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Heavy Metals and Polycyclic Aromatic Hydrocarbons in Water and Biota from a Drilling Waste Polluted Freshwater Swamp in the Mgbede Oil Fields of South-South Nigeria

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Abstract

Polycyclic aromatic hydrocarbons (PAHs), heavy metals (Ni, Mn, Zn, Pb, and Cd) in biota and water and Physico-chemical parameters [pH, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, sulphate, electrical conductivity, turbidity, salinity, chloride, phosphate, nitrate, sulphate, calcium, magnesium and water hardness] in water were measured in an oil drilling waste polluted freshwater swamp in the Mgbede Oil Fields of South-south Nigeria. Results showed that most of the parameters in the water column were within safe limits for biota except chromium, zinc, DO and PO_4^{3-} that had concentrations that can trigger eutrophication and where acute and chronic impacts on biota could occur. All other contaminants had concentrations that could engender health problems. Cadmium concentrations ranged between 1.0-8.64; chromium (2.17-34.22), lead (1.29-9.07), nickel (2.53-12.7), zinc(0.88-44.44), while PAH concentration was 0.0055 ppm in water and ranged between <0.001-0.104 (mg/kg) in biota. This study also reveals that the concentration of PAH was highest in the shell of the snail *P. Ovata* while concentrations of metals in the environment was highest in fish (Cd>Pb>Ni>Cr>Zn) followed by the water lettuce (Ni>Cr>Cd>Zn>Pb), snail shell (Zn>Cd>Pb>Cr>Ni) and water [(Cd,Pb)>Ni>Cr>Zn]. Polycyclic aromatic hydrocarbons also occurred at various cancer risk levels (10^{-5} in epiplatys and 10^{-6} in water lettuce and water snail). An official ban on the consumption of fish from this swamp and immediate remediation of the swamp are recommended.

Keywords: Drilling waste; Epiplatys; Nigeria; Agip; Oil pollution; Water lettuce; Water snail

Introduction

The Mgbede Oil Fields has been in operations since the 1960s by a member of the ENI Group, the Nigerian Agip Oil Company Ltd. In course of a drilling operation in 2012, a large quantity of drilling waste was discharged into a nearby freshwater wetland (Ode Swamp) causing massive ecosystem destruction and the pollution of traditional fish ponds. The livelihoods of people are usually tied to their immediate environment in rural Africa and the people in the study area source fish and other forest products from the fresh water swamps around their community, however, massive oil spills are threatening the very existence and productivity of these forested swamplands.

Oil drilling waste is a mixture of formation water, drilling fluids and associated wastes. Formation water, or produced water, accounts for about 98 percent of the waste stream during a drilling operation and usually contains naturally occurring radioactive material (NORM), including barium sulphate, radium sulphate and strontium sulphate; oil, high levels of chlorides and heavy metals [1,2]. Petroleum drilling waste mixture may also include cuttings, mud/chemical, oils, cement slurry/dust, condemned pipes, filters, and machinery part; and pre-treatment of waste is hardly undertaken by most oil prospective companies in Nigeria before they are discharged into the surrounding environment. Total dissolved solid and oil/grease values could be as high as 3700mg/l and 1100 parts per million respectively [3].

The most significant source of water pollution during drilling is inappropriate disposal of the formation water that is extracted along with oil. Although formation water can be disposed of by reinjection into the well, companies often choose to discharge it into local waterways to avoid the added time and expense of reinjection. The resulting contamination of ground and surface water can lead to serious and, sometimes, deadly impacts on local people, animals and vegetation. Another source of drilling waste pollution on water resources is from reserve pits, also called oil sumps or ponds. These sumps are open pits designed to store drilling wastes, primarily drilling and when subjected to heavy tropical rains and floods, the pits can overflow, contaminating water and soil and trapping wildlife [1,2].

Drilling mud (drilling wastes) are sometimes unintentionally or intentionally released into water bodies and can damage the gills of prawn, shrimp and other bottom dwellers at post larvae stages. For most aquatic animals, the gills are major sites through which waterborne pollutants can enter the body and are often affected by such substances. The toxic effect could be due to the paraformaldehyde biocides and heavy metals included in the different mud formulations/composition, which increases the toxicity to aquatic species especially bottom dwellers. Acute (short term) and chronic (long-term) health impacts can occur through bioaccumulation of oil, metals and other products in aquatic species that are consumed by humans underscoring the need for continuous monitoring of impacted areas [4].

According to the US based Agency for Toxic Substances and Disease Registry-ATSDR [5], PAH in hydrocarbons, especially petroleum

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hydrocarbons are when spilled into the aquatic system either float in water surface where they may suffocate fish or sink to the bottom and accumulate in sediments where they become available to bottom feeders like the water snail. These hydrocarbon compounds, particularly the smaller compounds such as benzene, toluene, and xylene can affect the human central nervous system or cause death if exposure is very high. Another compound (n-hexane) can affect the central nervous system in a different way, causing a nerve disorder called "peripheral neuropathy" or may negatively affect the blood, immune system, liver, spleen, kidneys, developing foetus, and lungs. Certain petroleum compounds can be irritating to the skin and eyes. The International Agency for Research on Cancer (IARC) has determined that benzene is carcinogenic to humans (Group 1 classification) and may cause leukaemia while benzo (a) pyrene and gasoline are considered to be probably and possibly carcinogenic to humans [6].

Therefore this study was aimed at investigating the levels of selected pollutants in food sources from this polluted swamp and to assess level of danger the people are exposed to as a result of the consumption of products from oil polluted swamps.

Study area

The study area is located within latitude N 5°28'6.24" and N 5°28'21.16" and longitude E 6°43'3.36" and E 6°43'29.28" including Mgbede Well 23 and adjoining swamps in Mgbede community in the Ogba/Egbema/Ndoni Local Government area of Rivers State in Nigeria.

The study area is a seasonal swamp and a flood plain of the Sombreiro-Orashi inter-basinal system. The swamp usually dries up between January and April allowing for the harvest of fish "stranded" in dug traditional fish ponds. This type of fishing activity is very common among local people in the Niger Delta area.

The Niger Delta Swamp Forests ecoregion is contained in a triangle with the town of Aboh on the Niger River being the northernmost tip. The Benin River forms the western boundary of the ecoregion where this ecoregion merges into the Nigerian Lowland Forest ecoregion. The Imo River forms the eastern side where this ecoregion merges into the practically vanished Cross-Niger Transition Forests ecoregion. Along its southern side the Niger Delta Swamp Forests is separated from the Atlantic Ocean by a band of mangroves, which can reach up to 10 kilometers (km) inland. In front of the mangrove belt and close to the sea are ephemeral coastal barrier islands often clothed in transitional vegetation [7].

The Mgbede fresh water swamps are part of the Niger Delta flood forest. This zone shows strong seasonal variation. During the dry season the soil is dry save for the seasonal flood channels, a few permanent creeks, and some lakes. During the rainy season water levels slowly rise, eventually leading to complete inundation during the Niger River flood, which lasts generally from October through December [7].

The climate of the study area is characterized by a long rainy season from March-April through October which is characteristic of the Tropical rainforest climate marked by very high rainfall, temperature and relative humidity. The temperature ranges are almost constant throughout the year ranging between 28°C (82.4 °F) for its hottest month in February and 26°C (78.8°F) in its coldest month which may be in July or September. Relative humidity is usually above 76 % and annual rainfall is characterized by a double rainfall maxima exhibiting two high rainfall peaks (in July and September), with a short dry season (in August) and a longer dry season between November and March.

Materials and Methods

The impacted ponds were purposefully selected for this study. Surface water and biota Water Lettuce-(*Pistia stratiotes*); water snail-(*Pila Ovata*) and cray fish-(Epiplatys fasciolatus-Banded Epiplatys) were sampled and analysed for physico-chemical parameters, heavy metals and PAH.

Data collection

Several methods of data collection were employed in this study. They include water and biota sampling, field and laboratory analysis, global position (GPS) measurements and on-the-spot interview.

Water sampling and analysis

Polycyclic aromatic hydrocarbons (PAHs), heavy metals (Ni, Mn, Zn, Pb, and Cd) and Physico-chemical characteristics of water in the ponds including pH, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, sulphate, electrical conductivity, turbidity, salinity, chloride, phosphate, nitrate, sulphate, calcium, magnesium and water hardness were measured with field devices and laboratory methods using standard procedures [8-10].

Two samples of water were taken at each sampling point for physico-chemical and metals analysis following the methods described in Ezekwe et al. [11]. Water samples were collected with new 1 L plastic containers pre-rinsed with dilute nitric acid and rinsed three to four times with the water sample before being filled to capacity and labelled; while samples for metal analysis were treated with 2 mL of nitric acid (100 %, trace metal grade, Fisher Scientific) to stabilize the oxidization states of the metals. They were further placed in ice-packed coolers and stored below 4°C prior to laboratory analysis. Metals were analysed by atomic absorption (AA) spectrophotometry using a Perkin-Elmer and Analyst 100 AA spectrophotometer (detection limit 0.001 mg/L). All manipulations were done under controlled conditions and in duplicate to avoid contamination.

Measurements of pH, temperature, EC, turbidity, and salinity were done in situ, using a Horiba water checker (model U-10) after calibrating the instrument with the standard Horiba solution. Total dissolved solids (TDS) were measured with a Lovibond cm-21 Tintometer, while total alkalinity, hardness, Ca, and Cl- were determined by titration. Phosphate, nitrate, and sulphate were determined using the stannous chloride, brucine, and turbidimetric methods, respectively, while Mg concentration was determined by calculation [8].

Samples for hydrocarbon analysis were collected in 250ml glass bottles and preserved by adding 1ml HCl (analytical grade). 200ml of sample water was batch extracted with 20ml chloroform in 5ml replicates using a 250ml glass separator funnel. After complete phase separation the lower organic phase was removed for absorbance determination and total hydrocarbon content determined spectrophotometrically at 420nm wave length using HACH DR 890 [12].

Biota sampling and analysis

Samples of macerated biota tissues were digested and extracts evaluated for selected heavy metal and PAH contents. Before analysis, two grams (2g) of ground oven dried total body weight were weighed using a high precision microscale and put in a digestion flask and digested with a mixture of 10ml of concentrated nitric acid and 2ml of concentrated perchloric acid. The contents of the flask was, for each case, digested gently and slowly, by heating in a water bath until the contents got to near dryness. It was then set aside to cool. The digest was filtered into a 50ml volumetric flask, made up to mark with distilled water and the concentrations of selected metals were determined by atomic absorption spectrophotometry using the Buck Scientific Model 200a Spectrophotometer, equipped with a high sensitivity nebulizer. Calibration of Buck Scientific Model 200a Spectrophotometer was performed before every run by successive dilution of a 100mg/l multi-element instrument calibration standard solution (Fisher Scientific) [13].

Polycyclic Aromatic Hydrocarbons were extracted from macerated biota tissues and shells after digesting with potassium hydroxide and the digest extracted with 1,1,2-trichlorotrifluoroethane (TCTFE). The extracts were further purified to avoid interferences by aliphatic hydrocarbons, porphrins, chlorins, and carotenoids using I alumina as an adsorbent. Concentrated extracts were then dissolved in hexane and subsequently introduced to the wet adsorbent and eluted with hexane to remove aliphatic hydrocarbons. A second eluant was benzene, which removed the aromatic components with sufficient purity for the Capillary Gas Chromatographic analysis. The purified aromatics were analyzed by capillary gas chromatography using an HP 6890 Series GC system equipped with a flame ionization detector (FID). The column used was a HP-5, 30 m X 0.25 mm X 0.25µm (HP Part No. 19091S-433). Hydrogen (10.2psi) was used as carrier gas at 1.5ml/min. The column was kept at 80˚C for 1 minute and was programmed to 280˚C at the rate of 20˚C/min. The column temperature was further programmed to a final hold at 300˚C at the rate of 2.5˚C/min. Temperature of the FID and T_{ij} (1 µl, 0.01 mg each/ml, split 25/1) were kept at 325˚C [13].

Results

Table 1 reveals that most of the parameters measured in the water column were within acceptable international limits apart from chromium, zinc and DO (based on the water quality criteria of America's National Oceanic and Atmospheric Administration) and PO_4^{3-} (based on the Australian and New Zealand Environment and Conservation Council criteria) that occurred at concentrations where both acute and chronic impacts on biota could occur.

Table 2 shows that of all the contaminants analysed in the biota samples from the study area only zinc were within safe limits for the protection of health. All other contaminants had concentrations that could engender health problems. Nickel concentration ranged between 2.53-12.7; chromium 2.17-34.22; cadmium 1.0-8.64; lead 1.29-9.07; zinc 0.88-44.44 and PAH < 0.001-0.1 ppm**.**

Nickel in fish was higher than the WHO [14]/FEPA [15]/FAO [16] allowable limit of 0.5-0.6 mg/kg. Chromium concentrations were above same standards in water lettuce, fish and snail shell. Highest concentration of 34.22 mg/kg occurred in fish. Concentrations of cadmium and lead were also above the WHO [14]/FEPA [15]/FAO [16] limits for occurrence of these metals in food.

Discussion

Environmental proxies

According to Aboho et al. [17], *Pila ovata* (the most common species of water snail in the study area) is usually found in the bottom of streams, ponds and lakes. The snail's habitat and feeding habits makes it vulnerable to the bioaccumulation of metals from algae, sediments and vegetal matter. The snail can accumulate higher concentrations of

S/N	Parameter(s)	Pond Water	Standards (NOAA)*	
			Acute	Chronic
1	Temp ºC	28		≤15˚C Acceptable maximum [39]
2	Conductivity Us/cm³	348		250 µS/cm [39]
3	pH	6.72		Desirable: 6.5-8.5 [39]
4	Salinity (mg/l)	160	-	-
5	TDS (mg/l)	230	-	-
6	ORP mV	115	-	-
7	Turbidity (JTU)	10	-	Desirable: less than 5 NTU [39]
8	Nickel, Ni	0.064	0.47	0.052
9	Chromium, Cr (mg/l)	0.267	0.016	0.011
10	Cadmium, Cd (mg/l)	<0.001	*0.002*	*0.00025*
11	Lead, Pb (mg/l)	<0.001	0.0651	0.0025
12	Zinc, Zn (mg/l)	0.295	0.12	0.12
13	Calcium, Ca (mg/l)	39.454	-	-
14	Magnesium, Mg (mg/l)	4.230	-	-
15	Sodium, Na (mg/l)	31.007	-	-
16	Potassium, K (mg/l)	25.840	373	-
17	PAH (mg/l)	0.006	0.3	-
18	Phosphate PO_4^{3-} (mg/l)	1.05	< 0.10 (PO4) [40]	< 0.10 (PO_4^{3-}) [40]
19	Sulphate, SO_4^{3-} (mg/l)	7	-	-
20	Nitrate, NO_3^- (mg/l)	2.0	50 [40]	50 [40]
21	BOD (mg/l)	0.265	class I fisheries ≤ 1 class II fisheries ≤ 2 class III fisheries ≤ 3 (Japanese EWQS)	class I fisheries ≤ 1 class II fisheries ≤ 2 class III fisheries ≤ 3 (Japanese EWQS)
22	DO (mg/l)(lab)	2.12	>5	>5
23	Alkalinity (mg/l)	42.5	≥ 20 [40]	≥ 20 [40]
24	Hardness (mg/l)	36.0		Desirable: 150-500 [39]

Table 1: Surface water results and standards.

Parameter(s)	Nickel, Ni (mg/kg)	Chromium, Cr (mg/kg)	Cadmium, Cd (mg/kg)	Lead, Pb (mg/kg)	Zinc, Zn (mg/kg)	PAH (mg/kg)
WHO [14]/ FEPA [15]/FAO [16] Limit in fish food	0.5-0.6	0.15-1.0	2.0	2.0, 0.5-0.6 [16]	150	
Indonesia ministry of Health			1.0		100	
USFDA			2.0			
Ambient criteria to protect human health-Total PAH: cancer risk level=10^{-5} cancer risk level = 10^{-6} cancer risk level = 10^{-7} [41]						0.02800 0.00280 0.00028
	Results					
Epiplatys	12.11	34.22	2.94	4.22	44.44	0.00236
Water lettuce	2.53	3.61	8.64	9.07	8.99	<0.001
***P. ovata* shell**	2.71	2.17	1	1.29	0.88	0.01

Table 2: Results of Biota analysis and Standards for contaminants in food.

metal ions than any other group of invertebrates especially in aquatic systems. These snails constitute an important source of diet, while their shells are applied in traditional medicine. The water snail's use in food and medicine and its unique place in the food chain make it a very good proxy for investigating environmental quality. The *Pila ovata* has also been used severally and successfully in environmental monitoring studies [18-21].

The water lettuce (*Pistia stratiotes*) is another unique proxy for this investigation. It is a free-floating waterweed found mostly in tropical waters. Under favourable conditions, it forms dense mats over the surface of slow-moving waterways, including dams and reservoirs. Sharma [22] stated that water lettuce is one of the dominant aquatic weeds in fresh waters, polluted lakes and streams of Nigeria. *Pistia stratiotes L*. (water lettuce) was selected for this study because of its ability to take up metals from water and produce internal concentrations several folds greater than their surroundings. It shows much higher metal-accumulating capacity than non-hyper accumulating terrestrial plants [23]. It also has medicinal properties and is used for traditional medicine and fodder in the study area [24].

The fish of the genus Epiplatys are native to Africa and are found in small watercourses and pools with sandy bottoms and live almost exclusively at or near the surface of the water. Their behaviour can be described as generally motionless, pike-like, with occasional abrupt lunges at prey. This fish species is therefore best suited for gauging the quality of surface water.

This study reveals that the concentration of metals in the environment was highest in fish (Cd>Pb>Ni>Cr>Zn) followed by the water lettuce (Ni>Cr>Cd>Zn>Pb), snail shell (Zn>Cd>Pb>Cr>Ni) and water [(Cd,Pb)>Ni>Cr>Zn]. Concentrations in fish showed a direct pattern with concentrations in the water column indicating a most direct impact of pollution. while the snail showed a preferential bioaccumulation of cadmium and lead while the water lettuce bioaccumulated lead more.

Contaminants in water

In the water column, a very high level of nutrient in the form of above limits concentration of phosphates was found. According to the Ecological Society of America [25], nutrient over-enrichment leads to hypoxia and anoxia (periods of oxygen depletion) and has a range of effects leading mainly to biological diversity loss. Hypoxia and anoxia alters the structure of ecological communities by killing off more sensitive or less mobile organisms, reducing suitable habitat for others, and truncating trophic interactions especially between predators and their prey. For instance, recurring periods of low oxygen tend to shift the dominance in the aquatic bottom community away from large, long-lived species to opportunistic and short-lived species such as polychaete worms that can colonize and complete their life cycles quickly between the periods of hypoxia. Zooplankton that normally graze on algae in surface waters during the night and migrate toward the bottom in the daytime to escape predation may be more vulnerable to predation if hypoxia in bottom waters forces them to remain near the surface.

Dissolved oxygen (DO) was also above limits. DO is considered as one of the most important aspect of aquaculture. It is needed by fish to respire and perform metabolic activities. Thus, low levels of dissolved oxygen are often linked to fish kill incidents. In general, a saturation level of at least 5 mg/L is required. Values lower than this can put undue stress on fish, and levels below 2 mg/L may result in fish kills [26]. DO was found to be around 2.12 mg/l which is quite dangerous to the survival of most fish species.

In the water column also, only Benzo (b) fluoranthene [27] and Indeno (1, 2, 3-cd) pyrene occurred at levels above food safety individually (Table 3), although total PAH occurred at cancer risk levels where 1 in 10,000 persons can be affected [27].

Heavy metals in biota

Heavy metals in water have been reported [28] to be dangerous to living organisms because they are easily bioaccumulated; and because they exist in the form of cations, they have a strong affinity for sulphur and the sulfhydril groups in enzymes and easily attach themselves to molecules and so block enzymytic activity. From the results of this study (Tables 1 and 2), zinc occurred within limits of referenced regulations. However, the British Columbia Ministry of the Environment [29] counselled that in order to protect aquatic life from acute and lethal effects, the maximum concentration of total zinc at any time should not exceed 0.033 mg/L when water hardness is less than or equal to 90 mg/L $CaCO_3$, while to protect freshwater aquatic life from chronic effects, the average concentration of total zinc should not exceed 7.5 µg/L when water hardness is less than or equal to 90 mg/L CaCO3 like in this study. Zinc has a tendency to be biomagnified and easily gets bioaccumulated in the fatty tissues of aquatic organisms, including fish and is known to affect reproductive physiology in fishes over long term of exposure [30].

Cadmium is another element capable of producing chronic toxicity even when present at concentrations as low as 1 mg/ kg and is potentially more lethal than any other metal [31]. Cadmium has been reported to exert acute and chronic deleterious effects in animals in terms of nephrotoxicity, cytotoxicity, genotoxicity, immunotoxicity and carcinogenicity at very low levels of exposure [32].

Lead is a nonessential element and is known to cause neurotoxicity, nephrotoxicity, and many other adverse health problems including systemic effects such as hypertension, gastrointestinal upsets, anemia,

S/N	PAH	Epiplatys (mg/kg)	Water lettuce (mg/kg)	P.ovata shell (mg/kg)	Water (ppm)
1	Naphthalene	0.00000244	0.00000	0.000000659	0.00000
2	Acenaphthylene	0.000000521	0.00000	0.000000180	0.00000521
	Acenaphthene	-	-	-	0.00000598
3	Fluorene	0.00000651	0.00000	0.000000699	0.00000350
4	Phenanthrene	0.00000157	0.00000	0.000000267	0.000000807
5	Anthracene	0.000000993	0.00000	0.000000829	0.00000129
6	Fluoranthene	0.000000311	0.00000	0.000000179	0.000000245
7	Pyrene	0.000000517	0.00000	0.000000362	0.000000907
8	Benz (a) anthracene	0.00000167	0	0.000000983 (0.002)	0.00000103 (0.0001) [26] (0.0001)
9	Chrysene	0.0000117	0	0.000007	0.00000213 (0.0002) [26] (0.0001)
10	Benz (b) fluoranthene	0.00227	0	0.00000023	0.00517 (0.0002) [26]
11	Benz (k) fluoranthene	0.00000077	0	0.000000779	0.00000114 (0.0002) [26] (0.0001)
12	Benz(a)pyrene	0.000011	0	0.0000023 (0.002)	0.00000212 (0.0002) [26] (0.00001) [26]
13	Indeno(1,2,3-cd)pyrene	0.0000465	0	0.00275	0.000314 (0.0004) [26] (0.0001)
14	Dibenz(a,h)anthracene	0.0000027	0	0.0000067	0.00000153 (0.0003) [26] (0.0001)
15	Benzo(g,h,i)perylene	0.000000471	0.00000	0.00000567	0.00000372

Table 3: Characterization of PAHs in Biota from Mgbede Fields.

nephropathy, nervous system effects such as Intelligence Quotient (IQ) defects and encephalopathy [33].

Nickel is a human carcinogen and human based studies have proved that there is a causal relationship between exposure to nickel compounds and cancer in man. Experimental exposure of animals to an assortment of nickel compounds by multiple routes caused malignant tumours to form at various sites in multiple species of experimental animals [34]. A recent study by Abou-Hadeed et al. [35] showed that short term exposure of fish to nickel chloride at 7.2 mg/l for one week caused behavioural changes in fish. The exposed fish were immobile, gathered near the bottom of the aquatic medium and had delayed reactions to light and sound.

Aquatic pollution by chromium does not occur naturally in the pure metallic form of the element. The element is present in divalent [Cr(II)], trivalent [Cr(III)], and hexavalent [Cr(VI)] oxidation states, with Cr(VI) and Cr(III) being the most stable forms. The health hazards associated with exposure to Cr are dependent on its oxidation state, ranging from the low toxicity of the metal form to the high toxicity of the hexavalent form. Hexavalent chromium is a toxic industrial pollutant and classified carcinogen possessing mutagenic and teratogenic properties [36].

PAHs in biota

Several international studies [International Programme on Chemical Safety (IPCS), the Scientific Committee on Food (SCF) and by the Joint FAO/WHO Expert Committee on Food Additives (JECFA)] have evaluated the health effects of exposure to PAHs. In one of the studies, the SCF concluded that 15 PAHs, namely benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, cyclopenta[*cd*]pyrene, dibenz[*a,h*]anthracene, dibenzo[*a,e*]pyrene, dibenzo[*a,h*]pyrene, dibenzo[*a,i*]pyrene, dibenzo[*a,l*]pyrene, indeno[1,2,3-*cd*]pyrene and 5-methylchrysene show clear evidence of mutagenicity/genotoxicity in somatic cells in experimental animals *in vivo* and with the exception of benzo[*ghi*]perylene have also shown clear carcinogenic effects in various types of bioassays in experimental animals. Thus, SCF reasoned that these compounds may be regarded as potentially genotoxic and carcinogenic to humans and therefore represent a priority group in the assessment of the risk of long-term adverse health effects following dietary intake of PAHs [37].

Of the listed PAHs, eight (PAH_8) are the highest levels of specific contaminants in foodstuffs including benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene and indeno[1,2,3-*cd*]pyrene which are now used as lead substances for the analysis of PAHs contamination of foods [37,38]. Analysis of compliance with the EU and USEPA food safety standards for the eight carcinogenic PAHs shows that they occur within acceptable limits for food safety (Table 3); however, the application of the USEPA Cancer Risk levels for total PAH in biota reveals that PAH cancer risk levels occurred at 10^{-5} levels in fish, a level where about 1 in 100,000 of the population will develop cancer as a result of eating fish from the ponds. Exposure levels in water lettuce and water snail were within the 10^{-6} cancer risk level, a level where 1 in 1,000,000 of the population will develop cancer as a result of exposure to PAH.

Conclusion

This study attempted to examine the post impact of drilling waste pollution on a freshwater swamp after over a year of impact with a view to determining the level of selected contaminants in the environment and evaluating possible impacts the observed pollutant levels could have on man who is the ultimate consumer in the food chain. This study showed that the chromium, zinc, DO and PO_4^{3-} had concentrations that could cause acute and chronic impacts on biota. It was also revealed that apart from zinc all other contaminants had concentrations that could engender health problems in man and biota. This study also reveals that the concentration of PAH was highest in the shell of the snail *P. Ovata* while concentrations of metals in the environment was highest in fish (Cd>Pb>Ni>Cr>Zn) followed by the water lettuce (Ni>Cr>Cd>Zn>Pb), snail shell (Zn>Cd>Pb>Cr>Ni) and water [(Cd,Pb)>Ni>Cr>Zn]. Concentrations in fish showed a direct pattern with concentrations in the water column indicating a most direct impact of pollution. While the snail showed a preferential biomagnifications of cadmium and lead, the water lettuce biomagnified lead. Consumption of water and fish from this wetland therefore exposes the consumers to high levels of cancer risk and other diseases.

The study also showed that nutrient levels may trigger eutrophication, while dissolved oxygen is at a level where changes in aquatic community structure which may lead to fish kill incidents and create undue environmental stress on the fish is plausible.

In the light of the foregoing, it is hereby recommended that the government's health ministry place an official ban on the consumption of fish from the swamp while the polluting company should be made to clean up or remediate the environment and pay the pond owners adequately for environmental and livelihood damages.

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