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Ecological and Human Health Risk Assessment (Integrated Risk Assessment): A Case Study of Ekerekana and Okochiri Creeks Using the Mudskipper Fish

Allison Theodore Athanasius, Paul, Chikwuogwo wokpeogu*

Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Science, University of Port Harcourt Nigeria

***Corresponding author**
Paul, Chikwuogwo wokpeogu

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Abstract: The aim of this study was to assess the possible risk posed by suspected contaminants in Ekerekana and Okochiri river channels on ecological and human health using a resident fish, Periophthalmodon papillo. In this study, chemical- and bio-monitoring assessments were carried out in two sampling stations, Ekerekana (EKE) and Okochiri (OKO). The chemical monitoring involved sediment and environmental water quality analysis with the goal to identify target chemicals and evaluation of environmental water quality index (EWQI) for Ekerekana and Okochiri river channels. The bio-monitoring involved the assessment of target chemicals in fish tissue for the evaluation of the edibility status of the bio-indicator fish. Fish edibility study showed that the bio-indicator fish was found to be unsafe for consumption because lead (Pb) (5,4mg/kg) and Copper (Cu) (0,99mg/kg) were beyond their oral reference dose (RfD). The FCS showed an average Fish Consumption Rate (CR) of 5.3g/day in Okochiri and 4.6g/day in Ekerekana by subsistence fishers, with an age group range of 20-29 forming the highest consumers. The HQ>1 for Pb and Cu, meaning their levels in the edible part of the study fish is of potential concern and the estimated rate of the fish consumption can be hazardous to human health. The results suggest that the EKE and OKO creeks have a negative ecological and human health impact on the affected communities. There is therefore the urgent need to check the contamination of these creeks and river system in order to avert a more serious environmental consequence.

Keywords: Ecology, Human Health, biomonitoring, Edibility, water quality, fish consumption survey.

INTRODUCTION

The Port Harcourt Refining Company (PHRC) located at Alesa Eleme, in Eleme Local Government Area of Rivers State, Nigeria, is a subsidiary of the Nigerian National Petroleum Corporation (NNPC). PHRC is a government owned oil and Gas Company primarily specialized in refining crude oil into petroluem products. The company operates two oil refineries that can process a combined volume of 210,000 barrels of oil per stream day. The PHRC refining process requires large volumes of process water which needs to be recycled to meet up the demand. PHRC has constructed paved waste water drainage running from their facility, several miles, into Okirika local Government Area, where it is channelled into to a receptacle, which is a creek at Ekerekana community. This effluent- receiving water body is a creek which connects with other adjoining rivers of another contiguous community - Okochiri Community. The level of impact of these discharges on the adjoining Ekerekana /Okochiri creek has always been a cause of concern to the affected communities. The waste water bears a pungent smell, and as such the locals refer to the primary affected creek as the "smelling river". Fishing activities have thus been stopped around the immediate effluent receiving creeks in Ekerekana community, making the adjacent community (Okochiri) river channels as the nearest available alternative for subsistence fishers to earn a livelihood. Nevertheless, the creek serves as home to many aquatic foods such as fish, crab, prawn, crayfish, etc [1]. It is therefore the main objective of this research to provide some valuable information on the potential health risk of the aquatic ecosystem on Ekerekana and Okochiri communities.

Over the years, focus of environmental protection has expanded tremendously from stressor specific to broader objectives of ecosystem integrity and sustainability. Not until later were the effects measurement, such as fish population assessment added to determine whether the valued public resources were actually being protected [2]. More recently, society has recognized the need to protect a larger number and greater diversity of valued resources. Another contributing factor is the recognition that many human concerns (e.g. food safety) are directly linked to environmental quality [2].

Risk assessors had often seen the ecology and human health as independent entities and as such assessed differently. This has resulted in design of narrow assessment of environmental outcome. And in some cases the core stressors of the ecosystem are under-valued or completely missed out. One of the major trends in the assessment of environmental contaminants has been to increase integration [3]. This increase in integration is predictable. As we gain experience in contaminant assessment, instances in which narrowly focused assessments fail to provide adequate guidance become apparent [4].

Because humans and other organisms exist in real environments they are exposed to a variety of hazardous agents which may interact with chemical contaminants to induce mortality and other deleterious effects. Assessments should integrate risks to humans and the environment from all relevant agents. The simple models used for chemical mixtures are not adequate when more heterogeneous sets of agents are involved. The objective of risk assessment is to support decision making by assessing risks of adverse effects on human health and the environment from chemicals, physical factors, and other environmental stresses. For practical reasons, the methodologies for human health and ecological risk assessment developed independently. However, with increased recognition of the need to more effectively protect both humans and the environment, it is time to consider a move to a more integrated, "holistic" approach to risk assessment [4].

The purpose of this study is to quantify the potential risk posed by consumption of *Periophthalmodon papillo* harvested from Okochiri River by subsistence fishers from Ekerekana and Okochiri communities, and to characterize the risk based on their hazardous quotient and carcinogenic index.

MATERIALS AND METHODS

Study Area

Ekerekana (EKE) and Okochiri (OKO) communities are used as the experiment area, both in Okrika Local Government Area (LGA) of Rivers State, Nigeria. The Okrika LGA lies between latitude 40351 and 40451N and longitude 7000N and 70151E. It is situated in the tropical rainforest belt dominated by secondary forest and bush fallow and the soil type is of coastal plain terrace and sedimentary in origin. EKE and OKO communities are intersected by creeks, rivulets and rivers forming an inter-connected river channel or system. EKE community creeks form the upstream part of the creek and a receptacle to PHRC waste water effluence via a paved and open gutter;-a point-source drainage system. Their creeks are salt water with the Okochiri part connecting at its upstream to the tributaries of Bonny River which discharge into the Atlantic Ocean about 56km from the North Bank of the Bight of Benin. Indigenous people of both communities are predominantly subsistence fishers, though increasing population and development is creating some semblance of urbanization with increase in commercial activities. Nevertheless, the people still engage in traditional fishing practices and even the working class among them still engage in part-time fishing to augment resources.

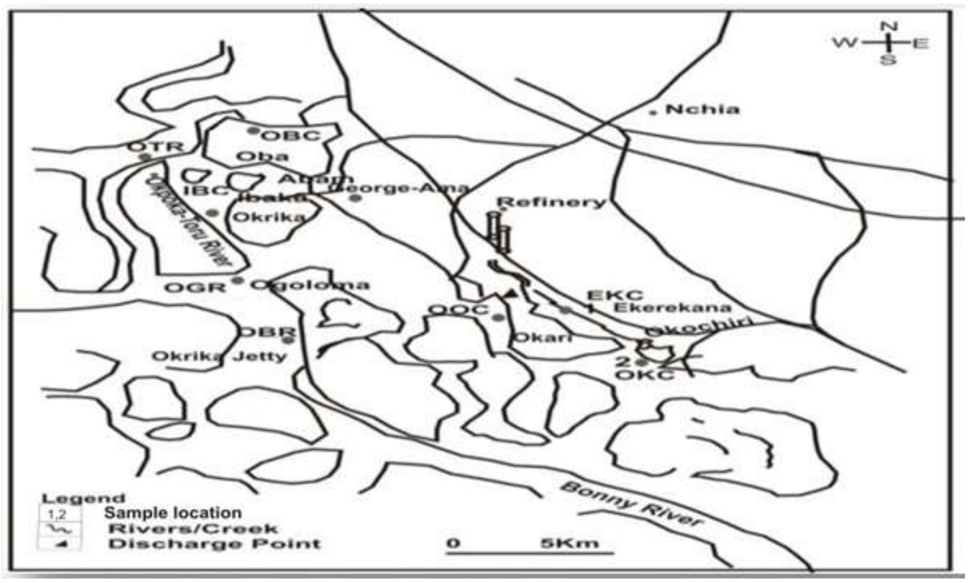

Fig-2: Map showing Ekerekana (2), Okochiri (3), the PHRC discharge point (1) and the connectivity of rivers flowing down stream into the larger Bonny River which connects to the Atlantic Ocean. Source: (www.josrjournal.com)

Study Species

Mudskipper fish (*Periophthalmus papillo*) are member of the subfamily Oxudercinae (*Periophthalmin*) [5], within the family Gobidae (gobies). They are completely amphibious fish that can use their pectoral fin to walk on land [6]. They are found in tropical, subtropical and temperate zones. Mudskipper are very sensitive to ambient environment, they easily accumulate heavy metals in their tissue as compared to other fishes. The fish is a good monitor of aquatic pollution of PAH, as studies have shown that mudskipper species have high plasma enzyme level causing a change in its protein metabolism that enables bioavailability of PAH [7, 8]. Due to their natural abundance, and considerable resistance to their highly polluted habitat and benthic habitat they can be used as viable bio-indicator. Its feeding habit is carnivorous because it feeds on small prey such as crabs and other anthropods. It is an indigenous fish as is been consumed by members of the study communities (i.e. EKE and OKO). It is called *ishila* by the locals.

Sampling

Sampling was done for water, sediment and fish. A total number of four (4) samples at two weeks interval was taken for water and sediment from EKE (i.e. the point of discharge of the PHRC effluence into the Ekerekana creek) and OKO (i.e. a creek in Okochiri community, about 2.5Km away from the effluent discharge point, where fishing activities take place). A total of twenty fishes (20) were sampled for the study from the Okochiri community location (OKO) only (i.e excluding EKE where fishing activities has been stopped by community authorities). The water samples for heavy metal and PAH were collected using polypropylene bottles and glass bottles respectively. Samples were iced and sent to the laboratory for further analysis. Sediment samples were collected using a stainless steel trowel at EKE and an erkman grab sampler at OKO. Samples were put in an aluminum foil, iced and sent to the laboratory for heavy metals and PAH analysis. Fish were caught using gills net. Fish were sacrificed and skin and muscle tissues were then collected and iced for further laboratory analysis.

LABORATORY ANALYSIS

Heavy metals

Atomic Absorption Spectrometre (AAS) was used to analyse water and sediment samples for heavy metals**.** Samples were first prepared for AAS by the Digestion Procedure A [9]. For water sample, the procedure involves adding of 5cm^3 of concentrated HNO_3 to a well-mixed 100cm^3 of the water sample in a beaker. The solution was evaporated to near dryness on a hot plate, making sure that the sample does not boil (using low to medium heat). The beaker and content was allowed to cool to room temperature. Another 5cm^3 conc. HNO_3 was added to the beaker and it was immediately covered with a watch glass. The beaker was returned to the hot plate and a set a gently reflux action of the solution by increasing the temperature of the hot plate (Medium to high heat). There was a continous heating with an addition of conc. HNO3 as necessary until light-coloured residue is obtained (which indicated that digestion is completed). For sediment samples, 5g air-dried and sieved sediment sample was put a 100ml of distilled water. 2ml of HNO3 and 6ml HCL in the ratio 1:3 is added to the sample and heated to digest the sample. Digested samples are introduced to the pre-calibrated AAS for analysis.

PAH Analysis

Water and sediment samples for PAH were analysed using Gas Chromatography. Extraction of PAH from water samples was done by measuring out 250ml of sample into a separation funnel and into a container rinsed with Dichloromethane. The organic extract was passed through a receiving container containing columns of cotton, silica-gel and anhydrous sodium sulphate. The silica-gel aids the clean-up of the extract by disallowing the passage of debris from the extract while the anhydrous sodium sulphate acts as a dehydrating agent to rid the extract of every form of moisture/water. The collected organic extract was washed and injected into the Gas Chromatography chamber. For sediment, extraction was done collecting 1gm of samples into 10ml of extraction solvent (Dcm), mixed thoroughly and allowed to settle. The mixture was carefully filtered into a clean paper fitted into butcher funnels. The extract was concentrated to 1ml and then transferred for clean-up/separation. Afterwards the recovered concentrated organic extract is analysed via the Gas Chromatographic method.

Fish Tissue Analysis

5 grams of muscle and skin tissues was excised from each fish and placed in different plastic vials and iced. A composite sample was made out of the fish tissues collected and analysed for the target chemicals using the method describe by Allison and Paul [10].

EVALUATION

Environmental Water Quality (EWQ) Index

Analytical values of physical parameters (dissolved oxygen concentration DO, temperature, total disposed solids TDS and pH) and chemical parameters (heavy metals and PAH) were used to estimate EWQ Index in accordance with CCME [11] protocol for Water Quality Index. Estimated EWQ index is ranked by relating it to the following categories: EXCELLENT (95-100)-Water quality is protected with a virtual absence of threat or impairment, conditions very close to natural or pristine level; GOOD (88-94)- Water quality is protected with only a minor degree of threat or impairment. Conditions rarely depart from natural or desirable levels; FAIR (65-89) - Water quality is usually protected but occasionally threatened or impaired. Conditions sometimes depart from natural or desirable levels: MARGINAL (45-64) - Water quality is frequently threatened or impaired. Conditions often depart from natural or desirable levels; POOR: (0-44) - Water quality is almost always threatened or impaired [11].

Integrated Risk Assessment (IRA)

This risk assessment follows the methodology recommended by the U.S. Environmental Protection Agency (USEPA) for the assessment of cancer and noncarcinogenic toxicity [12]. This methodology generally includes the following four steps:

Hazard Identification

It is the identification of the chemicals of potential concern (COPC) to be included in the risk assessment and characterization of the toxicological hazards posed by these chemicals in humans. COPCs for this study were identified in the bioaccumulation analysis of fish muscle and skin result and their characterization were made based on the literature review on their weight of evidence of toxicity.

Dose-Response Assessment

It is the quantitative characterization of the relationship between the dose of a toxicant and the incidence of adverse health effects in humans. For this study default benchmark Oral reference dose (RfD) values [13] were used as substitute values for Dose-response assessment.

Exposure Assessment

It is the characterization of the magnitude, frequency, and duration of exposure to COPCs in fish. This assessment addresses how often individuals eat fish, how much and what portions of the fish. It is the estimation of the potential for adverse health effects by integrating the information from the dose-response assessment with the exposure assessment in a mathematical model to analyse hazardous quotient (HQ) for non-carcinogenic compounds and carcinogenic risk characterization. Non-carcinogenic and carcinogenic risk estimates are calculated separately because of fundamental differences in their critical toxicity values. Equations used to derive risk estimates for both types of health effects are presented below.

Non-carcinogenic Health Effects

This is a measure of the Hazardous Quotient (HQ) of target chemicals. The potential for non-carcinogenic health effects is evaluated by calculating the ratio of the chemical exposure over a specified time period to an RfD that is derived for a similar time period. This ratio of exposure to toxicity for an individual chemical is called the hazard quotient (HQ):

$$HQ = CDI/RfD$$

Where:
HQ = Chemical-specific hazard quotient (unitless)
CDI = Chemical-specific chronic daily intake (mg/kg-day)
RfD = Route- and chemical-specific reference dose (mg/kg-day)

The non-carcinogenic HQ assumes that there is a threshold level of exposure, the RfD, below which it is unlikely that even sensitive populations will experience adverse health effects [14]. If the exposure exceeds this threshold (HQ > 1), there may be concern for potential non-carcinogenic health effects. Generally the greater the magnitude of the HQ above a value of 1, the greater the level of concern for non-carcinogenic health effects. It should be noted, however, that exposures above the RfD do not represent the same increase in risk for all chemicals as RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects [14, 15]. Furthermore, the level of concern does not increase linearly as the RfD is approached. The HQ values presented in this risk assessment evaluate chronic exposure durations, which in humans are defined as ranging in duration from seven years to a lifetime [14]. Sub-chronic exposures of two weeks to seven years or shorter-term exposures are not evaluated in this risk assessment.

Carcinogenic Risk

Risk for carcinogens is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen [14]. Under current risk assessment guidelines, USEPA assumes that a threshold dose does not exist for carcinogens and that any dose can contribute to health risks [12]. In other words, the risk of cancer is proportional to dose exposure and there is never a zero probability of cancer risk when exposed to carcinogenic chemicals. Carcinogenic risk probabilities were calculated by multiplying the estimated exposure level by the SF for each chemical. This product represents the excess cancer risk, or the additional risk that an individual has of developing cancer in their lifetime due to exposure to a particular toxic substance. Risk = CDI × SF where: Risk = Estimated chemical-specific individual excess lifetime cancer risk (unitless) CDI = Chemical-specific chronic daily intake (mg/kg-day) SF = Route- and chemical-specific cancer slope factor (kg-day/mg) For this risk assessment, an individual lifetime excess cancer risk of 1.0E-04 (EVS2000a) was adopted as the Acceptable Risk Level (ARL) to assess the potential for adverse health effects due to ingestion of fish containing carcinogenic chemicals. To assess the risk posed by simultaneous exposure to multiple carcinogenic chemicals in fish tissue, the excess cancer risk for all carcinogenic chemicals was summed to calculate a total cancer risk.

RESULTS

Environmental Water Quality Index

Table-1: Physico-Chemical Parameters Used for evaluation of EWQI for OKO and EKE

Parameters	EKE Mean	OKO Mean	CCME Guideline	Remark
Temperature (C	32.3	28.2	Ambient (31.0) *	Non-applicable
Conductivity (µs/cm).	669.7	399.9	150-500 **	Non-applicable
Salinity ppm	889.8	2560.5	-	Non-applicable
TDS	69.75	392,2	-	Non-applicable
DO (mg/L)	2.89	2.22	5.5-9.5	Applicable
PH	6.5	6.0	6.0-9.5	Applicable
Pb (mg/L)	0.001	0.173	1-7	Applicable
Cd (mg/L)	0.001	0.035	0.017-0.10	Applicable
Cr (mg/L)	0.001	0.14	1	Applicable
Hg (mg/L)	0.001	<0.001	0.026	Applicable
Cu (mg/L)	0.001	0.04	2-4	Applicable
PAH (mg/L)	0.001	0.003	-	Non-application

Key: * = SON (2007) [24] Guideline and ** = USEPA (2012) [18] Guideline

Using CCME [11] and SON guideline for mathematical evaluation of EWQI, EKE EWQI was estimated to be 10.5 and OKO EWQI was estimated to be 57.5.

Sediment Quality Analysis

The result of heavy metals in the sediment from the two stations is represented in Fig-2.

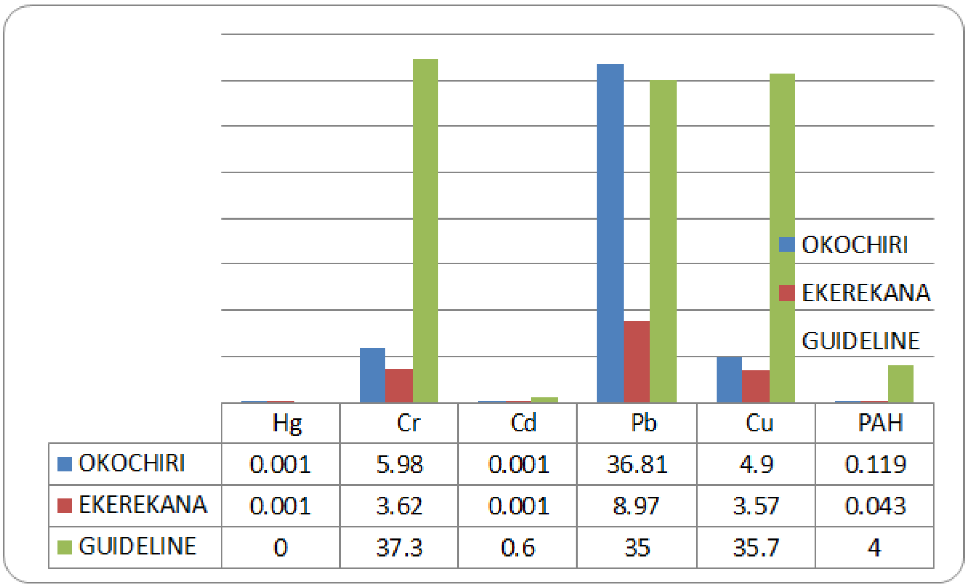

Fig-2: Graph showing heavy metal profile from two stations using NOAA 2009 [16]. PAH –BCWQ Guidelines (2006) [17]

Edibility of Fish

Mean concentration of heavy metals and PAH in edible part (muscle and skin tissue) of the fish from Okochiri was compared with standard oral reference dose (RfD) values benchmarks of US EPA [18] for fish consumption in human.

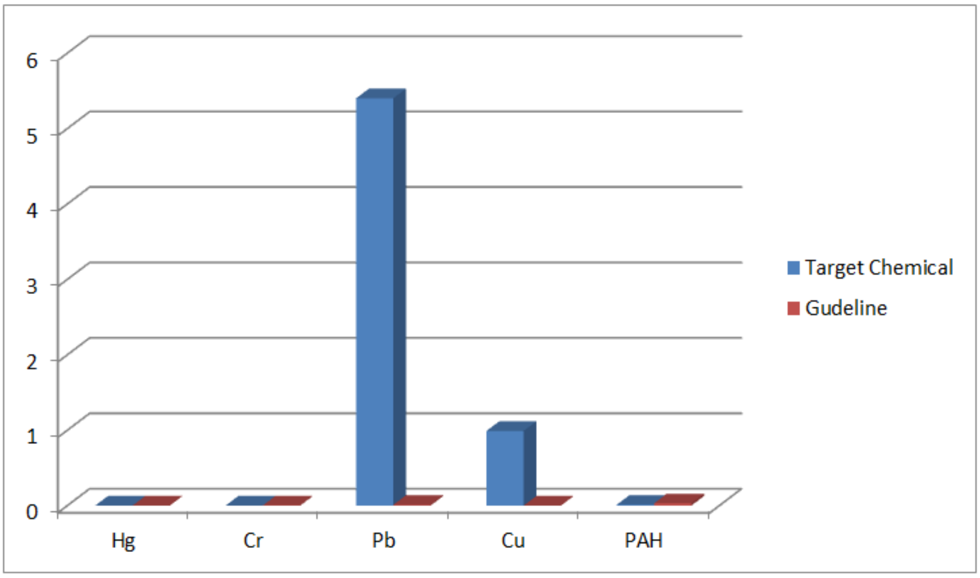

Fig-3: Graph showing the average concentrations of target chemicals measured in fish tissues

Integrated Risk Assessment (IRA)

Exposure Assessment: Fish Consumption Survey.

Below are some of the demographic results of target population biodata of respondents from Okochiri and Ekerekana obtained from the FCS.

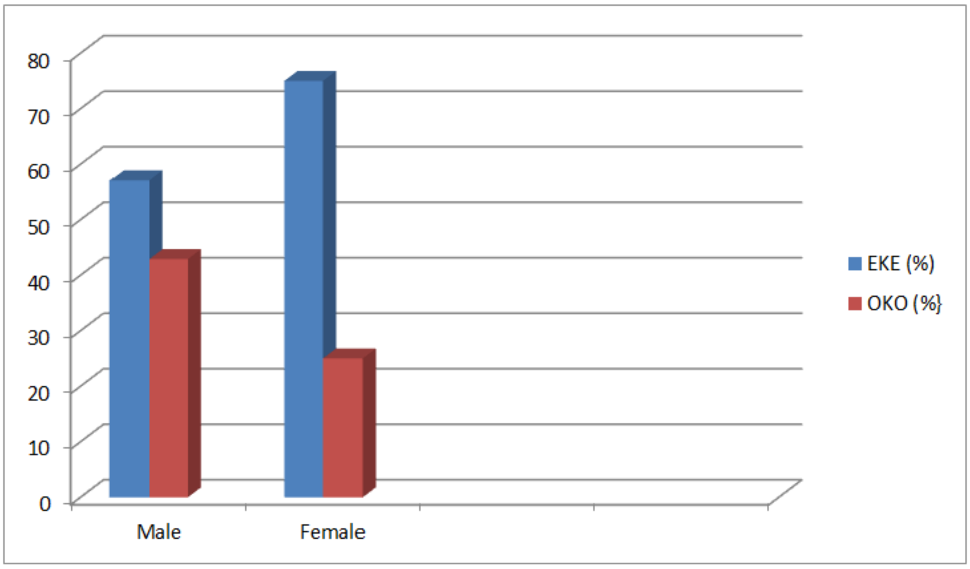

Fig-4: A Graph showing % distribution of sex among respondents

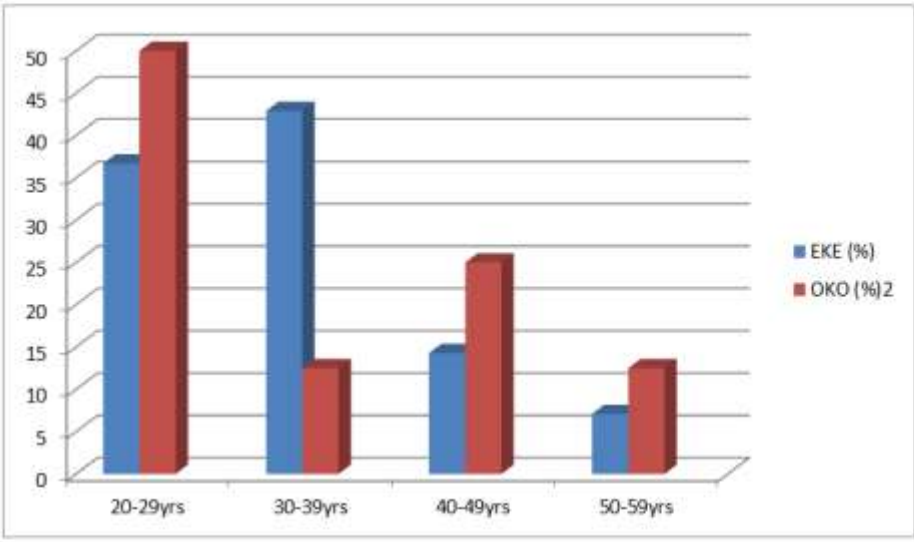

Fig-5: A Graph showing age distribution among respondents

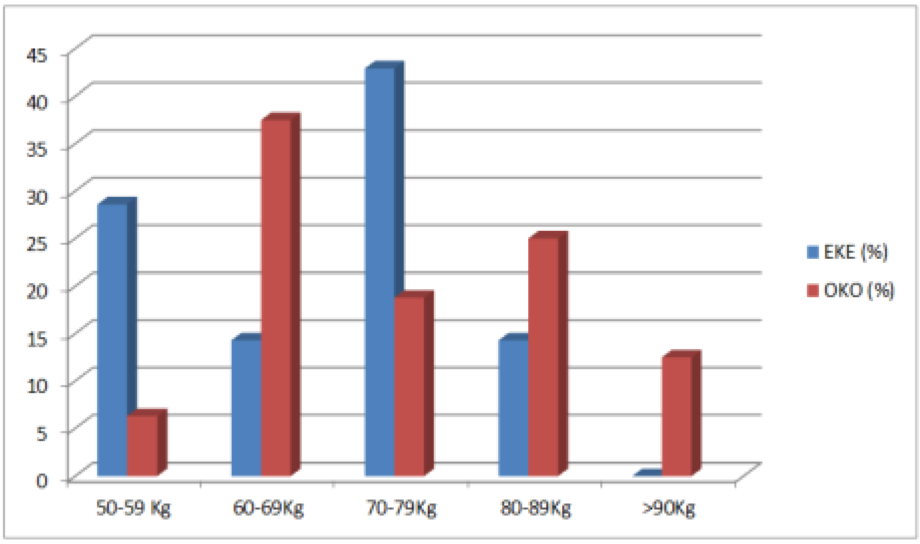

Fig-6: A Graph showing weight distribution among respondents

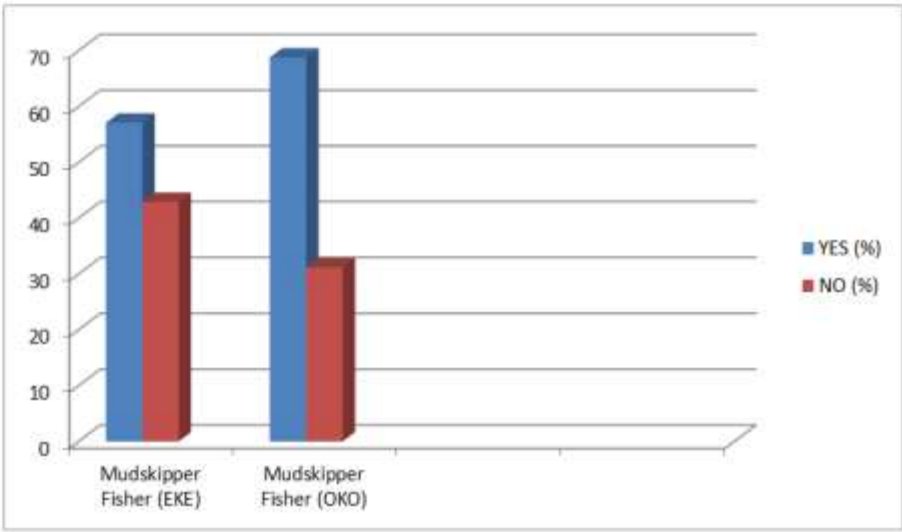

Fig-7: A Graph showing mudskipper/ishila fishers among respondents

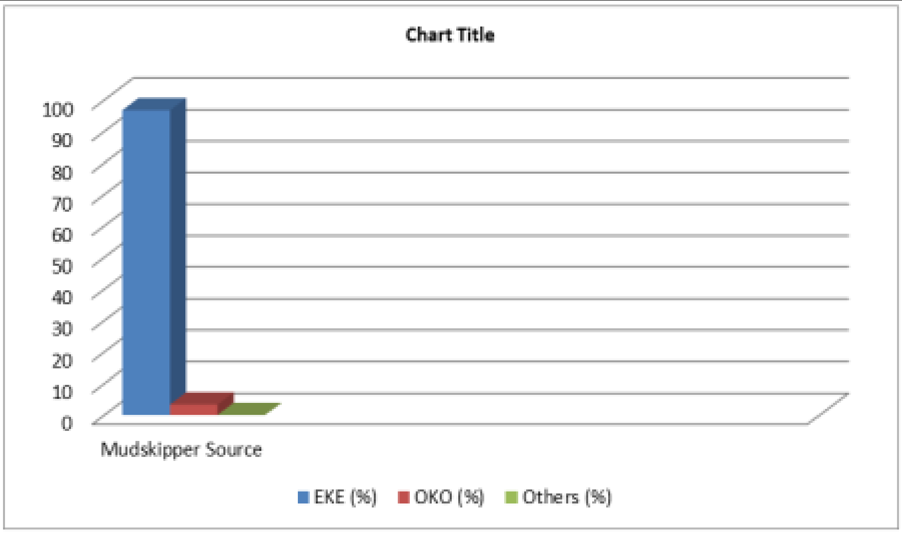

Fig-8: A Graph showing source of mudskipper/ishila among respondents

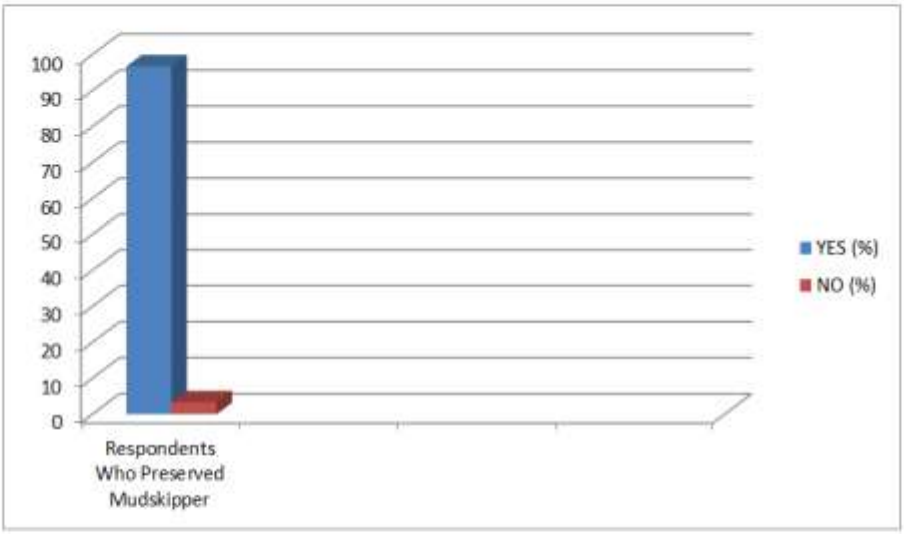

Fig-9: A Graph showing number of respondents who preserved mudskipper before consumption

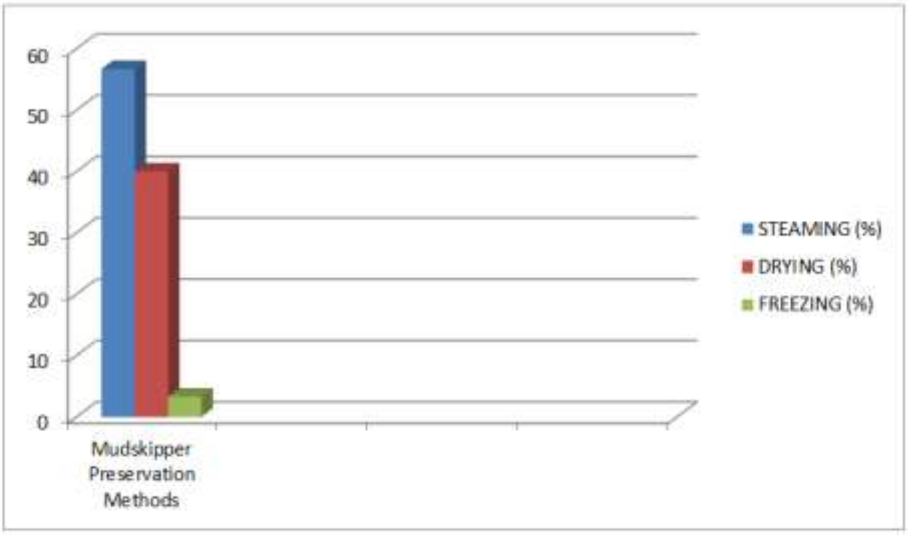

Fig-10: A Graph showing preservation method of mudskipper/ishila among respondents

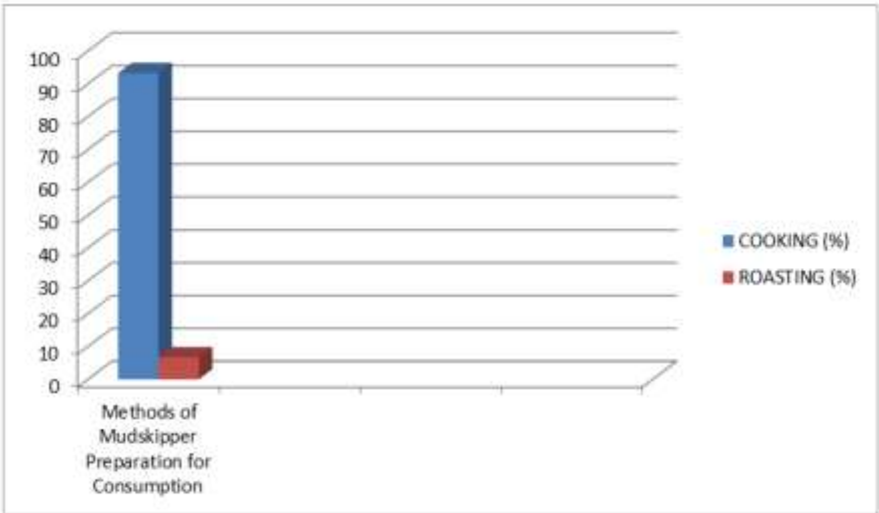

Fig-11: A Graph showing Mudskipper/*Ishila* preparation for consumption among respondents

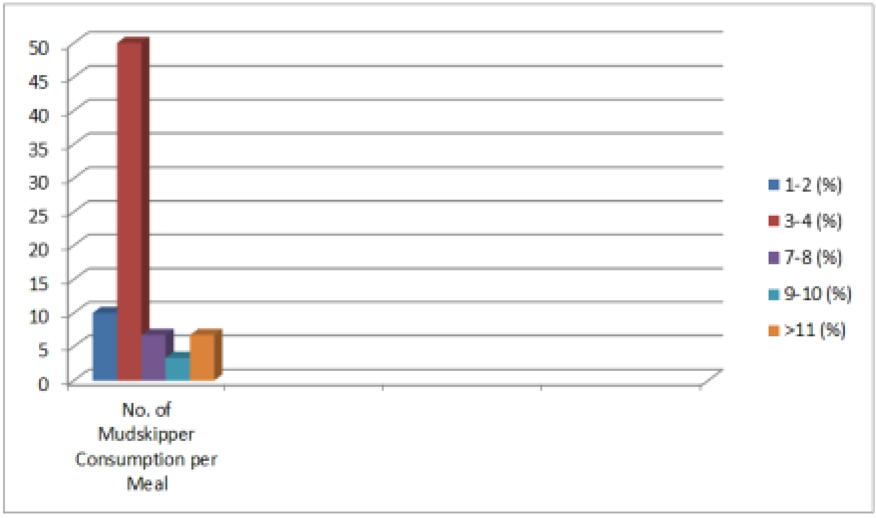

Fig-12: A Graph showing how many Mudskipper/Ishila consumed per meal among respondents

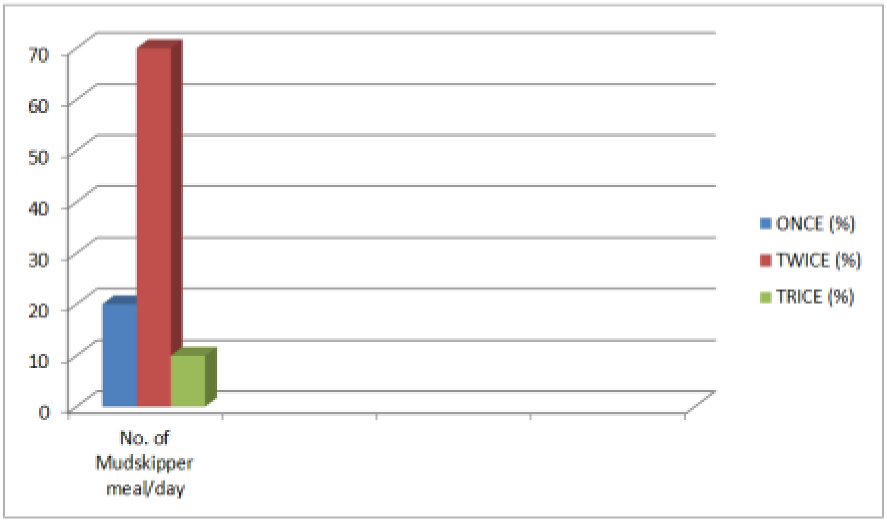

Fig-13: A Graph showing No. of Mudskipper meal consumed per day among respondents

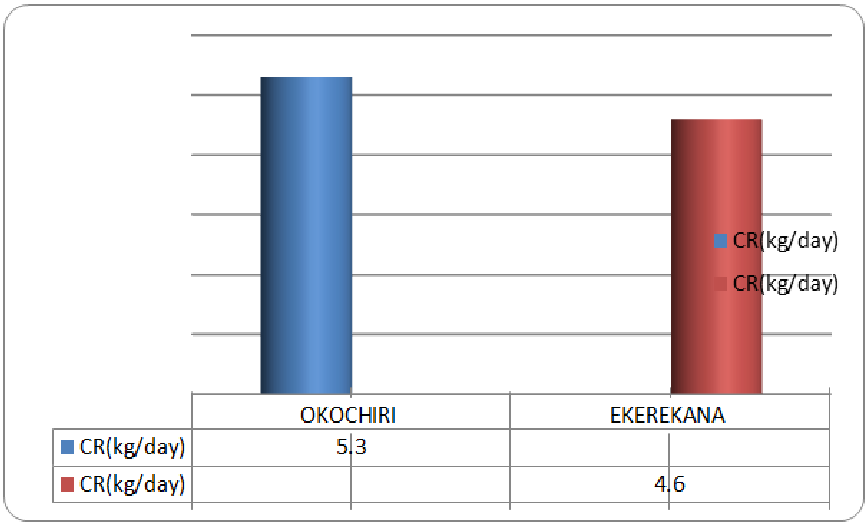

Fig-14: A Graph showing the result of consumption rate (CR) of mudskipper by target population

CDI

The CDI of chemicals present in fish tissue was calculated using the following equation:

CDI = C × CR × EF × ED / BW × AT.

Table-2: Target Chemicals concentration in fish tissues ingested (mg/kg)

S/N	COPC	*concentration in fish (muscle mg/kg)*
1	Hg	0.001
2	Cr	0.001
3	Cd	0.001
4	Pb	5.40
5	Cu	0.99
6	PAH	0.012

Table-3: Shows values used for exposure parameters to calculate chronic daily intake for target populations

Parametrs	Community		Source
	EKE	OKO	
Conc. of target chemicals in fish tissues	See Table	See Table	PS*
Consumption Rate (CR) (Kg)	0.53	0.46	PS**
Exposure Frequency (EF) (Days/Year)	365	365	DV
Exposure Duration (ED) (Years)	70	70	DV*
Average Body Weight (BW) (Kg)	71.5	69	PS
Average Time (AT) (Days: a. Non-carcibogen b. Carcinogen	25,550 (ED x EF)	25,550 (ED x EF)	

PS = present study. DV* (Default value) = Average life expectancy of the general public [14].

Table-4: Showing average CDI of respondents from target population in the study

CDI	OKOCHIRI (kg/mg/day)	EKEREKANA (kg/mg/day)
Hg	$7.4x10^{-5}$	$6.7 x10^{-5}$
Cr	$7.4x10^{-5}$	$6.7 x10^{-5}$
Cd	$7.4x10^{-5}$	$6.7 x10^{-5}$
Pb	$4 x10^{-1}$	$3.6 x10^{-1}$
Cu	$7.3 x10^{-2}$	$6.6 x10^{-2}$
PAH	$8.9 x10^{-4}$	$8 x10^{-4}$

RISK CHARACTERIZATION

Non-carcinogenic and carcinogenic risk estimates are calculated separately because of fundamental differences in their critical toxicity values.

Non-Carcinogenic Risk

The evaluated Hazardous Quotient values for non-carcinogenic chemicals are shown in the graph below.

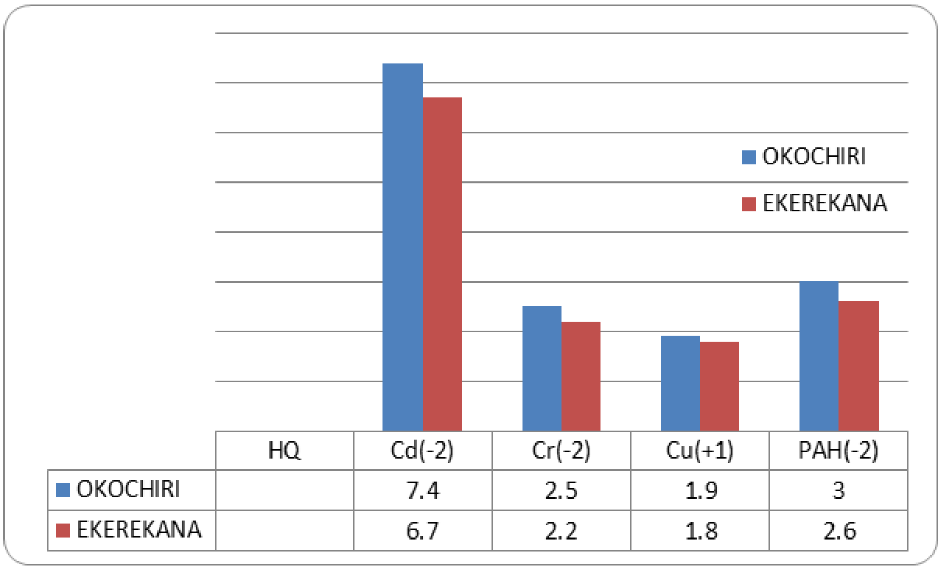

Fig-15: A Graph showing the result HQ of target population

Carcinogenic Risk

Table-5: Showing the carcinogenic risk effect of PAH on target population

CDI	OKOCHIRI	EKEREKANA
PAH	8.9 ε -^{04}	8 ε -^{04}

DISCUSSIONS

EWQI and Sediment Quality

The distribution of contaminants within a reservoir depends on several factors, including reservoir retention time, sedimentation rate, sediment remobilization, food web interactions, and physical and chemical properties of the contaminant [19]. Because retention time is related to flow, we expect the distribution mechanisms of contaminants in creeks to be less than that of rivers and estuaries. In large rivers and estuaries, most contaminants are likely to be transported away from the source rather quickly, while in a creek the distribution of contaminants is likely to be directly related to distance from any source of contaminant. EWQI values for this study were estimated as 10.5 and 57.5 EKE and OKO respectively. Based on CCME, 2001 score ranking, water quality was rated as poor at EKE and marginal at OKO. EKE EWQI result was in accordance with the perception of the community leaders that their creeks may be impacted by the PHRC effluence resulting in low yield in fish harvest. For this reason, all fishing activities were stopped in the creeks within their community by community authorities. Owing to the flow pattern and tidal dilution methods of creeks and rivers, it was not surprising that the EWQI of OKO was better than EKE. This would simply mean that, aquatic organisms, including fishes would be exposed to deleterious condition that would cause their migration to better condition and cleaner environment. This would definitely be one of the reasons why fish yields are said to be poor at EKE part of the creek leaving subsistence fishers from EKE and OKO communities no other choice than to fish at the OKO part of the creek and in bigger rivers far away from their communities.

The concentration of chemicals adsorbed to sediments—generally affects the quality of habitat for sediment-dwelling organisms, which live in contact with the sediments and may ingest sediment particles. Chemicals adsorbed to sediments can also re-enter the water column depending on environmental conditions such as dissolved oxygen concentrations, pH, and temperature. The chemical characteristics of sediment depend on the natural geology of the basin and erosional processes that transport minerals into the waterbody, as well as human activities that cause pollution to enter the river system. Sediments' trace elements of Cd (Cadmium), Cr(Chromium), Cu and PAH measured for both stations were found to be less than CCME [11] guideline levels for aquatic life protection, except for Pb in Okochiri station which was found to be higher (Pb = 36.8mg/g) than the CCME guideline value (Pb = 35.7mg/g). Trace elements in water and sediment tend to bio-accumulate in aquatic organisms. The observed ecological effects point to EKE and OKO creek as the most likely place for significant impacts to the fish community. This can pose a public health risk to those who eat such fishes due to bio-concentration of such hazardous chemicals in their bodies.

Fish Edibility Study

Differences in contaminant concentration among fish species within a system are common [20, 21]. Such differences are primarily a function of the rate of contaminant ingestion or absorption (which is directly related to size, age, and diet) and the assimilation efficiency (which is related to lipid content and various biochemical and physiological interactions). It is known that highest concentrations of exogenous chemicals are usually found in long-lived species, with a large terminal size, a high lipid content, and are either bottom-feeders or top carnivores. Depending on the relationship between contaminant assimilation by fish and food web dynamics, annual variation in productivity could have a significant effect on the availability of contaminants via the food chain. The study fish, mudskipper has all the characteristics to bio-accumulate environmental toxicants because of its versatility in exploiting its aquatic habitat – it is amphibious, has variable diets and is a top carnivore. From the analysis of the fish tissues, Pb and Cu were found to be high (Fig-3): Pb was 5.4mg/kg as against its oral reference dose of 0.01mg/Kg and Cu was 0.99mg/Kg as against its Oral reference dose of 0.037mg/Kg. There is the urgent need to sanction fish consumption advisories on mudskipper fish harvested from EKE and OKO creeks. Fish consumption advisories are common in developed countries like the United States for a variety of aquatic systems and species as a result of a variety of contaminants [22]. From a public resource perspective, the ramifications of environmental contamination include reduced recreational opportunities, reduced angling success due to an impacted fish community, and the loss of a source of food. The identification of precise impacts and causes can be difficult, costly, and time-consuming. Remediation to correct the problem can be even difficult and costly.

Exposure Assessment and Risk Characterization

In this study, the demography and fish consumption status of subsistence fishers show that most respondents were between the age 20-29 year and > 50-59 year. From the FCS the major source of *Periophthalmodon papillo* was from Okochiri. The average body weight of respondents was vital because it was used as the factor in estimation of the fish consumption rate and chronic daily intake (CDI). The non-carcinogenic (HQ) assumes that there is a threshold level of exposure below which is unlikely that sensitive population will experience adverse health effect, that is ,if the exposure exceed the threshold level (HQ > 1), there may be concern for potential non-carcinogenic health effect. From this study all results were less than the exposure threshold (HQ < 1) except for Pb and Cu. Studies investigating oral absorption of copper has found the percentage absorbed ranged from 21-60 percent. Lead poisoning is a type of metal poisoning and a medical condition in humans and other vertebrates caused by increased levels of the heavy metal lead in the body. Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behaviour disorders. Symptoms include abdominal pain, confusion, headache, anemia, irritability, and in severe cases seizures, coma and death. Factors affecting the amount absorbed include the amount of copper in diet and competition with other metals found in food such as iron and zinc. Other sources of absorption are low. The chronic over exposure to copper can damage the human liver and kidney [23]. Further accumulation of copper through the consumption of *Periophthalmodon papillo* by the study population would increase their HQ, and thus their ability to cause more potent deleterious effect to human.

The excess cancer risk estimation in this report is shown in scientific notation format. For example, the PAH risk value for OKOCHIRI and EKEREKANA population are 8.9xE-04 and 8x E-04 respectly. This is means that 8.9 individuals out of ten thousand people from Okochiri might have cancer in their lifetime if mudskipper is consumed at the rate it is presently being consume by subsistent fishers. Also, 8 individuals out of ten thousand people from Ekerekana might have cancer in their lifetime if mudskipper is consumed at the rate it is presently being consumed by subsistence fishers from that community.

When contaminants are identified as harmful to ecological or human health, their production, use, and release is usually reduced or discontinued, resulting in a gradual decline in concentrations in the environment due to biodegradation, biological unavailability, and removal from the system. High rainfall may tend to dilute contaminant concentration resulting in reduced bioaccumulation or flush contaminants from the reservoir, but could also have the opposite effect (i.e., cause an increase in contaminants) as a result of high runoff of both urban and rural land and resuspension of previously deposited contaminants.

CONCLUSION

Owing to the contamination pattern of the study area we suspect that the PHRC effluence is causing most of the ecological impacts identified in this study. There is not yet any indication that human health problems have occurred as a result of contamination of the Ekerekana and Okochiri creeks and as such an epidemiology study is highly recommended.

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CONFLICT OF INTEREST

We write to state that there is no conflict of interest

AUTHORS' CONTRIBUTIONS

We write to state that below is the author's contribution for the Manuscript titled: Ecological And Human Health Risk Assessment (Integrated Risk Assessment): A Case Study of Ekerekana and Okochiri Creeks Using The Mudskipper Fish. 'Author A' (Allison, Theodore Athanasius) designed the study the design, protocol, the write-up and intellectual content and 'Authors B' (Paul, Chikwuogwo Wokpeogu) reviewed the design, protocol, the write-up and managed the literature searches, managed the analyses of the study, wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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