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(Research Article)

Plankton composition and heavy metal concentrations in fish from Bundu-Ama Creek, Port Harcourt, Rivers State

Oriakpono Obemeata Emmanuel * and Gabriel Victory Ima-Owaji

Department of Animal and Environmental Biology, Faculty of Science, University of Port Harcourt, P. M. B. 5323, Port Harcourt, Rivers State, Nigeria.

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Abstract

This study examines plankton composition and diversity as well as the heavy metal concentrations in fish from Bundu-ama creek, rivers State, Nigeria. The heavy metals tested were Nickel (Ni), copper (Cu), chromium (Cr), Zinc (Zn), Cadmium (Cd), using Atomic Absorption Spectrophotometer. The results for the heavy metals are as follows; Ni was below detectable limit throughout the points in the first month, while in the second month and third month it ranged from (0.038±0.046mg/kg to 0.0213±0.037mg/kg), Cr ranged from (0.029±0.006mg/kg to 0.409±0.0386mg/kg), Cu ranged from (2.116±0.773mg/kg to 3.467±0.248mg/kg), Zn ranged from (3.393±0.280mg/kg to 2.75±0.844mg/kg) and Cd was below detectable limit. The highest phytoplankton species identified belongs to the family Bacillariophyta, while the highest zooplankton species identified belongs to the family Copepoda. Heavy metals were above WHO limits indicating that the creek is polluted due to anthropogenic activities in the area and consumption of the fishes may be considered unsafe.

Keywords: Plankton composition; Heavy metal 2; Fish 4; Bundu-Ama 5; WHO Limits

1. Introduction

The increased in the use of heavy metals over the past few decades have tremendously and inevitably resulted in an increased influx of metallic substances in the aquatic environment [1]. This consequently results in the contamination of the animals that are living in contaminated waters with high metal concentrations [2, 3, 4, 5 & 6]. The metals are of special concern because of their diversified effects and the range of concentration stimulated toxic effects to the aquatic organisms. Industrial waste constitutes the major source of metal pollution in natural water. Aquatic systems are exposed to effluent discharged from industries, sewage treatment plants and drainage from urban and agricultural sites (areas). These pollutants are capable of causing serious damages to the aquatic life [7 & 8] and can result in the imbalance in the composition of planktons. The imbalance in the population and distribution of planktons as a result of anthropogenic activities such as the ones mentioned above could result in the damage to the fishery resources that is dependent on them. As any factor that influences plankton composition directly affects the plankton feeders such as the commercial fishes [9]. Generally, Phytoplanktons and zooplanktons are microorganisms that are located at the first and second lower tropic levels [10,11] and the health of the aquatic environment depends on the plankton colony because the planktons are vital in the food chain, as the Phytoplanktons form the basis of the aquatic food web as primary producers, and are capable of using the sun's energy to transform air into sugars therefore providing a rich supply of food for the zooplanktons and other aquatic creatures such as fishes which are also eaten by other animals and mammals [12]. These discharges especially those from the industries contains heavy metals which are inorganic

* Corresponding author: Oriakpono Obemeata Emmanuel
Department of Animal and Environmental Biology, Faculty of Science, University of Port Harcourt, P. M. B. 5323, Port Harcourt, Rivers State, Nigeria.

chemicals that are non-biodegradable and they tend to accumulate over time as they cannot be metabolized by the body and converted into a form that is harmless, and as such has made it important to determine the heavy metal concentration in edible sea foods in order to evaluate the components of these heavy metals on human health. [13]. Fish and mussels constitute a major part of the human diet and many studies have been conducted on the accumulation of metals in different fish species [14,15,16,17,18,19 & 20].

Fishes are well known bio-indicators of heavy metals contamination in aquatic ecosystems because they are higher tropic level organisms and are usually eaten by man, there organs and tissues such as liver, kidney, muscle, viscera and whole organisms are analysed to assess the concentration of the metals [21,22,23]. Large amounts of these metals may accumulate in the soft and hard tissues of fish [24]. In aquatic environment, the availability of a metal to organisms is dependent on many physico-chemical in addition to biological factors [25,26 & 27]. However, heavy metals are known to enter fish through a number of routes such as; the gills, skin, liver and once absorbed, are transported into the blood stream to either a storage point or to the liver for biotransformation and/or storage [28,29]. According to [30], heavy metals are not destroyed in humans who have indirectly consumed them but instead tend to accumulate in the body tissues such as; the liver, muscles and bones and thus threaten the health status. Heavy metals are non-biodegradable and possess the ability to accumulate in the tissues of plants and animals through the food chain, so that when humans feed on these plants and animals the heavy metal trace are transferred to the muscles which results in various diseases depending on the metal involved [31,32,33 & 34]. This research will provide detailed information on the levels of these heavy metals (chromium, copper, nickel, lead and iron) in fish and sustainability of the fish population via the assessment of the plankton composition and distribution in Bundu-ama creek.

2. Material and methods

2.1. Study Area

Bundu-ama is a heavily populated community and is also one of the known shanties in port-harcourt. It is enclosed by a network of creeks dissecting its landmass and all linked creeks are connected to the Bonny River which is the largest river in the area with an average width of 0.5km [35]. The community experiences the injection of large quantities of effluents due to the activities on one hand and improper domestic waste management that creates a poor sanitary condition. The weather climate of the region shows that the mean annual temperature is 28°C with an annual range of 3.8 °C, while humidity is 85% [36]. Three sample stations were established along the creek, after a reconnaissance visit to the areas.

2.2. Sampling Stations

Station 1 is located upstream with latitude N04o45.007" and longitude E007o01.037". It has good vegetation of mangroves. Station 2 is located midstream with latitude N04o44.711" and longitude E007o01.393. Point 2 also has vegetation with dead roots of mangrove and the surface of the water filled with oil film. Station 3 is located downstream with latitude N04o44.724" and longitude E007o01.403". The station has an island with plastic waste disposal and faecal discharges as well as illegal bunkering discharges.

2.3. Samples and Sampling Techniques

For the collection of both phytoplankton and zooplankton, water samples were collected at every station. For the phytoplankton, surface water was collected using the plankton net which had a bottle underneath and was transferred to the labelled sample collecting bottle. While for that of the zooplankton, water samples were collected just under the surface of the water with another sample labelled bottle and immediately fixed with 4% formalin for identification.

2.4. Fish

Fishes were collected by the local fishermen, and stored in a cooler pack stuffed with ice blocks in other to maintain freshness and later transported to the laboratory. Samples were collected once every second week of ever**y** month for three months.

2.5. Analysis/ Microscopy for Plankton

Plankton samples were collected with the help of a plankton net (mesh size: 20 µm) through vertical hauls from the upper layer of 10 cm. Filtered plankton samples were kept in sampling bottles and immediately fixed with 10% formalin. In the laboratory, Samples for the extraction of plankton comprised of a uniform volume of 100 ml using distilled water. Following a thorough agitation and homogenization, 1 ml subsamples were taken using a Stempel

Pipette and transferred to a graded 1 ml counting chamber for observation under a binocular microscope with magnification of 40x. The organisms were simultaneously identified using the specialized literature for each taxonomic group (key) and enumerated.

2.6. Heavy Metal Preparation and Digestion of Fish Samples

The fish samples were ashed in a furnace at about 450 °C and allowed to cool in a dissicator after which they were ground to fine homogenous powder. 3 g of sample was weighed into a 100ml beaker in a calibrated weighing balance. 10ml of Aqua Regia was added to the sample in a fume hood. The sample was then placed in a hot plate and heated till digestion was completed. The beaker was rinsed with distilled water and the digest was filtered into 50ml standard flask. The beaker was filled up to the 50ml mark with distilled water. 3-point calibration was prepared for each metal, which was used to calibrate the Atomic Absorption Spectrophotometer (AAS). The absorbance of the standards and the sample were measured on the Agilent-SPECTRAA 55B AAS using appropriate hallow cathode lamp. Quality control standard were used as check samples every 5 run.

3. Results

3.1. Phytoplankton and Zooplankton species of Bundu-Ama Creek

The station point that had the highest population is point 3 while point 2 and 1 followed. The division that contributed the most to the population of the phytoplanktons is Bacillarophyta while the least is the Chaetocerotaceae as seen in Table 1. The zooplankton species was only made up of two divisions with 34 different species. The division copepod contributed the highest population and diversity in the creek, while the least was contributed by the division Cladocera. The station point with the highest diversity is point 1 while point 2 and 3 had the same number of species. The species population was highest in point 1 and least in point 3 as seen in Table 2.

3.2. Heavy Metal concentration in Bundu-Ama Creek

Table 1 Phytoplankton Species of Bundu-Ama Creek

Taxonomic Groups	Station 1	Station 2	Station 3
Bacillariophyta			
Amphipleura pellucida	3	*	6
Amphora sp.	*	*	1
Gyrosigma attenuatum	*	3	7
Nitizschia sigma	*	2	14
Cymatopleura elliptica	*	*	1
Diplonesis elliptica	*	*	2
Gyrosigma spenceri	*	3	7
Nitizschia seriata	*	*	7
Cymbella hybrid	*	4	1
Cymbella lata	*	2	*
Nitizschia denticula	*	6	*
Caloneis amphisbaena	*	3	*
Brebissonia boeckii	*	2	*
Nitizschia lanceolata	*	5	4
Stauroneis anceps	*	2	3
Nitizschia pleudo	7	1	8
Antinocyclus curvatulus	*	1	*
Antinocyclus octonarius	*	*	3
Coscinodiseus wailesii	*	*	3

Antinella punclata	*	1	*
Dactyliosolen antarcticus	*	2	*
Synedra sp	6	4	6
Pleurosigma sp	6	*	4
Fragilaria virescens	*	*	3
Flagilariopsis curta	*	3	*
Amphiprosa sp	2	2	*
Cocconeis scutellum	2	*	8
Hannaca arcus	*	1	*
Pinnularia gentilis	2	1	*
Cylindrotheca closterum	3	5	4
CYANOPHYTA			
Anabenopsis auociborkii	6	2	*
Oscillatoria tenius	*	11	*
Oscillatoria priceps	*	2	*
Rivularia plankton	*	1	*
Aphauizomenon sins-aquae	*	3	*
Lyngbya humnetica	*	*	2
Achnanthes gracillina	3	*	9
Melosira pusilla	*	*	7
Navicula amphibola	*	*	20
Navicula plicata	*	*	2
Melosira varians	*	*	2
Anabaena flos-aquae	2	*	2
Oscillatoria limosa	*	*	3
Achnanthes hungarica	*	*	2
Phormiaium sp	*	2	*
Navicula mutica	*	4	5
Achnanthes peragallii	*	*	4
CHLOROPHYTA			
Closteriopsis longisscina	*4*	*	*
Chlorigonuim euchlonim	4	*	*
Chlamyclomonas elliptica	1	*	*
Chodatella longiseta	1	1	*
Gonatozygon aculeatum	*	2	1
Cyclotella meneghiniana	*	2	2
Tetmemorus brebissonii	*	1	*
CHAETOCEROTACEAE			
Bacteriastrum delicatum porosira	*	2	*
Bacteriastrum furcaluin	*	1	*
XANTHOPHYTA			
Tribonema viride	*	*	3

Gloeobotrys lumneticus	1	2	*
Triboruma minus	*	1	1
Total population	53	90	157
Total species diversity	17	36	35

Key: * means absence of organism

Table 2 Zooplankton Species of Bundu-Ama Creek

TAXONOMIC GROUPS	**STATION 1**	**STATION 2**	**STATION 3**
CLADOCERA			
Daphinia pulex	*	*	1
Daphinia longiremii	*	2	*
COPEPODA			
Cyclops copepodid	*	*	1
Diaptomus siciloides	2	1	*
Female senecella calanoidas	1	*	*
Thermocyclops hyalinus	1	*	*
Female Macrocyclops ater	1	*	*
Fifth leg of Mebocyclops tenius	1	*	*
heterocope appendiculata	1	*	*
TOTAL POPULATION	7	3	2
TOTAL SPECIES DIVERSITY	6	2	2

Key: * means absence of organism

Table 3 Concentration of Chromium (mg/kg) In Bundu-Ama Creek

	Station 1	**Station 2**	**Station 3**
1st Month	0.029 ± 0.006^{aA}	0.243 ± 0.250^{aA}	0.115 ± 0.097^{bA}
2nd Month	0.399 ± 0.242^{aA}	0.189 ± 0.091^{aA}	0.126 ± 0.095^{bA}
3rd Month	0.409 ± 0.386^{aA}	0.392 ± 0.046^{aA}	0.45 ± 0.078^{aA}

a-d Different letters in the same column indicate significant difference (P<0.05); A-C Different letters in the same row indicate significant difference (P<0.05)

Table 4 Concentration of Copper (mg/kg) In Bundu-Ama Creek

	Station 1	**Station 2**	**Station 3**
1st Month	2.116 ± 0.773^{aA}	2.383 ± 0.574^{aA}	2.381 ± 0.204^{aA}
2nd Month	2.593 ± 0.528^{aA}	2.555 ± 0.217^{aA}	2.234 ± 0.093^{aA}
3rd Month	3.467 ± 0.248^{aA}	2.147 ± 1.152^{aA}	3.147 ± 0.777^{aA}

a-d Different letters in the same column indicate significant difference (P<0.05); A-C Different letters in the same row indicate significant difference (P<0.05)

The concentration of heavy metals is presented in Table 3 – 6 and also in Fig 1 to 4. The highest concentration of Chromium in the first month was recorded in point 2, with a mean value of 0.243± 0.250 while the least concentration was observed in point 1 with a mean value of 0.029± 0.006 In second month the highest concentration was recorded in point 1, with a mean value of 0.399± 0.242. while the least concentration was observed in point 3, with a mean value of 0.126± 0.0095. In the third month, the highest concentration was recorded from point 1, with a mean value of 0.409± 0.386, while the least was observed in point 3, with a mean value of 0.45± 0.078. For Copper, the highest concentration in the first month was recorded from point 3, with a mean value of 2.381± 0.204, while the least concentration was recorded in point 1, with a mean value of 2.116± 0.773. In second month the highest concentration was recorded in point 1, with a mean value of 2.593± 0.528. while the least concentration was observed in point 3, with a mean value of 2.234± 0.093. In the third month, the highest concentration was recorded from point 1, with a mean value of 3.467± 0.248, while the least was observed in point 2, with a mean value of2.147 ± 1.152. For Nickel, it was observed that the first month was below detectable limit in all points. In second month the highest concentration was recorded in point 1, with a mean value of 0.038± 0046. while the least concentration was observed in point 2, with a mean value of 0.0103± 0.018. In the third month, the highest concentration was recorded from point 3, with a mean value of 0.0673± 0.012, while the least was observed in point 1, with a mean value of 0.054 ± 0.028. For Zinc, the highest concentration in the first month was recorded from point 1, with a mean value of 3.393± 0.280, while the least concentration was recorded in point 3, with a mean value of 2.6± 0.229. In second month the highest concentration was recorded in point 2, with a mean value of 3.153± 0.285. while the least concentration was observed in point 3, with a mean value of 2.234± 0.093. In the third month, the highest concentration was recorded from point 3, with a mean value of 3.347± 0.458, while the least was observed in point 1, with a mean value of 2.75± 0.844.

Table 5 Concentration of Nickel(mg/kg) in Bundu-Ama Creek

	Station 1	**Station 2**	**Station 3**
1st Month	BDL	BDL	BDL
2nd Month	0.038± 0.046aA	0.0103± 0.018bA	0.0213± 0.037aA
3rd Month	0.054± 0.028aA	0.075± 0.026aA	0.0673± 0.012aA

$^{a-d}$ Different letters in the same column indicate significant difference (P<0.05); $^{A-C}$ Different letters in the same row indicate significant difference (P<0.05)

Table 6 Concentration of Zinc (mg/kg) in Bundu-Ama Creek

	Station 1	**Station 2**	**Station 3**
1st Month	3.393± 0.280^{aA}	2.99± 0.630^{aA}	2.6± 0.229^{aA}
2nd Month	3.077± 1.015^{aA}	3.153± 0.285^{aA}	2.167± 0.366^{aA}
3rd Month	2.75± 0.844^{aA}	3.22± 0.050^{aA}	3.347± 0.458^{aA}

$^{a-d}$ Different letters in the same column indicate significant difference (P<0.05); $^{A-C}$ Different letters in the same row indicate significant difference (P<0.05)

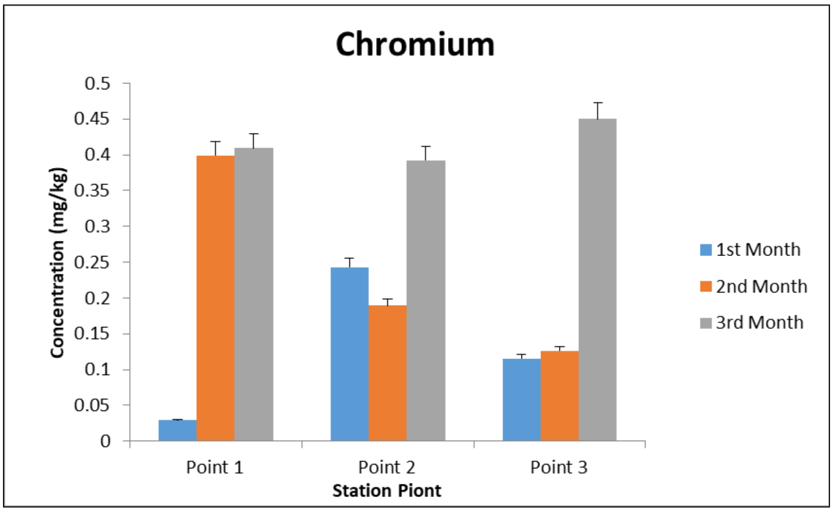

Figure 1 Concentration of Chromium in bundu-ama creek

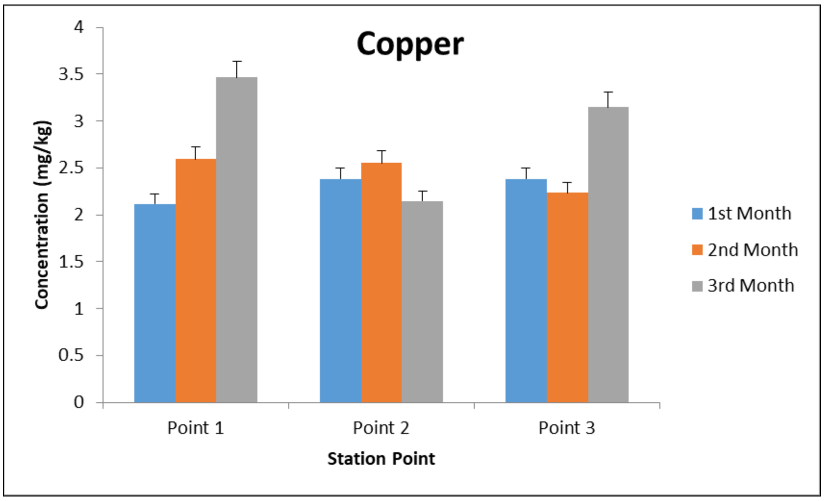

Figure 2 Concentration of Copper in bundu-ama creek

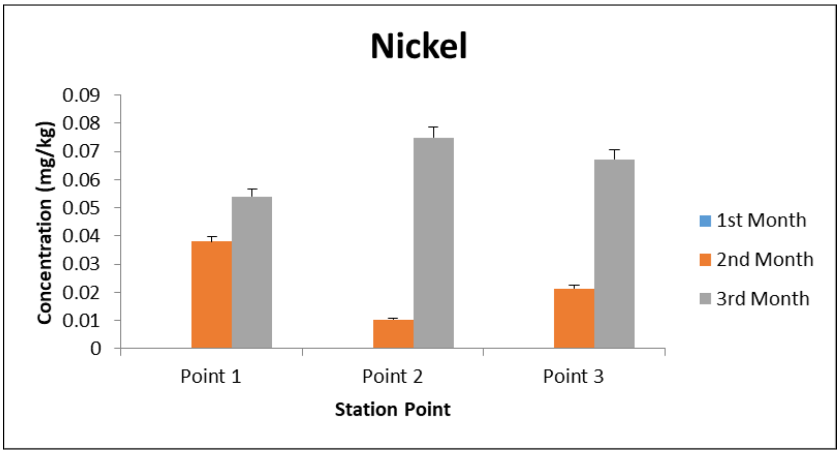

Figure 3 Concentration of Nickel in bundu-ama creek

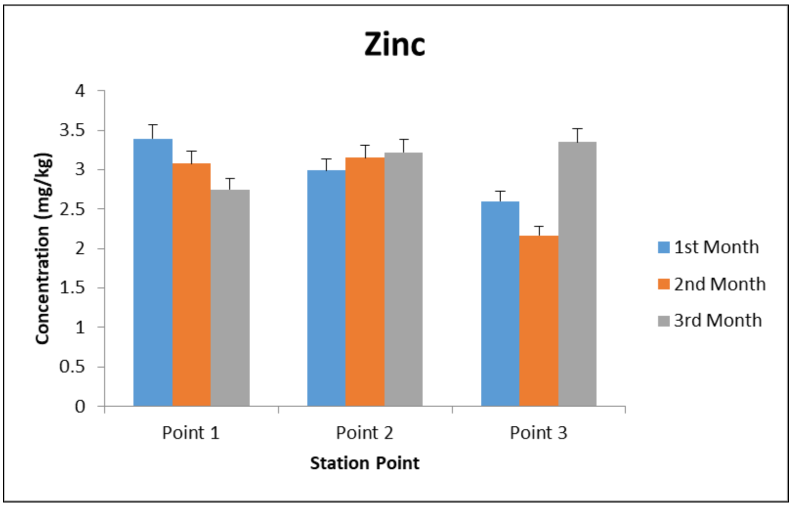

Figure 4 Concentration of Zinc in bundu-ama creek

4. Discussion

4.1. Phytoplankton and Zooplankton Species

The results indicate that there are variations in the population and species diversity of plankton, which may be due to seasonal variations such as; temperature, climate etc. and also anthropogenic activities. According to [37], the distributions of zooplankton vary from place to place and year to year and this is due to the dynamic nature of the aquatic systems. [38], also reported that most zooplankton move upwards from deeper layer of water column as darkness approaches and return back at dawn. [39] stated that zooplankton species number and distribution in a particular marine environment tells the prevailing chemical and physical conditions of the habitat. As regards the zooplanktons in this study, two taxonomic groups were identified and each group was widely distributed in all the sampling stations. These groups are the Copepods and the Cladocerans. The population of phytoplankton in Station 1 is the lowest when compared to the other stations or points while the population of zooplanktons in point 1 was the highest when compared to the other points. The low population and diversity recorded in Station 1 can be attributed to the fact that the location of station is upstream where the rate of the water flow is not conducive for the sedentary phytoplankton species that utilise the sun for their photosynthesis. The high population of phytoplankton that is recorded in Station 3 can be as a result of the activities that occurs in that region such as the discharge of faeces and the disposal of waste, as these activities can an increase in the nitrogen and other nutrients that encourages the growth of the phytoplankton species as it has been reported that Species composition changes significantly over time at a specific spatial location in response to temporal variation in the concentrations of local nutrient [40]. It is important to note that among the different families identified, the family Bacilliariophyceae has about 20 species and is the predominant in the water body. This result is in agreement with most reports from some Niger Delta rivers. [41] reported a total of 17 species from River Nun. [41] also observed 20 and 34 species from Orashi and Nkisa Rivers respectively, whereas [42] recorded a total of 27 species from the New Calabar River. Different studies on phytoplankton in the rivers and creeks of the Niger Delta and Nigeria have recorded the dominance of Bacillariophyceae. Such reports include [41], [43,44 &45]. It is believed that only those species that have developed the highest self-sustaining natural mechanisms of natural increase or multiplication usually becomes the predominant species. The population of phytoplankton is generally influenced by the temperature of the water, the velocity of the water current, nutrient availability and light penetration into the water [40].

The level of pollution due to anthropogenic activities can be linked to why there is a record of low diversity and population of zooplanktons in station 3 as seen in the results presented above. This is because although there is limited knowledge on the nature of interaction that exists between pollution and zooplanktons, it is reported that these pollutants have direct toxic effects on zooplankton, including lethal or sub lethal effects [46]. In addition, there is a form of interaction that occurs in the physicochemical characteristics of the pollutants in the water column due to the presence of the zooplanktons via the process of absorption, transformation and elimination and all these significantly affects the composition of the zooplanktons [47]. However, when we compare the results of station one with that of station 3, there is a significant difference in the composition. Station 1 is free from any form of pollution via anthropogenic activities which makes is suitable for the zooplanktons there to thrive.

4.2. Metal Concentration in Fishes

The results from the laboratory showed that five (5) heavy metals were tested for and found to be present and they include; Cd, Ni, Cr, Cu, Zn. But also from the results, it was discovered that Cadmium was below detectable limit in all the sampling stations. For Chromium, it was observed all the months exceeded the WHO 0.05mg/kg limits, however in the first month, station 1 was below the WHO limit. The main sources of Chromium into the water body is through industrial waste such as; pigments of paint, cement, paper, production of corrosive inhibitors [48], electroplating and metal fishing industries, municipal waste water treatment plants and oil drilling. Chromium has been classified as a human carcinogen and hence exposure to it can lead to cancer of the respiratory tract, renal damage, allergy, asthma in the individuals that feed on fishes that have accumulated chromium. The levels of Copper in the fish samples from all points and months were above the [49] standard values of 3.0mg/kg. And the concentration of copper (Cu) in fishes from Bundu-Ama creek is due to the contamination of the aquatic environment with refined hydrocarbon products during their loading operations. It is also released to the atmosphere during combustion of fossil fuel, decaying vegetation. However, copper is an essential substance to human life and is found in water as a trace element less than 5 μL/L [50]. but when there is high accumulation it causes Anaemia, increase in brittleness of various blood vessels and bones, stomach and intestinal irritation [51]. Nickel (Ni) concentration in all the points in the first month were below detectable limits, whereas in the second and third months all the stations were below the WHO 0.05-0.6mg/kg limit. It is released into the environment from power plants and trash incinerators and its presence leads to an increase in the acidity of the river and fishes tend to accumulate it in their systems when present in zinc-polluted water body. In humans, high intake of Ni leads to cancer of the lung and nasal cavity, it also causes skin rash liver, brain and endocrine glands, it can also be transferred to children from their mothers through breast milk and placenta [52]. Zinc (Zn) concentration in all the points in all the months exceeded the WHO standard limits. Zinc enters the environment as a result of both natural processes and anthropogenic activities. It is found naturally in air, water and soil but its absorption rises unnaturally due to human activities. It increases the acidity of the river and fishes tend to accumulate it in their systems when present in zinc-polluted water body. Fishes tend to accumulate zinc in their bodies when they live in zinc polluted canals. When in high accumulation in humans, it causes gastrointestinal disorders such as; abdominal cramps, vomiting, diarrhoea etc. [53].

5. Conclusion

From these results it is observed that there is the presence of heavy metals in Bundu-Ama Creek and from the observed plankton results, there is also an abundance of species in those areas. Due to the fact that some fishes depend on planktons, there is the tendency to find these fishes present in abundance in these areas and as such are exposed to the presence of these heavy metals. And once consumed by animals and humans, there is the transfer of these metals into our system and although its effects may not be visible at the moment, it does not exempt the risk of deleterious health effects in the future.

Compliance with ethical standards

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All individuals who have contributed to this work have been listed as authors.

Disclosure of conflict of interest

No potential conflict of interest reported by the authors.

References

[1] Yang H, Rose NL. Distribution of mercury in six lake sediment cores across the UK Sci Total Environ. 2003; 304(1-3): 391-404.

[2] Nsikak UB, Joseph PE, Akpan BW, David EB (2007). Mercury accumulation in fishes from tropical aquatic ecosystems in the Niger Delta. Nig. Curr. Sci. 92(6): 781-785.

[3] Langston WJ. Toxic effects of metals and the incidence of marine ecosystems. In: Furness RW, Rainbow PS, editors. Heavy Metals in the Marine Environment. CRC Press, New York. 1990; 256.

[4] Moslen, M. and Miebaka, C. A. (2017). Concentration of heavy metals and health risk assessment of consumption of fish from an Estuarine Creek in the Niger Delta, Nigeria.

[5] Bryan G, Langston WJ. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ Pollut. 1992; 76: 89-131.

[6] Kalay M, Ay Ö, Canli M. Heavy Metal Concentrations in Fish Tissues from the Northeast Mediterranean Sea. Bull. Environ. Contam. Toxicol. 1999; 63: 673-681.

[7] Al-Masri M, Aba S, Khalil AH, Al-Hares Z. Sedimentation rates and pollution history of the dried lake. Sci. Total, Environ. 2002; 293(1-3): 177-189.

[8] Karbassi R, Bayati I, Moattar F. Origin and chemical portioning of heavy metals in Riverbed sediments. Int J. Environ. Sci. Tech. 2006; 3(1): 35-42.

[9] Robin RS. Distribution of zooplankton from Arabian Sea, along southern Kerala. Current research Journal of Biological Sciences. 2009; 1(3): 155-159.

[10] Marcus, A.C., Okoye, C.O. B and Ibeto, C.N. Organic matter and trace metals levels in sediment of Bonny river and creeks around Okrika in River State Nigeria, International Journal Phys. Sci 2013; 8(15), 652-656.

[11] Akinrotimi OA, Edun OM, Makinde OO. Seasonal Variation of Heavy Metals in Selected Sea Foods from Buguma and Ekerekana Creeks Niger Delta. International Journal of Innovative Studies in Aquatic Biology and Fisheries (IJISABF). 2015; 1(1): 46-53.

[12] Jayasiri HB, WNC Priyadarshani. Hydrobiological aspects of Palk Bay and Palk Strait area PART (II): Diversity and abundance of marine plankton and benthos at selected locations in the Gulf of Mannar and Palk Bay, SriLanka. Journal of Natural and Aquatic Resource Research Development Agency. 2007; 38: 45-59.

[13] Stankovic S, Jovic M, Stankovic RA, Katsikas L. Environmental Chemistry for a Sustainable World. Chapter 9 Heavy Metals in Seafood Mussels. Risks for Human Health. Nanotechnology and Health Risk. 2005; (1): 311-362.

[14] Alam MGM, Tanaka A, Allinson G, Laurenson LJB, Stagnitti F, Snow E. A comparison of trace element concentrations in cultured and wild carp (Cyprinus carpio) of lake Kasumigaura, Japan. Ecotoxicology and Environmental Safety. 2002; 53: 348–354.

[15] Farkas A, Sala´nki J, Speczia´r A. Age and size-specific patterns of heavy metals in the organs of freshwater fish Abramis brama L. populating a low-contaminated site. Water Research. 2003; 37: 959–964.

[16] Mendil D, Uluo¨zlu¨ O¨D, Hasdemir E, Tu¨zen M, Sari H, Suicmez M. Determination of trace metal levels in seven fish species in lakes in Tokat, Turkey. Food Chemistry. 2005; 90: 175–179.

[17] Tu¨rkmen M, Ciminli C. Determination of metals in fish and mussel species by inductively coupled plasma-atomic emission spectrometry. Food Chemistry. 2007;103: 670–675.

[18] Tu¨rkmen A, Tu¨rkmen M, Tepe Y, Akyurt I. Heavy metals_ in three commercially valuable fish species from Iskenderun Bay, Northern East Mediterranean Sea. Turkey. Food Chemistry. 2005; 91: 167–172.

[19] Tu¨rkmen, A., Tu¨rkmen M, Tepe Y, Mazlum Y, Oymael S. Heavy metal levels in blue crab (Callinectes sapidus) and mullet (Mugil cephalus) in Iskenderun Bay (North Eastern Mediterranean, Turkey). Bulletin of Environmental Contamination and Toxicology. 2016; 77: 186–193.

[20] Dural M, Go¨ksu MZL, O¨ zak AA. Investigation of heavy metal levels in economically important fish species captured from the Tuzla lagoon. Food Chemistry. 2007; 102: 415–421.

[21] Dublin- Green WF, Nwankwo JN, Irechukwu DO. Effective Regulation and Management of HSE Issues in the Petroleum Industry in Nigeria. SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Caracas, Venezuela. June 1998; 7-10.

[22] Olaifa FE, Olaifa AK, Adelaja AA, Owolabi AG. Heavy Metal Contamination of Clarias Gariepinus from A Lake and Fish Farm In Ibadan, Nigeria. African Journal of Biomedical Research. 2004; 7: 145 – 148.

[23] Burger J, Gochfeld M. Heavy metals in commercial fish in new jersey, Elsevier Inc. Environmental Research. 2005; 99: 403-412.

[24] Mansour SA, Sidky MM. Heavy metals contaminating water and fish from fayoum governorate, Egypt. Food chemistry. 2002; 78: 15-22.

[25] Färstner U, Wittman GTW. Metal pollution in the aquatic environment. Springer, Berlin Heidelberg New York. 1981; 2: 486.

[26] Hgtkanson L. Metals in fish and sediments from the river Kolbficksan water system, Sweden. Arch Hydrobiol. 1984; 101(3): 373-400.

[27] Dallinger R, Prosi F, Segner H, Back H. Contaminated food and uptake of heavy metals by fish: a review and a proposal for further research. Oecologia (Berlin). 1987; 73: 91-98.

[28] Zhou JL, Salvador SM, Liu YP, Sequeria M. Heavy metals in the tissues of dolphins (Delphinus delphis) stranded on the Portuguese coast. Science of the Total Environment. 2001; 273: 61–76.

[29] Obasonhan EE, Eguavoen IO. Seasonal Variations of bioaccumulation of heavy metals in a freshwater fish (Erpetoichthys calabaricus) from Ogba River, Benin City, Nigeria. African Journal of General Agriculture. 2008; 4(3): 153-156.

[30] Castro-Gouzeza IM, Mendez-Armentab M. Heavy metals implications associated to fish consumption. Environmental toxicology and pharmacology. 2008; 26: 203-271.

[31] Tuzen M. Determination of heavy metals in fish samples of the middle Black Sea (Turkey) by graphite furnance atomic absorption spectrometry. Food Chem. 2003; 80: 119-23.

[32] Otitoloju AA, Don-Pedro KN. Bioaccumulation of heavy metals (Zn, Pb, Cu and Cd) by Tympanotonus fuscatus var. radula exposed to sublethal concentrations of the test metal compounds in laboratory assays. West Afr J Appl Ecol. 2002; 3: 17-29.

[33] Otitoloju AA, Don-Pedro KN. Integrated laboratory and field assessments of heavy metals accumulation in edible periwinkle, Tympanotonus fuscatus var radula (L.). Ecotoxicol Environ Saf. 2004; 57(3): 354-62.

[34] Otitoloju AA, Ajikobi DO, Egonmwan RI. Histopathology and Bioaccumulation of Heavy Metals (Cu & Pb) in the Giant land snail, Archachatina marginata (Swainson). The Open Environmental Pollution & Toxicology Journal. 2009; 1: 79-88.

[35] Aisuebeogun A. The Port-Harcourt region; Landforms characteristics of the environment. Journal of geographic thought. 1995; 1(1): 10-14.

[36] Marcus, A., and Ekpete, O.N. Impact of discharged process waste water from on oil refiney on the physicochemical waster body in Rivers State, Nigeria Journal of Appli. Chem, 2014; 12(1), 1-8.

[37] FAO (Food and Agriculture Organization of the United Nations). Stock assessment for fishery management – A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). FAO Fisheries Technical Paper. No. 487. Rome, FAO. 2006; 261.

[38] Carney HJ. A general hypothesis for the strength of food web interactions in relation to trophic state. Int. Vereinigung Theoret. Ange. Limnol.: Verhandlungen. 1990; 24: 487-492.

[39] Jakhar P. Role of Phytoplankton and Zooplankton as Health Indicators of Aquatic Ecosystem: A Review. International Journal of Innovative Research and Studies. 2013; 2: 489-500.

[40] Okoseimiema IJ, Vincent-Akpu IF, Onyeagbodor P, Oriakpono EO. Composition of phytoplankton communities in Ikpukulu-Ama Creek, Niger Delta. International Journal of Contemporary Applied Researches. 2020; 7(2): 21-31.

[41] Yakubu AF, FD Sikoki, JFN Abowei, SA Hart. A comparative study of phytoplankton communities of some Rivers, Creeks and burrow pits in the Niger Delta. Area. Journal of Applied Science and Environmental Management. 2000; 4(2): 41-46.

[42] Erondu ES, AC Chinda. Variations in the physicochemical features and phytoplankton of new Calabar River at Aluu, Rivers State, Nigeria. Nigerian Institute of Oceanography and Marine Research, Technical. 1991; 75: 3-18.

[43] Ogamba EN, AC Chinda, IKE Ekweozor, JN Onwuteaka. Water quality and phytoplankton distribution in Elechi Creek Complex of the Niger Delta. Journal of Nigerian Environmental Society. 2004; 1(2): 121-130.

[44] Emmanuel BE, IC Onyema. The plankton and fishes of a tropical creek in South Western Nigeria. Turkish Journal of Fisheries and Aquatic Science. 2007; 7: 105-113.

[45] Davies OA, JFN Abowei, CC Tawari. Phytoplankton community of Elechi Creek, Niger Delta, Nigeria - A nutrient polluted tropical creek. American Journal of Applied Sciences. 2009; 6(6): 1143-1152.

[46] Walsh GE. Toxic effects of pollutants on Plankton. In: Butler GC, editor. Principles of Ecotoxicology. John Wiley & Sons, Inc., New York. 1978; 257–274.

[47] Almeda R, Wambaugh Z, Wang Z, Hyatt C, Liu Z, et al. Interactions between Zooplankton and Crude Oil: Toxic Effects and Bioaccumulation of Polycyclic Aromatic Hydrocarbons. PLoS ONE. 2013; 8(6): e67212.

[48] Galvin RM. Occurrence of metals in water: An Overview. Water Sanitation. 1996; 22(1): 7-18.

[49] WHO/IPC. World Health Organisation. Geneva, Switzerland. Environmental Health Criteria 61: Chromium. 1988.

[50] Alabaster JS, Lloyd R. Water Quality Criteria for fresh water fish. Second Edition. London, Butterworth. 1982; 361.

[51] Turnland JR. Copper nutrition, Bioavailability and influence of dietary factors. J. Am. Dietetic Assoc. 1988; 1: 303-308.

[52] ATSDR (Agency for Toxic Substances and Disease Registry). Toxicological profile for nickel. ATSDR/U.S. Public Health Service, ATSDR/TP-88/19. 2005.

[53] ATSDR (Agency for Toxic Substances and Disease Registry). Toxicological profile for zinc. ATSDR/U.S. Public Health Service, ATSDR/TP-88/19. 2005.