a detrimental effect on fertility (Sukhn *et al*., 2018; Maeda *et al*., 2019) [31, 22] Infertility in women is influence by a hormonal imbalance brought on by Hg exposure. LH (luteinizing hormone) release, is inhibited when the progesterone/oestrogen ratio shifts in favour of oestrogen growth. As a result, Hg may cause female infertility by increasing prolactin secretion, which has adverse effects on galactopoiesis and female genital development and is similar to the dopamine effect at the pituitary and midbrain levels (Davis *et al*., 2001) [11].

The result of reproductive hormone profile from participants comprising of three females and two males as seen in Table 4 from Abakpa, depicts the concentration of analysed hormones level and the enzyme aromatase with reference standard on footnote. The concentrations of testosterone and follicle stimulating hormones were below normal standard for both male and female in sampling area as seen on the Table 4 footnote. The result showed no significance difference in all parameters across samples except in Progesterone at $p<0.05$. Ayman *et al.* (2021) [4] reported a similar result on levels of reproductive hormones being low on test individuals. However, the result of the present study contrasts with the result of Babu *et al.* (2004) [5], in FSH, LH and Testosterone on fertile males. The low aromatase activity observed in the present study is in agreement with the report of Dhefer *et al*. (2017) [12]. While the concentration of estradiol contrasts on both studies. This could be as a result of diet, different activities employed by the various participants. Aromatase is a unique enzyme found in the cytochrome P450 system that converts androgen precursors into estrogens. The CYP19A1 gene on chromosome 15q21.2, which encodes for this enzyme, expressed in the ovary and testis as well as numerous extra glandular tissues like the placenta, brain, adipose tissue, and bone. Aromatase activity controls estrogen levels with endocrine, paracrine, and autocrine impacts on specific concerns, including bone (Merlotti, 2011) [23]. Testosterone, FSH all showed low concentrations against the normal level. The results of Otitoju and Onwurah (2007) [26], on PAH toxicity to hormone concentration shows significantly higher concentrations of all enzymes as against the low levels recorded in the present study. This distinction could be a result of variations in study animals or samples

The risk assessment as calculated depicts that consumption of water within all sample locations are moderately safe across all analysed metals with exception of mercury which had a very high risk assessment value and makes it unfit for use.

Conclusion

Following the outcome of this research, the physicochemical properties of water samples from all sampling locations were all within the WHO 2011, recommended limit except Dissolved Oxygen and pH which were higher and acidic respectively. Heavy metals (Zinc, Lead and Mercury) concentration was seen to be high across all sampling locations with others (Chromium and Cadmium) analysed samples being below WHO (2011) recommended limits. Surprisingly, the hormonal results showed much imbalance across all analysed parameter in all sampling locations. These high acidic nature of the water can expedite the corrosion of metal pipes used in pipping the water thus enhancing the heavy metal exposure. The high concentration of heavy metals could be attributed to the hormonal imbalance recorded in the present study as most heavy metals are seen to reduce the expression and activity of 3β-HSD and 17β-HSD, thus interfering with steroidogenesis.

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