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Gross Anatomical-Base Whole Effluent Chronic Toxicity: A Case Study of Crude Oil Drilling Effluent Impact on The Hepatopancreas of Palaemonetes Africanus.

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Abstract- The Odimodi shoreline, which is used as a effluent discharge point, is close to forcados estuary which is a major commercial fisheries for the shrimps industry in Nigeria. This shoreline is a major source of livelihood for the communities that inhabit its river basin. This study is designed to simulate, in the laboratory, the effect of whole effluent collected from a point source at the Odimodi axis of the Atlantic Ocean, on the bioaccumulation and histological health of Palaemonetes africanus, a resident commercial shrimp, using the effluent receiving water as the dilution solution. The experiment was setup as a 90 days whole effluent sub-chronic toxicity study. Six (6) of twenty litres (20l) capacity plastic tanks with open top were used. 5 tanks, of 25 fish per tank, were treated with 10 litres of graded whole effluent stock solution concentrations of 6.25%, 12.5%, 25%, 50% and 100%. while one (1) tank was untreated and used as a control chamber. Effluents was sample from a point discharge source and evaluated for their physico-chemical parameters, while the shrimp was sampled from African Regional Aquaculture Centre (ARAC) and used in the evaluation of muscle tissue bioaccumulation and hepatopancreatic exposure effect. Effluent analytical result showed that conductivity (2,370) , Total dissolved solids (TDS-1,302), turbidity (16), iron (Fe – 0.709), phosphate (0.44) and zinc (Zn- 0.006) failed to meet the effluent maximum allowable toxicant concentrations (MATC) guidelines selected for the study. Bioaccumulation analysis showed that the chemical parameters all fell with the permissible guideline range except for Zn and Fe. These elements where also found to be above the effluent MATC levels, indicating that Palaemonetes africanus is an environmentally proven biomarkers for bioaccumulation studies and sentinel organism for environmental bio-monitoring. Histological alterations include Sloughing of hepatopancreatic cells, haemorrhage (arrow), structural distortion of tubules, enlargement of hepatopancreatic nuclei; and loss of B, R and F cells. Its consistent with other study implicates Zn toxicity as the cause of the observed histological alterations. This study has shown that the petrochemical effluent discharge is toxic to the aquatic ecosystem of the receiving water and can affect commercial fisheries of shrimp.

Indexed Terms- Histology; Petrochemical effluents; Bio-monitoring; Biomarker; Bioaccumulation; Shrimp.

I. INTRODUCTION

Odimodi is a geographical area in the south-south part of Nigeria, and it is located in Burutu local government area of Delta State. The community is bordering the Bight of Bonny shoreline at the Gulf of Guinea of the Atlantic Ocean. It is bordered by two major estuaries; the Ramos estuary on the east and the Escravos estuary on the west. The odimodi people are majorly fishers, and these estuaries are major sources of artisanal fisheries.

The artisanal fisheries in Odimodi are divided into brackish water fisheries and coastal inshore fisheries. The brackishwater fisheries consist of estuaries, beach ridges, intertidal mangrove swamps, intersecting rivers and numerous winding saline creeks. Fishing operations in the brackiswater area are conducted from small dugout canoes. The coastal inshore artisanal fishery is mainly confined in waters of less than 40 m depth. This fishery employs large motorized "Ghana-type" canoes which are more durable on the surf-beaten coast shoreline

The Nigerian multispecies demersal stocks are exploited with a wide variety of artisanal gears: set gillnets, beach seines, large meshed shark drift nets, hooks on longline/handlines and various traps. The demersal target species exploited by artisanal fishing units are: croakers (*Pseudotolithus*), threadfins (*Galeoides*, *Pentanemus* and *Polydactylus*), soles (*Cynoglossidae*), marine catfish (*Arius*), brackishwater catfish (*Chrisichthys*), snapper (*Lutjanus*), grunters (*Pomadasyidae*), groupers (*Epinephelus*), and the estuarine white shrimp (*Palaemon*) (FAO, 1986)

Odimodi is one of the communities in the Niger Delta that is host to multinational oil corporations, which includes Shell Petroleum Development Company (SPDC), Nigerian Agip Oil Company (NAOC) Beniboye cooked wells and other subsidiary drilling companies. The land and rivers around the community has a reticulation of crude oil pipelines, prominent of which is the SPDC trans Ramos trunk pipeline. A line that is used for transport of crude oil to the Forcados export terminal, just some few kilometers away, along the same shoreline. In 2018, this line had system failure that caused a major spill which negatively impacted Odimodi and other contiguous communities along the Ramos estuary in Delta and Bayelsa State (NOSDRA, 2019).

Odimodi is also a host to a SPDC's petrochemical waste disposal pipeline. A pipeline that has been in the community for over five decades, and has been alleged to have in several occasions leaked its content to the environment. The pipeline terminates at the coastal shores, where it discharges into the shallow waters of the Odimodi axis of the Atlantic Ocean. There is palpable fear by the community that the effluent discharge from these pipelines might be negatively affecting the brackishwater and inland shore fisheries by reducing fish yield and other public health concern.

Plate 1: Picture showing shell oil drilling waste pipeline discharging effluent into the Atlantic ocean off the shores of Odimodi

The Nigeria Shell Petroleum Development Company (SPDC) is one of the largest fossil fuel producing company in Nigeria, in their operations, they control 6,500 kilometres (4,300 mi) of pipelines with the flowlines, about 80-89 flowstations, 8 natural gas plants and more than 1,500 producing wells. The company's operations are concentrated mainly in the Niger Delta regions and in conjunction with some shallow offshore areas where they operate in an oil mining lease area of around 30,000 square kilometres (SPDC, 2012).

Considering the water in the Odimodi river that receive effluents directly from the refinery industry waste products, has become a major problem both at local and global scale. Therefore, shrimps and fishes of other kinds have been extensively used for various tests, because its containment can be a useful strategy for monitoring of toxic agents in the aquatic environment (Adams et al. 1969; Adams, 1990; Cairns et al. 1993) Also between the natural and anthropogenic discharge of effluent (human factor) constitutes the primary pollutant (USEPA, 2002; Vosylienë, 2007)

Crude oil waste is used drilling mud and cuttings generated by the drilling of oil and gas wells or related injection wells that are permitted by the equivalent permitting authority in the state in which the well is located (USEPA, 2016). It is associated with the exploration, development, or production of crude oil, natural gas, or geothermal energy; "drilling waste" includes drilling muds, cuttings, hydrocarbons, brine, acid, sand, and emulsions or mixtures of fluids (USEPA, 2016). Crude oil drilling waste is a waste derived intrinsically from primary field operations, produced from a well, and removed at the drill site or removed at a crude oil production facility by crude oil or wastewater treatment process before custody transfer of the crude oil; "drilling waste" does not include spent solvents and oils from equipment maintenance activities, discarded chemical products, or fuels (USEPA, 2011).

Whole effluent toxicity is the total aggregate toxic effect to aquatic lives coming from all pollutants contained in a facility's effluent. In the whole effluent toxicity tests, organisms are exposed to different kinds of effluent concentrations for a specific period of time in order to estimate the effluent's toxicity. Receiving water (the water which the effluent is discharged into) is used as dilution water in whole effluent toxicity tests in order to stimulate what actually happens in the aquatic environment when effluent is introduced.

Measuring only physical and chemical water quality cannot provide the sole assessment of the health of an aquatic system (Ten Brink & Woudstra, 1991). Histological monitoring (a biomarker of effect) allows for a greater sensitivity as effects will be seen in a smaller dosage in comparison to that of toxicological endpoints like behavioral changes or death (Wester et al; 2002). Furthermore, alterations can be assessed in animals that are too small to dissect for biochemical purposes and it allows the sex and reproductive status of animals to be determined. Histopathology does not depend solely upon qualitative light microscope observations at tissue level as newer technologies allow cellular and molecular analyses (Hinton and Lauren, 1990; Wester et al, 2002). Histopathology may also reconstruct possible etiologies for the lesions found (Hinton and Lauren, 1990; Allison and Paul, 2018).

Shrimp respond to various insults in ways very similar to mammals. Therefore, shrimp histopathology utilize knowledge gained over many years in human and veterinary pathology. Histopathologic changes observed in infectious and non-infectious shrimp diseases have also been documented in a number of sources (Ribeln and Migaki 1975; Kubota et al, 1982; Ellis 1985; Ferguson 1989; Roberts 1989; Sinderman 1990). It has been recognized for many years that shrimp respond to toxicant exposure, sometimes in fairly specific ways (Braunbeck 1994), but often the same response is elicited by a variety of chemicals or chemical mixtures. There have been a number of excellent receives directed toward evaluation of histological changes as biomarkers of contaminant exposure (Hendricks et al 1985; Hinton et al. 1992; Hinton 1993; Allison and Paul, 2014; Allison and Ogoun, 2024).

Shrimp health studies deal with causes, processes and effects of diseases; and can form a complementary indication of overall ecosystem health. The current study can be categorized as a bio-assessment in conjunction with bioaccumulation and shrimp health studies.

II. MATERIALS AND METHOD

Study type

This study was a chronic whole Effluent toxicity testing using the gross anatomical features of *Palaemonetes africanus* as the biomarker. This test was carried out for a period of 90 days (USEPA, 2002).

STUDY SPECIE

Shrimp are swimming crustaceans with long narrow muscular abdomens and long antennae. They have well developed pleopods (swimmerets) and slender walking legs; they are more adapted for swimming than walking.

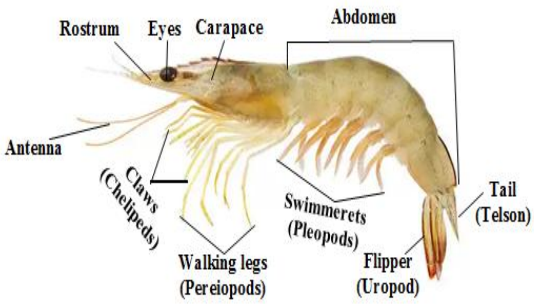

Plate. 3.10: An image showing shrimp surface anatomy

The laterally-compressed shrimp body is grossly divided into an anterior cephalothorax and a posterior abdomen. The cephalothorax includes the head as well as eight thoracic somites. This section includes the animal's sensory and masticatory apparatus and houses most of its organs. The abdomen is made up of six segments and contains most of the musculature. The shrimp bears 19 pairs of appendages as well as one pair of eyestalks. The appendages each consist of a basal protoiodide, a lateral exopodite, and a medial endopodite. Variations on this basic structure have allowed the shrimp to adapt different appendages for specific purposes such as propulsion, manipulation, and mastication.

Hepatopancreatic Organ:
This is an organ of the digestive tract. It provides the functions which in mammals are provided separately by the liver and pancreas including the production of digestive enzymes and absorption of digested food. It is a gland that ends in ducts that open into the stomach.

The hepatopancreas is an important organ for the absorption and storage of nutrients. It is a complex midgut diverticulum and acts as primary digestive organ of shrimps. It has the dual role of secreting digestive enzymes and absorbing nutrients. It is also considered a major organ for shrimp for other functions.

- The hepatopancreas is comprised of four types of epithelial cells and each plays a different role in hepatopancreas function.
- E – Cells found at the distal tips of each tubule with proximal nuclei and conspicuous nuclear bodies give rise to the other three cell types of the digestive gland.
- R – Cells multi-vacuolated cells occur throughout the hepatopancreas and have absorptive and lipid and glycogen storage functions. They also have community sequester mineral deposits such as calcium, magnesium, phosphorus, sulfur and others.
- B – Cells large, primary secretor cells, are the primary producers of digestive enzymes in the hepatopancreas and are responsible for nutrients accumulation, intracellular digestive, transport of digested material.
- F – Cells are responsible for protein synthesis and storage of minerals.

Sampling
Effluent: The study effluent was sampled from a crude oil drilling company's effluent discharge point at the Odimodi axis of the shallow water shoreline of the Atlantic Ocean. The sample effluents was collected in a black 5 litres container which were clean and rinsed with the sample effluents prior to sampling and stored in a cooler of ice to avoid entropy. This effluent was transported under room temperature to the Environmental Histology Laboratory, anatomy Department, University of Port Harcourt. In the laboratory a portion of the sample effluent was taken for analysis.

Diluting Water: Dilution water for the formation of the stock solutions of graded effluent concentrations needed for the test was collected from the of location the effluent receiving water body immediately upstream of the discharged zone (USEPA, 2002).

Fish: The study fish was harvested from African Regional Aqua-culture Centre (ARAC), located at Buguma in Asari Toru Local Government Area of Rivers State. ARAC was chosen for this study because it is an internationally recognized aquaculture Centre with good control of its fish containment water quality.

Experimental Design
Experiment Set-up Area: The study was carried out in the Environmental Histology Laboratory of the Department of Anatomy, Faculty of Basic Medical Science of University of Port Harcourt, Nigeria.

Stock Solution: The stock solution for the test was prepared by diluting the effluent with graded volumes of receiving water to form the following stock concentrations of the effluent: 6.25% (1L dilution water added 62.5 ml of Effluent), 12.5%, 25%, 50% and 100%.

Tanks	Effluent Conc. Administered
Control	0%
1	6.25%
2	12.5%
3	25%
4	50%
5	100%

Table 1: Effluent concentrations administered per tank

Test Chamber: Six (6) of twenty litres (20l) capacity plastic tanks with open top were used. 5 tanks were treated with 10 litres of graded whole effluent stock solution concentrations of 6.25%, 12.5%, 25%, 50% and 100%. while one (1) tank was untreated and used as a control chamber. Since receiving water was used for test dilution, an additional control was set-up which was made up of standard laboratory water (0% effluent). This control will be used to verify the health of the test organisms (USEPA, 2002).

Fish Stock: Each tank was stocked with 25 shrimps. Done according to USEPA (2002) guideline. Twenty five (25) juveniles of the test shrimp were introduction into each of the test chambers and acclimatized for a period of two (2) weeks before the commencement of the experiment.

Exposure System: A static renewal system was used, in which, the test organisms were exposed to a fresh solution of the same concentration of sample every 24 hours, either by transferring the test organisms from one test chamber to another, or by replacing all or a portion of solution in the test chamber.(USEPA, 2002).

Evaluations

Effluent Analysis: A portion of the sampled effluent was analyzed for their physio-chemical characteristics. The results were compared against waste water quality standards, in regulations and guidelines to evaluate treatment system performance in order to verify compliance with specific discharge limits.

Bioaccumulation:

Estimation of chemicals from the excised muscle of the the study shrimp was carried out by following tissue digestion methodology. Tissue samples were thawed, rinsed in distilled water, and blotted with blotting paper. After blotting, the samples were transferred to 100 ml volumetric flasks. The entire flask was washed properly and rinsed with distilled water, before transferring the tissue samples. Then, the known weights of each tissue were transferred to these volumetric flasks. Samples digestion was carried out according to the methods presented in (Du Preez and Steyn, 1992; Van Loon, 2012;). A slight modification was made in the procedure (Yousafzai and Shakoori, 2006) instead of putting 10 ml nitric acid (60%) and 5 ml per chloric acid (70%) at the time of digestion, 5 ml nitric acid (60%) and 1 ml per chloric acid (70%) were added to each flask and the flasks were then kept overnight. The next day, a second dose of 5 ml nitric acid (60%) and 4 ml per chloric acid (70%) was added to each flask. The flasks were kept on a hot plate, covered with Pyrex glass cover, and allowed to digest at 200 to 250°C until a clear transparent solution was observed. Initially, dark brown fumes appeared followed by white fumes. The dense white fumes from the flask, after brown fumes, were an intimation of completion of the digestion process. By this method, digestion was accomplished in about 30 minutes instead of 3 to 4 hours as described in (Lillie, 1944). After digestion, the samples were cooled, filtered through Whatman 42 filter paper and diluted to 100 ml with distilled water by proper rinsing of the digestion beakers. Samples were stored in properly washed glass bottles until the metal concentration determination. Determination of heavy metals was carried out through an atomic absorption spectrophotometer (AAS).

Histological Assessment: Harvested shrimp kidney were preserved in 10% buffered formalin solution and taken to the laboratory for histological tissue preparation (Allison and Paul, 2014; Allison and Ogoun, 2024). Light microscopy (Olympus BH2) was used to identify and interpret tissue slides and micrograph specimens at 40X, X100 and X400 magnification. The percentage prevalence of tissue histopathology from various target organs of the different sites were observed and compared with the contr

III. RESULT

Table 2: Physical Parameters of Effluent

Parameter	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	National standard	International standard	Remark
PH	5.36	5.37	5.37	5.40	5.45	6 -9	6 -9	Good
Temperature (C^0)	26.6	26.3	26.2	26.3	26.2	≤ 35©	≤ 35©	Good
Salinity (mg/l)	0.48	0.46	0.41	0.23	0.09	2000	2000	Good

Table 3: Chemical constituents of Effluent

S/N	Parameter(s)	Concentration	National standard (NESREA)	International standard (USEPA)	Remarks
1	PH	6.15	6 – 9	6-9	Good
2	Electrical conductivity (µs/cm)	2,370	≤ 1000	≤ 1500	Bad
3	Total Dissolved Solids, TDS (mg/l)	1,302	1000	10	Bad
4	Salinity (mg/l)	1,180	≤ 2000	≤ 2000	Good
5	Total suspended solids (TSS) (mg/l)	6.9	25	50	Good
6	Turbidity (NTU) (mg/l)	16	5.0	75	Fair
7	Alkalinity (mg/l)	6	≤ 100	8	Good
8	Sulphate (mg/l)	67	≤ 200	250	Good
9	Nitrate(mg/l)	0.08	10	45	Good
10	Phosphate (mg/l)	0.44	1.0	0.1	Poor
11	Polycyclic Aromatic Hydrocarbon, PAH (mg/l)	<0.001	0.001	1.5	Good
12	Barium,Ba (mg/l)	<0.01	5	2.0	Good
13	Chromium, Cr (mg/l)	<0.001	1.0	0.3	Good
14	Cadmium, Cd (mg/l)	<0.001	1.0	≤0.01	Good
15	Nickel, Ni (mg/l)	<0.001	<1	0.5	Good
16	Lead, Pb (mg/l)	<0.001	<0.05	≤0.11	Good
17	Zinc, Zn (mg/l)	0.006	2	≤0.001	Poor
18	Mercury, Hg (mg/l)	<0.001	0.05	≤0.02	Good
19	Iron, Fe (mg/l)	0.709	≤ 0.3	≤0.1	Bad
20	Copper, Cu (mg/l)	<0.001	1	5	Good
21	Manganese, Mn (mg/l)	<0.001	5	0.2	Good
22	Vanadium, V (mg/l)	<0.001	4.3	1	Good

Bioaccumulation Status.

Table 4: Result of the bioaccumulation status from the shrimp's muscle after analysis.

PARAMETERS	TANK 1	TANK 2	TANK 3	TANK 4	TANK 5	GUIDELINES INTERNATIONAL USEPA 2002
Barium Ba	<0.001	<0.001	<0.001	<0.001	<0.001	-
Chromium Cr	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Cadium Cd	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Nickel Ni	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Lead Pb	<0.001	<0.001	<0.001	<0.001	<0.001	0.11
Zinc Zn	0.006	0.002	0.002	0.03	0.3	5.0
Mercury Hg	<0.001	<0.001	<0.001	<0.001	<0.001	0.02
Iron Fe	0.009	0.018	0.020	0.022	0.23	0.5
Copper Cu	<0.001	<0.001	<0.001	<0.001	<0.001	2.25
Manganese Mn	<0.001	<0.001	<0.001	<0.001	<0.001	0.02
Vanadium Va	<0.001	<0.001	<0.001	<0.001	<0.001	-
pAH	<0.001	<0.001	<0.001	<0.001	<0.001	0.001

Table 5: Showing statistical analysis for bioaccumulation profile in the shrimps.

Variables	Tank 1 MeanSD	Tank 2 MeanSD	Tank 3 MeanSD	Tank 4 MeanSD	Tank 5 MeanSD	Control MeanSD	Guidelines USEPA
Barium	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.001
Chromium	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.07
Cadmium	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.01
Nickel	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.07
Lead	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.05
Zinc	0.010.00	0.0020.00	0.020.00	0.030.00	0.0010.03	0.0010.00	0.001
Mercury	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.001
Iron	0.0090.00	0.0180.00	0.020.00	0.220.00	0.230.00	0.0010.00	0.5
Copper	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	1.5
Manganese	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.001
Vanadium	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.001
PAH	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.0010.00	0.001

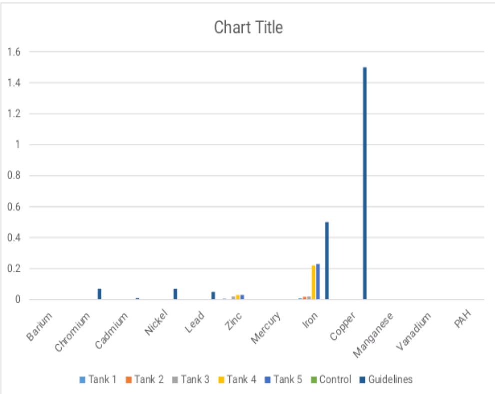

Fig. 1: Graph of the of the shrimp's bioaccumulation profile

Histological Effect of Effluent Exposure Qualitative analysis.

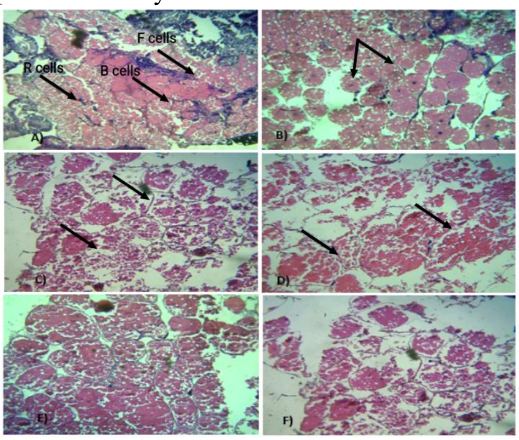

Plate 2: Photomicrograph (H&E x400) of the Hepatopancreas A) Control Control showing the B, R and F cells of the hepatopancreas, B) Tank 1 (6.25% effluent): : Sloughing of hepatopancreatic cells (arrows), C) Tank 2 (12.5% effluent): : hemorrhage (arrow), D) Tank 3 (25% effluent): : structural distortion of hepatopancreatic tubules, E) Tank 4 (50% effluent): enlargement of Hepatopancreatic nuclei, F) Tank 5 (100% effluent): loss of B, R and F cells.

Table 4.6 Percentage prevalence of hepatopancreas histopathology of shrimps exposed to crude oil whole effluent.

Hepatopancrease alterations	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Control tank
Sloughing of Hepatopancreatic cells	8	1	2	12	12	0
Hemorrhage	1	9	0	0	0	0
Structural distortion of tubules	1	0	8	2	1	0
Enlargement of Hepatopan	1	2	2	6	0	0

creatic nuclei						
Loss of B, F and R cells	0	1	2	1	10	0
Average % prevalence	1.63	2.24	2.56	3.04	5.3	0.00

Table 6: Sample t test comparing the mean organ index of Hepatopancrease of the shrimp from different tanks exposed to crude oil whole effluent.

Parameter	Tanks	Mean index (I_{org})	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
	Control	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.00
	Tank 1	1.62	0.79	0.9	-0.83	2.41	1.52	24	0.100
	Tank 2	2.22	1.09	0.9	-1.13	2.31	1.51	24	1.320
Hepatopancrease	Tank 3	2.54	1.25	1.0	-0.71	3.79	2.79	24	1.130
	Tank 4	3.04	1.50	1.9	-1.54	4.54	2.64	24	1.220
	Tank 5	5.20	2.58	0.8	0.38	7.78	6.68	24	1.620

IV. DISCUSSION

The physico-chemical analysis of effluent showed that electrical conductivity (EC) total dissolved solids (TDS), turbidity, Fe, Zn, and phosphate did not meet the effluent MATC guideline limits.

- EC and TDS are positively related to each other in terms of indicating the mineralization of a sample. Charged ions of TDS contribute to the EC in the aqueous relationship. Therefore, it is generally a common variable to easily measure for the estimation of the TDS (Gustafson and Behrman, 1939). Elevated EC causes toxicity by impairing the osmo-regilatory ability of shrimp. This ecological stress negatively affects survival of fish eggs, teratogenic deformities and growths reduction in the adults (Gustafson and Behrman, 1939).
- Fe exceeded the MATC effluent standards. Although, Fe is an essential element for many physiological functions of most organisms (Aisen et al., 2001), however, its presence in excess causes toxicity to the cells. It catalyzes the Fenton reaction (Fenton, 1894), resulting into generation of free radical species, including hydroxyl that can potentially cause cellular oxidative damage such as lipid peroxidation, oxidation of proteins and histological alternations (Bagnyukova et al., 2006, Bresgen and Eckl, 2015,, Papanikolaou and Pantopoulos, 2005, Tarifeno-Saldivia et al., 2018).
- Zn concentration exceeded the international guideline, although it fell within NESREA standard. Zn is an essential micro-mineral for shrimps and is closely related to many biochemical processes including normal growth, metabolic and immune function, gene regulation, and reproduction but when it is found in excess it becomes harmful to aquatic life (Watanabe et al., 1997). Zhu et al., (2022) reported that Zn has a gross morphological and transcriptional effects on *Paleamontes afafrican.*
- Phosphate is an essential nutrient for living organisms. It has the potential to cause increased algal growth leading to eutrophication in the aquatic environment (Otokunefor and Obiukwu, 2005). From the result, it was observed that the concentration of phosphate fell within the

NESREA standard and exceeded the USEPA standard.

Bioaccumulation analysis in the study shrimp showed that the chemical parameters all fell with the permissible guideline range except for Zn and Fe. These elements where also found to be above the effluent MATC levels, indicating that *Palaemonetes africanus* is an environmentally proven biomarkers for bioaccumulation studies and sentinel organism for environmental bio-monitoring. Furthermore, Zn and Fe can therefore be implicated in any histological alterations findings in the shrimp.

Histological findings in the hepatopancreas of the study shrimp includes Sloughing of hepatopancreatic cells, haemorrhage (arrow), structural distortion of tubules, enlargement of hepatopancreatic nuclei; and loss of B, R and F cells. Findings in this study was consistent with Tran et al. (2013) where it was observed that the sloughing of Hepatopancreatic cells, was as a result of bioccumulation of toxicant in the hepatopancreas. It further stated that heavy metals such as iron, copper, Mercury, zinc and lead, which accumulated in shrimps beyond permissible levels led to other histological alterations like the shedding off of cells within the hepatopancreas (Tran et al., 2013.). This has further implicated the bio-accumulated elements (Zn and Fe) in the muscle tissues of the study shrimp as the likely cause of the observed histopathological lesions.

CONCLUSION

This study has shown that the petrochemical effluent discharged at the Odimodi axis of the shallow water shoreline of the Atlantic Ocean contained hazardous contaminates that are above the permissible levels for effluent discharge. It has further proven *Palaemonetes africanus as a* reliable biomarkers for bio-accumulation and environmental bio-monitoring studies. The effluent is further known to be toxic to aquatic organism, and has the potential of causing low yield of the estuary commercial shrimp fisheries around the receiving water bodies. Findings in this study therefore underscoring the need for frequent regulatory audit of waste treatment facility of produced wastewater disposing companies.

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