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Assessment of health hazards of selected heavy metals in surface water from contaminated river in Aleto Eleme, Southern Nigeria

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Abstract

This study investigated the levels of some heavy metals (HMs) in surface water samples from River Aleto, located in Aleto-Eleme, Southern Nigeria. The possible health hazards associated with exposure to the selected heavy metals were evaluated. Experimental surface water samples were collected from River Aleto at upstream and downstream locations while midstream surface water samples from Ogharefe River served as Control sample. Surface water samples were analyzed for the concentrations of Cadmium (Cd), Nickel (Ni), Copper (Cu), Arsenic (As), Chromium (Cr), Lead (Pb), Iron (Fe) and Vanadium (V) using atomic absorption spectrophotometry (AAS). Mean concentration of the selected heavy metals in the surface water samples analyzed was in the order: Fe>Pb>Ni>Cd>Cu>Cr>As>V and Fe>Ni>Cd>Cu>Pb>Cr>As>V for upstream and downstream surface water samples respectively. Results obtained for Cd, Ni, As, Pb and Fe in the analyzed water samples from the different sampling locations were above WHO permissible limits for these heavy metals in water samples. Comparatively, downstream surface water samples had higher concentrations of Cd (0.56±0.00 mg/dl), Ni (0.62±0.00 mg/dl), Cu (0.44±0.00 mg/dl) and Fe (5.23±0.00 mg/dl) than upstream surface water samples. Health risk evaluation was performed using Average Daily Dose (ADD), Target Hazard Quotient (THQ), Hazard Index (HI), Life Cancer Risk (LCR) and Total Life Cancer Risk (TLCR), and indicated that the levels of Cd, Ni, Cr, Pb and Fe in surface water from Aleto River poses potential health and carcinogenic risk, via ingestion and dermal contact exposure routes, in adult and children populations. These findings demonstrate that residents of Aleto Eleme are exposed to health risks associated with consumption of heavy metal contaminants in water.

Keywords: Heavy metals; Health hazard; Risk assessment; Surface water; Contaminated River

1. Introduction

Contamination of water by heavy metals (HMs) has become a growing environmental and public health concern, particularly in rapidly industrializing regions. Pollution of natural water sources by heavy metals (HMs) has grown to be a significant global problem. Toxic chemicals and heavy metals enter rivers through industrial and anthropogenic activities of urban settlement around the drainage basin of rivers. [1, 2]. Heavy metals contaminate surface and ground water, resulting in deterioration of drinking water quality. Due to bioaccumulation, biomagnifications and toxicity of heavy metals in the food chain, heavy metal contamination causes serious problems [3 - 5]. Heavy metals, including Cadmium (Cd), Chromium (Cr), Nickel (Ni) Arsenic (As), Lead (Pb) and Iron (Fe) exhibit high toxicity at high concentrations [6]. Heavy metals like Cd and Cr have been found to possess carcinogenic properties [7]. Also, the accumulation of heavy metals in adipose tissues and the liver has been reported to have detrimental effects on the nervous, circulatory, and immune systems [8]. When introduced through drinking water, HMs like Cd, Hg, Pb, As, Cr, etc., can lead to several health concerns, such as cancer, kidney damage, and neurological diseases [9, 10]. Children and pregnant people are particularly vulnerable to the harmful effects of HM consumption [1].

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Clean water is essential for human existence as well as the health of ecosystems, communities, and economies [10]. Importantly, water plays a crucial role in the body metabolism and proper functioning of cells. The quality of water is a major concern with reference to public health, as health and well-being of the human populace is closely tied to the quality of water humans consume [11, 12]. In recent times, transformation by anthropogenic contaminants greatly affect surface water [14]. Hasan & Khan [15] estimated that over 80 percent of global human waste to highly toxic industrial discharges is released untreated into the surface water. In Nigeria, oil spillage caused primarily by the leakage of crude petroleum pipe contribute greatly to surface water pollution [16].

The possible health risks that locals may face as a result of drinking water contamination can be identified using a health risk assessment approach. The impact of hazardous heavy metals (HMs) on human health when consumed through the drinking of contaminated water can be evaluated using prospective human health risk assessment models [17].

The aim of the present study was to evaluate the concentrations of Cd, Ni, Cu, As, Cr, Pb, Fe and V in river Aleto, in Southern Nigeria, in order to determine their associated human health risk, following ingestion and dermal contact exposure.

2. Materials and methods

2.1. Study Area

Aleto Community is located in Eleme LGA of Rivers State, Nigeria. Eleme Local Government Area is located between latitude 4°44' N and longitude 7°15'E, to the east, lies Tai, to the west, Okrika and Port Harcourt Local Government Areas, and to the North, Obio/Akpor and Oyigbo. It is a crude oil producing local government with presence of oil and gas, petrochemical, and fertilizer industries. Apart from major Oil Companies like SPDC, Mobil etc., the local government also host Port Harcourt refinery Company, Alesa Eleme; Indorama Eleme Petrochemical Company Limited; Notore Chemicals Limited; and Indorama Fertilizer Chemicals Ltd. Eleme has a mean annual rainfall of 160–298 mm, a relative humidity of above 90%, and a mean temperature of 27°C. It undergoes alternating rainy and dry seasons [18]. Convectional rains are known to occur in the dry season months of November through March, whereas the rainy season typically lasts from April to October. Eleme is home to Aleto surface water, which empties into the Imo River. Runoffs into the Aleto surface water banks are caused by a number of adjacent activities, including sand mining, roasting cow-skins, oil spills, vehicle repairs, illicit refining operations, and catchment areas [19].

Figure 1 Map of Eleme communities showing the sampling location (Aleto)

2.2. Water Sample Collection

Water samples were collected from the Aleto River in plastic vials at a depth of 25 cm under water at upstream and downstream locations, and the vials immediately capped. Sample collection was done in triplicates at each sampling point and was done between the months of July and August, 2024. The samples were placed in ice-cold chest packs and transported to the laboratory, where they were stored at a temperature of 4°C. Midstream surface water samples

(Control) were collected from Ogharefe River in Delta State, Nigeria, a distance of over 232km away from the study area and having no history of contaminant pollution.

Table 1 Sampling locations and their coordinates

Sampled Surface Water	Location	Elevation	Distance	Coordinates
Aleto surface water (Upstream)	Aleto Community, Eleme LGA, Rivers State	427m	69.2m	N-4°43'23.2" E-7° 06'10.6"
Aleto surface water (Downstream)	Aleto Community, Eleme LGA, Rivers State	465m	115.0m	N-4°43'23.2" E-7° 01'26.5"
Ogharefe surface water (Control)	Ogharefe Community, Okpe LGA, Delta State	178m	192.5m	N-5° 56' 47.27" E-5° 37' 57.32"

2.3. Heavy metal determination

Heavy metal (Cd, Ni, Cu, As, Cr, Pb, Fe and V) levels in surface water samples were determined using an atomic absorption spectrophotometer (ASTM-E594-96) [20].

2.4. Health Risk Assessment for heavy metals

Health risk evaluation was performed using Average Daily Dose (ADD), Target Hazard Quotient (THQ), Hazard Index (HI), Life Cancer Risk (LCR) and Total Life Cancer Risk (TLCR). To assess the exposure of the human population to the presence of the assessed heavy metal present in the water samples, the main routes of exposure considered were ingestion and dermal contact.

2.4.1. Average Daily Dose (ADD)

The formula below was used to determine the average daily dose (ADD) (mg kg^{-1} day^{-1}) by ingestion and dermal contact:

$$\text{ADD} = \frac{\text{C X IRX EF X EDX CF}}{\text{BW X AT nc}} \text{ [20]}$$

Where:
C = the concentration of the contaminants (heavy metals) in water

IR = the ingestion rate of water

EF = exposure frequency

ED = exposure duration

CF = conversion factor

BW = adult body weight

AT nc = average time for non-carcinogens.

2.4.2. Target Hazard Quotient (THQ)

THQ levels were used in the estimation of non-carcinogenic risk of heavy metal ingestion and dermal contact. This is the ratio of a determined dose of pollutants to reference values that is thought to be dangerous, or the ratio of a studied concentration to an oral dose. THQs estimation was done according to the methodology described by [20].

$$THQ = Efr \times ED \times FIR \times CRfDo \times B_{averageweight} \times ATn \times 10^{-3}$$ (US EPA 2011).

Where:

C = metal concentration in sample in mg/kg or mg/l,

ATn = life span average in years,

EFr = frequency of exposure in day^{-1} $year^{-1}$,

ED = duration of exposure in years,

FIR = food intake rate in mg^{-1} day^{-1},

RfD = reference dose

2.4.3. Hazard Quotient and Hazard Index

Hazard quotient (HQ) and hazard index (HI) methodology were used to quantify the risks related to exposure to non-carcinogens in the pollutants. The likelihood that an individual would experience a negative outcome is represented by the quotient, which is a number without a unit and is calculated by dividing the average daily dosage (ADD) of a particular heavy metal or PAH by the corresponding reference dose (RfD) (mg/kg/day) for both ingestion and dermal contact.

Hazard quotient for oral and skin contact of water and sediment samples as well as ingestion of seafood were calculated using the formula below [20].

$$\mathrm{HQ} = \frac{\mathrm{ADD}}{\mathrm{RfD}}$$

According to [21], the total of the HQs for every congener in each sample was used to construct the Hazard Index (HIs) for the two pollutants, heavy metals and PAHs [21]. Contaminant HQ and HI values less than 1 are regarded as safe and suggest unlikely adverse health impacts, but values greater than 1 indicate a potential detrimental health effect [20].

$$\mathrm{HI} = \mathbf{\Sigma}\mathrm{HQ}$$

Hazard index (HI) = ΣTHQ (THQ_{Cd}+ THQ_{Ni}+ THQ_{Cu}+ THQ_{As}+ THQ_{Cr}+ THQ_{Pb}+ THQ_{Fe}+ THQ_{V}) or HI = THQ_{ingest}+ THQ_{dermal}

2.4.4. Life Cancer Risk (LCR) and Total Life Cancer Risk (TLCR)

In terms of carcinogenic risk, the population's life cancer risk (LCR) resulting from lifetime exposure to possible carcinogens can be computed as follows:

$$\mathrm{LCR} = \mathrm{ADD} \times \mathrm{SF}$$

Where:

ADD = average daily dose of pollutant(s)

SF = slope factor for cancer.

Total life cancer risk (TLCR) adds up all LCRs calculated for the individual metal.

$$\mathrm{TLCR} = (LCR_{Cd} + LCR_{Ni} + LCR_{Cu} + LCR_{Ar} + LCR_{Cr} + LCR_{Pb} + LCR_{Fe} + LCR_{V})$$

2.5. Statistical Analysis

Statistical Analysis Results in this study are expressed as Means ± Standard Error Mean (SEM) while one-way ANOVA was used to test for differences between treatment groups using SPSS version 20. The results were considered significant at p-values of less than 0.05, that is, at 95% confidence level ($P < 0.05$).

3. Results and discussion

Results for heavy metal contents of water samples from upstream and downstream sections of Aleto River are presented in Table 2. Analytical results for experimental samples were compared with Ogharefe midstream surface water samples. Mean concentration of the selected heavy metals in the surface water samples analyzed was in the order: Fe>Pb>Ni>Cd>Cu>Cr>As>V for upstream surface water samples. Mean concentration of heavy metals in downstream surface water samples was in the order Fe>Ni>Cd>Cu>Pb>Cr>As>V. Results obtained for Cd, Ni, As, Pb and Fe in the analyzed water samples from the different sampling locations were above WHO permissible limits for these heavy metals in water samples. Comparatively, downstream surface water samples had higher concentrations of Cd (0.56±0.00 mg/dl), Ni (0.62±0.00 mg/dl), Cu (0.44±0.00 mg/dl) and Fe (5.23±0.00 mg/dl) than upstream surface water samples.

Table 2 Heavy metal contents of upstream and downstream surface water samples from Aleto and Ogharefe Rivers

Heavy Metals (mg/l)	Upstream Aleto Surface Water	Downstream Aleto Surface Water	Ogharaefe Surface Water	WHO Standards
Cadmium (Cd)	0.50 ± 0.00^{b}	0.56 ± 0.001^{c}	0.13 ± 0.00^{a}	0.003
Nickel (Ni)	0.56 ± 0.00^{b}	0.62 ± 0.001^{c}	0.24 ± 0.00^{a}	0.02
Copper (Cu)	0.38 ± 0.00^{b}	0.44 ± 0.001^{c}	0.17 ± 0.00^{a}	1.0
Arsenic (As)	BDL	BDL	BDL	0.01
Chromium (Cr)	0.31 ± 0.00^{c}	0.15 ± 0.00^{b}	0.10 ± 0.00^{a}	0.02
Lead (Pb)	0.59 ± 0.00^{c}	0.43 ± 0.00^{b}	0.39 ± 0.00^{a}	0.05
Iron (Fe)	4.91 ± 0.00^{b}	5.23 ± 0.00^{c}	4.00 ± 0.00^{a}	0.30
Vanadium (V)	BDL	BDL	BDL	-

Values represent mean ± SEM. Values in the same row with different superscript alphabets are significantly different at $p \leq 0.05$ (n=3). BDL implies below detection limits of 0.01mg/l. Values are Mean ± Standard Deviation. Data with the same alphabets (a,b,c) as superscript shows non-significant differences ($p \geq 0.05$), while that with different alphabets as superscript shows significant differences ($p \leq 0.05$).

Table 3 Average daily dose (ADD) ingestion for surface water samples from Aleto and Ogharefe surface water

Samples	**Cd**		**Ni**		**Cu**		**As**		**Cr**		**Pb**		**Fe**		**V**	
	Adult	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**
USASW	1.66E-04	1.31E-03	3.12E-04	2.47E-03	2.21E-04	1.75E-03	-	-	1.24E-04	9.85E-04	5.09E-04	4.03E-03	5.18E-03	8.79E-03	2.59E-12	2.05E-11
DSASW	3.59E-04	2.85E-03	4.04E-04	3.20E-03	2.86E-04	2.27E-03	1.29E-06	1.03E-05	9.38E-05	7.44E-04	2.79E-04	2.21E-03	3.39E-03	5.75E-03	1.94E-06	1.54E-05
OSW	3.21E-10	2.54E-09	3.64E-10	2.88E-09	2.47E-10	1.96E-09	-	-	1.99E-10	1.57E-09	3.83E-10	3.04E-09	3.18E-09	5.39E-09	-	-
RfD Ingestion (US EPA, 2011)	1.0E-03	1.0E-03	2.0E-02	2.0E-02	5.0E-02	5.0E-02	3.0E-03	3.0E-03	5.0E-2	5.0E-2	5.0E-03	5.0E-03	3.0E-01	3.0E-1	5.0E-2	5.0E-2

* USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water; OSW – Ogharefe Surface Water; RfD - Reference dose values

Table 4 Average daily dose (ADD) dermal contact for water samples from Aleto and Ogharefe surface water

Samples	**Cd**		**Ni**		**Cu**		**As**		**Cr**		**Pb**		**Fe**		**V**	
	Adult	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**
USASW	2.09E-03	1.23E+00	4.74E-04	2.80E-01	1.61E-03	9.51E-01	0.00E+00	0.00E+00	1.29E-03	7.64E-01	2.49E-04	5.67E-02	2.07E-02	1.22E+01	3.37E-05	1.99E-02
DSASW	2.34E-03	1.38E+00	5.26E-04	3.11E-01	1.86E-03	1.10E+00	8.43E-06	4.98E-03	6.11E-04	3.61E-01	1.82E-04	4.13E-02	2.20E-02	1.30E+01	2.53E-05	1.49E-02
OSW	5.39E-04	3.19E-01	2.03E-04	1.20E-01	7.20E-04	4.26E-01	0.00E+00	0.00E+00	4.04E-04	2.39E-01	1.66E-04	3.76E-02	1.68E-02	9.95E+00	0.00E+00	0.00E+00
RfD Dermal (US EPA, 2011)	5.0E-4	5.0E-4	5.4E-3	5.4E-3	1.2E-2	1.2E-2	1.23E-4	1.23E-4	6.0E-6	6.0E-6	5.25E-4	5.25E-4	3.0E-1	3.0E-1	1.0E-4	1.0E-4

* USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water; OSW – Ogharefe Surface Water; *RfD - Reference dose values*

Table 5 Target hazard quotient (THQ) ingestion for water samples from Aleto and Ogharefe surface water.

Samples	Cd		Ni		Cu		As		Cr		Pb		Fe		V	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
USASW	1.66E-01	1.31E+00	1.56E-02	1.24E-01	4.43E-03	3.51E-02	-	-	2.49E-03	1.97E-02	1.02E-01	8.06E-01	1.73E-02	2.93E-02	5.18E-11	4.10E-10
DSASW	3.59E-01	2.85E+00	2.02E-02	1.60E-01	5.72E-03	4.53E-02	4.31E-04	3.42E-03	1.88E-03	1.49E-02	5.58E-02	4.42E-01	1.13E-02	1.92E-02	3.88E-05	3.08E-04
OSW	3.21E-07	2.54E-06	1.82E-08	1.44E-07	4.94E-09	3.92E-08	-	-	3.97E-09	3.15E-08	7.66E-08	6.07E-07	1.06E-08	1.80E-08	0.00E+00	0.00E+00

* USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water; OSW – Ogharefe Surface Water; RfD - Reference dose values; Note: Values from 1 and above implies non-carcinogenic health risk as stated by US EPA (2011).

Table 6 Target hazard quotient (THQ) dermal for water samples from Aleto and Ogharefe surface water.

Samples	THQ NC (Cd)		THQ NC (Ni)		THQ NC (Cu)		THQ NC (As)		THQ NC (Cr)		THQ NC (Pb)		THQ NC (Fe)		THQ NC (V)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
USASW	4.18E+00	2.47E+03	8.77E-02	5.18E+01	1.34E-01	7.92E+01	0.00E+00	0.00E+00	2.16E+02	1.27E+05	4.75E-01	1.08E+02	6.89E-02	4.07E+01	3.37E-01	1.99E+02
DSASW	4.68E+00	2.76E+03	9.74E-02	5.75E+01	1.55E-01	9.17E+01	6.85E-02	4.05E+01	1.02E+02	6.02E+04	3.46E-01	7.86E+01	7.35E-02	4.34E+01	2.53E-01	1.49E+02
OSW	1.08E+00	6.37E+02	3.76E-02	2.22E+01	6.00E-02	3.55E+01	0.00E+00	0.00E+00	6.74E+01	3.98E+04	3.15E-01	7.17E+01	5.61E-02	3.32E+01	0.00E+00	0.00E+00

* USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water; OSW – Ogharefe Surface Water;RfD - Reference dose values

Table 7 Hazard index (HI) for water samples from Aleto and Ogharefe surface water**.**

Samples	HI (Cd)		HI (Ni)		HI (Cu)		HI (As)		HI (Cr)		HI (Pb)		HI (Fe)		HI (V)		THI	
	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD
USASW	4.179213	2469.248	0.087691	51.81144	0.134111	79.28365	0	0	215.5609	127362.1	0.475056	107.9548	0.068923	40.72268	0.337033	199.1329	220.8429	130310.30
DSASW	5.035534	2765.816	0.117558	57.68731	0.160897	91.7192	0.068934	40.47759	101.814	60154.75	0.401649	79.03761	0.08476	43.43015	0.252814	149.35	107.9362	63382.27
OSW	1.24419	638.5383	0.053202	22.34168	0.064461	35.47055	0	0	67.40914	39826.61	0.417107	72.47222	0.073394	33.20152	0	0	69.26149	40628.63

***** USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water**;** OSW – Ogharefe Surface Water**;** RfD - Reference dose values; Note: Values from 1 and above implies non-carcinogenic health risk as stated by US EPA (2011).

Table 8 Life cancer risk (LCR) ingestion for water samples from Aleto and Ogharefe surface water.

	Cd		Ni		Cu		As		Cr		Pb		Fe		V	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
USASW	3.55E-02	5.63E-02	5.62E-03	8.90E-03	-	-	0.00E+00	0.00E+00	5.33E-04	8.44E-04	3.71E-04	5.87E-04	-	-	-	-
DSASW	7.70E-02	1.22E-01	7.27E-03	1.15E-02	-	-	2.77E-04	4.40E-04	4.02E-04	6.37E-04	2.03E-04	3.22E-04	-	-	-	-
OSW	6.88E-08	1.09E-07	6.55E-09	1.04E-08	-	-	0.00E+00	0.00E+00	8.52E-10	1.35E-09	2.79E-10	4.42E-10	-	-	-	-

* USASW – Upstream Aleto Surface Water; DSASW - Downstream Aleto Surface Water; OSW – Ogharefe Surface Water;RfD - Reference dose values; Note: Values from 10E-3 and above implies carcinogenic health risk; values from 10E-6 to 10E-4 falls within the reference range given by US EPA (2011).

Table 9 Life Cancer risk (LCR) dermal contact for water samples from Aleto and Ogharefe surface water**.**

Samples	LCR (Cd)		LCR (Ni)		LCR (Cu)		LCR (As)		LCR (Cr)		LCR (Pb)		LCR (Fe)		LCR (V)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
USASW	-	-	5.01E-06	1.48E-06	-	-	0	0	-	-	-	-	-	-	-	-
DSASW	-	-	5.56E-06	1.64E-06	-	-	5.99E-06	1.77E-06	-	-	-	-	-	-	-	-
OSW	-	-	2.15E-06	6.35E-07	-	-	0	0	-	-	-	-	-	-	-	-

Note: Values from 10E-3 and above implies carcinogenic health risk; values from 10E-6 to 10E-4 falls within the reference range given by US EPA (2011).

Table 10 Total life cancer risk (TLCR) for water samples from Aleto and Ogharefe surface water.

Samples	LCR (Cd)		LCR (Ni)		LCR (Cu)		LCR (As)		LCR (Cr)		LCR (Pb)		LCR (Fe)		LCR (V)		TLCR	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
USASW	3.55E-02	5.63E-02	5.62E-03	8.90E-03	-	-	0.00E+00	0.00E+00	5.33E-04	8.44E-04	3.71E-04	5.87E-04	-	-	-	-	4.20E-02	6.66E-02
DSASW	7.70E-02	1.22E-01	7.27E-03	1.15E-02	-	-	2.83E-04	4.41E-04	4.02E-04	6.37E-04	2.03E-04	3.22E-04	-	-	-	-	8.51E-02	1.35E-01
OSW	6.88E-08	1.09E-07	5.02E-06	1.49E-06	-	-	0.00E+00	0.00E+00	8.52E-10	1.35E-09	2.79E-10	4.42E-10	-	-	-	-	5.09E-06	1.60E-06

Note: Values from 10E-3 and above implies carcinogenic health risk; values from 10E-6 to 10E-4 falls within the reference range given by US EPA (2011).

Heavy metal contamination in surface water poses significant health and environmental risks, especially in industrial regions. Heavy metals in contaminated rivers pose significant health hazards, potentially causing various diseases and developmental problems. Metals like lead, cadmium, and chromium can accumulate in the body, leading to long-term health consequences, especially in vulnerable populations like children and pregnant individuals. Assessing these risks involves evaluating exposure pathways, such as ingestion and dermal contact, and using tools like Average Daily Dose (ADD), Target Hazard Quotient (THQ), Hazard Index (HI), Life Cancer Risk (LCR) and Total Life Cancer Risk (TLCR) to quantify the risks [1].

The results of Average daily dose (ADD) due to ingestion and dermal contact for water samples from Aleto and Ogharefe surface water for Heavy metals in children and adults are presented in Tables 3 and 4. Result Tables for Target hazard quotient (THQ) due to ingestion and dermal contact for water samples from Aleto and Ogharefe surface water samples are presented in Tables 5 and 6. Hazard index (HI) and Life cancer risk (LCR) due to ingestion for experimental surface water samples are presented in Tables 8 and 9. Table 10 shows the total life cancer risk (TLCR) for water samples from Aleto and Ogharefe surface water.

For carcinogenic risk, TLCRs between 1×10^{-6} and 1×10^{-4} are tolerable. When the risk is higher than the range, it suggests that there are carcinogenic dangers and that a carcinogenic effect is likely to occur [21]. TLCRs for surface water samples from Aleto were observed to show mean values higher than the regulatory threshold of 10E-6 – 10E-4. Carcinogenic Risk (CR) assessment of heavy metals were significantly ($p<0.05$) high for Cd, Ni, Cr, Pb and Fe in both adult and children populations. Findings in this study are quite similar to the previous report by Preonty et al. [1] in monitoring and assessment of heavy metal contamination in surface water of selected rivers who found that in the rivers studied, hazardous metals, including Cr, Cd, Pb, Ni and Fe exceeded the permissible limits of the WHO.

4. Conclusion

Results of this investigation showed that the levels of Cd, Ni, Cr, Pb and Fe in surface water from Aleto River poses potential health and carcinogenic risk in adult and children populations via ingestion and dermal contact exposure routes. These findings demonstrate that residents of Aleto Eleme are exposed to health risks associated with consumption of heavy metal contaminants in water.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have declared that no competing interests exist.

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