PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 9 (1): 35-42, 2010
ISSN 1680-5194

Bacteriological and Polycyclic Aromatic Hydrocarbon Accumulation in Mangrove Oyster (*Crassostrea tulipa*) from Douglas Creek, Nigeria

S.I. Eduok[1], G.A. Ebong[2], E.P. Udoinyang[1], J.N. Njoku[3] and E.A. Eyen[1]
[1]Department of Microbiology, University of Uyo, P.M.B. 1017, Uyo, Nigeria
[2]Department of Chemistry, University of Uyo, P.M.B. 1017, Uyo, Nigeria
[3]Sir Yahaya Memorial Hospital, Birnin Kebbi, Kebbi State, Nigeria

Abstract: Bacteriological density and polycyclic aromatic hydrocarbon concentrations were determined in the brackish surface water and mangrove oyster (*Crassostrea tulipa*) from Douglas creek, Nigeria. Total Heterotrophic Bacteria (THBC), Total Vibrio (TVC) and Total Coliform (TCC) counts ranged from 8.8 x 10^4 - 10.8 x 10^4 cfu/ml, 2.1 x 10^4 - 3.8 x 10^4 cfu/ml and 5.2 x 10^4 - 7.2 x 10^4 cfu/ml in water whereas THBC, TVC, TCC in the mangrove oyster ranged from 12.5 x 10^6 - 17.9 x 10^6 cfu/g, 3.9 x 10^5 - 5.8 x 10^5 cfu/g and 8.9 x 10^5 - 9.7 x 10^5 cfu/g. The microbial groups in the water and oyster exhibited varying correlations with r-values (p = 0.05) ranging from -0.3767 to 0.7209. The bacterial isolates were *Staphylococcus saprophyticus, Aerobacter aerogenes, Citrobacter sp, Bacillus cereus, Streptococcus sp, Vibrio parahaemolyticus, Vibrio cholerae, Pseudomonas putida, Pseudomonas aeruginosa, Escherichia coli, Enterococcus faecalis* and *Serratia marcescens, Acinetobacter iwoffii, Chromatium sp, Micrococcus sedentarius, Listeria monocytogenes* and *Klebsiella pneumoniae*. The individual PAH accumulated by the mangrove oyster ranged from 0.02-3.56 mg/kg against background surface water PAH concentration which ranged from 0.02 - 1.00 mg/l. Total PAH concentration in brackish surface water and mangrove oyster tissue was 7.51 mg/l and 11.96 mg/kg respectively. The Bioconcentration Factor (BFC) of the individual PAH in the mangrove oyster ranged from 0.51 [benzo (b) fluoranthene] to 17.8 [dibenzo (a,h) anthracene]. The microbial isolates are of health significance and PAH concentration in the mangrove oyster could biomagnify along the food chain with adverse toxicological effects on ardent consumers of the biota. The mangrove oyster (*Crassostrea tulipa*) could be used as a biomarker of bacterial and PAH contamination of the mangrove ecosystem.

Key words: Bioaccumulation, ecotoxicology, Douglas creek, mangrove oyster, polycyclic aromatic hydrocarbon

INTRODUCTION

The Niger Delta region is richly endowed with both renewable and non-renewable resources with oil and gas accounting for over 85% of Nigeria's Gross Domestic Product (GDP). However, the region remains the poorest due largely to the ecologically unfriendly exploitation of oil and gas and State policies that expropriate the indigenous people (Aaron, 2005). One of the most severe pollution problems in the Niger Delta is from oil and related activities which have been on the increase in recent times largely due to spillage and sabotage, although there are scanty quantitative details on the actual level of contamination. There is fecal pollution of water bodies and wetlands due to inadequate or nonexistent toilet facilities in the Niger Delta riverine communities (World Bank, 1995). Also, municipal solid waste and waste water in open drains and surface runoff which could adversely affect the environment are discharged directly into the water bodies, wetlands, creeks and estuaries. Several studies have reported oil-related pollution of the Niger Delta especially the Qua Iboe River Estuary (QIRE) (Ekwere *et al*., 1992; Asuquo *et al*., 1995; Udotong, 2000; Aaron, 2005; Essien and Antai, 2005; Itah and Essien, 2005; Udotong *et al*., 2008).

PAHs are present as natural constituents in fossil fuels, are formed during the incomplete combustion of organic material and are therefore present in relatively high concentration in products of fossil fuel refining (Bos *et al*., 1984; Deschenes *et al*., 1996; Lee *et al*., 1981; Nestler, 1974; Nishioka *et al*., 1986; Wang *et al*., 1990; Wang *et al*., 1999). Petroleum refining and transport activities are major contributors to localized loading of PAHs into the environment. PAH molecule stability and hydrophobicity are two primary factors which contribute to the persistence of high molecular weight PAHs in the environment (Kanaly and Harayama, 2000). In localized areas such as rivers, estuaries and harbours, the rate of accumulation greatly exceeded the rate of environmental degradation (Jhonson and Ghosh, 1998). Due to their lipophilic nature, PAHs have a high potential for biomagnification through trophic transfers (Lu *et al*.,

Corresponding Author: S.I. Eduok, Department of Microbiology, University of Uyo, P.M.B. 1017, Uyo, Nigeria

1977; Clements *et al*., 1994; Twiss *et al*., 1999). PAH are also known to exert acutely toxic effects and/or posses mutagenic, teratogenic or carcinogenic properties (Philips, 1983; Cerniglia and Heitkamp, 1989; IARC, 1990).

Oysters are filter-feeding organisms capable of accumulating microorganisms in high concentrations (Silval *et al*., 2004). According to Nunes and Parsons (1998), feeding oysters filter the surrounding water at a rate of 2-5 litres/hour eventually assimilating all the biotic and abiotic contaminants present in their environment. Indigenes of the Niger Delta are exposed to these microbial and chemical pollutants through the consumption of the diverse aquatic biota in the ecosystem. The ingestion of bivalve mollusks has been frequently associated with food-related infectious diseases (Cook *et al*., 2001). Additionally, exposure to contaminated sediments may occur during recreational activities such as wading, fishing, clamming and water sports. Inhalation of volatile contaminants released by sediments is also a potential exposure route. Although these exposure routes are generally not expected to contribute greatly to human health risks compared to consumption of seafood (WSDE, 1990).

Oysters are widely used for environmental monitoring purposes although some physiological factors such as spawning and growth can directly affect their ability to indicate pollution or environmental contamination (Rebelo *et al*., 2005). The inter tidal mangrove oyster *Crassostrea tulipa* cemented to the prop roots of mangrove macrophytes are freely harvested from the environment for domestic and commercial purposes being widely consumed by the coastal and estuarine communities in the Niger Delta as a delicacy and dietary protein supplement. The biota constituting lower level food chain could have elevated tissue burden of the pollutant due to their filter-feeding habit and ultimately be the route for transmission of these pollutants to humans. Several of these PAHs are known for their carcinogenic, mutagenic and teratogenic properties and also implicated in causing reproductive problems (Luch, 2005).

There is an increasing concern about PAHs due to their toxic and carcinogenic properties and the paucity of definite environmental information on these substances in the Qua Iboe River Estuary. This study was undertaken to assess the bacteriological load, PAH accumulation and possible toxicological implications due to the consumption and over-dependence by the indigenes of estuarine communities on the aquatic biota from the chronically polluted ecosystem for their dietary protein supplement.

MATERIALS AND METHODS

Study area: The Niger Delta region of Nigeria is characterized by a humid tropical climate with the Qua Iboe River Estuary (QIRE) located within latitude 4° 30'N and 4° 45'N and longitude 7° 30'E and 8° 45'E as a dominant hydrographic feature. The ecotone has mean minimum and maximum temperatures of 22°C and 30°C with an annual rainfall of 80% (Ukpong, 1995), although the ambient air temperature of Douglas creek during the sampling period was 39±2°C due to its proximity to the flare site. The estuary has a shallow depth ranging from 1-7 m at flood and ebb tide (Ekpe *et al*., 1995). The estuary is comprised of tidal creeks, lagoons, wetlands, and tributaries fringed with mangrove vegetation made up of species of *Avicennia, Rhizophora* and *Nypa* and harbor a rich collection of edible biotopes.

Sample collection/processing: The oyster samples were collected with the aid of machete at six different often exploited natural oyster beds in the creek during the wet season months of July and August, 2008. Samples for microbiological analysis were collected into a sterile isothermal container and transported to the laboratory. Mangrove oyster and surface water samples for chemical analysis were collected separately into Amber glass containers with Teflon-lined screw-cap. Water samples for chemical analysis were spiked with 5 ml of 1:1 HCl acid, stored in the dark at 4°C with a maximum holding time of 2 h before extraction (APHA, 1998). The oyster shells were extensively washed with water and rinsed with normal saline to remove all surface contaminants. The edible parts were removed with a sterile knife and transferred immediately to a sterile blender for homogenization and serial dilution.

Enumeration of Heterotrophic, Vibrio and Coliform bacteria: The counts of Total Heterotrophic Bacteria (THB) in the water and mangrove oyster was enumerated by pour plate technique (Harrigan and McCance, 1990) using diluents prepared with 25% Ringer's solution and cultured on nutrient agar (Difco) whereas Total Coliform (TC) counts were determined on MacConkey agar (Oxoid) and Total Vibrio (TV) counts on Thiosulphate Citrate Bile-salt (TCBS) medium. The nutrient agar was supplemented with cycloheximide (100 µg/ml and benomyl (50 µg/ml) to prevent fungal growth (Kinkle *et al*., 1995). Inoculated TC and TV plates were incubated aerobically whereas THB plates were incubated aerobically and anaerobically at room temperature (28±2°C) for 24 h and thereafter enumerated (Harrigan and McCance, 1990; Amadi and Braide, 2003). Representative bacterial colonies were purified by repeated subculturing and maintained as stock on nutrient agar slants. The identification of the isolates was done by comparing the cultural, morphological and biochemical characteristics of the cultures with the characteristics of known taxa using the Bergey's manual of determinative bacteriology (Holt *et al*., 1994) and Cowan and Steel's manual for the identification of medical bacteria (Barrow and Feltham, 1992).

Chemical analysis: Mangrove oyster sample was dried with anhydrous Na_2SO_4, extracted with a mixture of Dichloromethane (DCM) and acetone, thereafter solvent-exchanged with hexane. Clean-up and fractionation was done using silica gel permeation chromatography. The water sample was extracted with methylene chloride, dried with anhydrous Na_2SO_4 and solvent-exchanged into hexane. Clean-up and fractionation was done using silica gel permeation chromatography. Final extracts of water and mangrove oyster samples after reconcentration using a rotary evaporator was packed in a 2 ml GC vials and analyzed with a Gas Chromatography (GC), Perkin-Elmer/Clarius 500. GC columns conditions: Column made up of 5% PMS (100/120 mesh) coated with 3% OV-17 packed in a 1.8 x 2 mm ID glass column with helium carrier gas at 40 ml/min flow rate. Column temperature held at 100°C for 4 min, then programmed at 8°C/min to a final hold at 280°C. H_2 and Ar gas were used to light up the FID. Quantification of the PAHs was accomplished using a seven-point, external standard curve (APHA, 1998).

Statistical analysis: Correlation analysis of data were performed using Analyze-It General 1.73 statistical software® on log-transformed estimates of densities of heterotrophic, Vibrio and coliform bacteria in surface water (log cfu/ml) and mangrove oyster (log cfu/g) with levels of significance maintained at 95% for each test. Interpretation was done based on Hinkle *et al.* (1994) rule of thumb for interpreting the size of a correlation coefficient.

Bioconcentration factor determination: The quantification of the accumulation of polycyclic aromatic hydrocarbon in the tissue of the mangrove oyster in mg/kg body mass was made as a dimensionless factor, called Bioconcentration Factor (BCF) (Walker, 1987), expressed as:

$$BCF = \frac{\text{Concentration of the pollutant inside the tissue of the organism}}{\text{Concentration of the pollutant outside the tissue}}$$

"Outside" refers to the sources of the pollutant to which the organism is directly or indirectly exposed. In this study, outside is the brackish surface water in which the mangrove oyster grows and derives its nutritive material.

RESULTS AND DISCUSSION

The enumeration of viable heterotrophic and enteric microorganisms in the surface water and mangrove oyster tissues using different culture media are shown in Table 1. Counts of Total Heterotrophic Bacteria (THBC), Total Vibrio (TVC) and Total Coliform (TCC) ranged from 8.8×10^4 - 10.8×10^4 cfu/ml, 2.1×10^4 - 3.8×10^4 cfu/ml and 5.2×10^4 - 7.2×10^4 cfu/ml in water whereas THBC, TVC, TCC in the mangrove oyster ranged from 12.5×10^6 - 17.9×10^6 cfu/g, 3.9×10^5 - 5.8×10^5 cfu/g and 8.9×10^5 - 9.7×10^5 cfu/g respectively. The trend of counts taken separately for the different microbial groups was in the order THBC > TCC > TVC in both the surface water samples and mangrove oyster respectively. The different microbial groups in the brackish surface water and mangrove oyster exhibited varying correlation ships with r-values (p = 0.05) that ranged from -0.3767 to 0.7209 as shown in Table 2. There was a high positive correlation (r = 0.7209) in the relationship between counts of Vibrio in the water (TVCw) and oyster (TVCct) samples whereas moderately positive corelationships were exhibited between TVCw and THBCw, TVCw and TCCct, TBCct and TCCct and TVCct and TCCct indicating that an increase of the bacterial count in water directly influenced the load in the mangrove oyster.

The culturable microorganisms were isolated from both water and mangrove oyster tissues irrespective of the proximity of the sample location to human settlements and activities in the estuary, suggesting a widespread distribution of the isolates in the surface water. The heterotrophic, enteric and Vibrio species accumulated by the oyster were one order of magnitude higher in all the sample location than the background count in the surrounding brackish surface water. The bacterial isolates were *Staphylococcus saprophyticus*, *Aerobacter aerogenes*, *Staphylococcus aureus*, *Bacillus cereus*, *Streptococcus sp*, *Vibrio parahaemolyticus*, *Vibrio cholerae*, *Vibrio alginolyticus*, *Pseudomonas putida*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Enterococcus faecalis*, *Serratia marcescens*, *Acinetobacter iwoffii*, *Chromatium sp*, *Micrococcus sedentarius*, *Listeria monocytogenes*, *Klebsiella pneumoniae* and *Proteus vulgaris*.

In this study, emphasis was on the general occurrence of human pathogens instead of total coliform. This is because many studies (Carlucci and Pramer, 1959; Dutka, 1973; Dawe and Penrose, 1978; Rhodes *et al.*, 1983) have indicated the inadequacy of the coliform as an indicator of fecal contamination of marine ecosystem and the safety of shellfish harvested from sewage impacted areas. They demonstrated that *E. coli* is rapidly eliminated from seawater whereas other pathogenic bacteria in sewage effluents may survive for extended periods.

The occurrence of *Escherichia coli* in the samples indicated recent fecal pollution of human origin (Duffour *et al.*, 1985) and together with other bacterial isolates have been implicated in infectious diseases involving every organ system (Gracey *et al.*, 1982; Burke *et al.*, 1983; Smith and Williams, 1984; Von Graeventz and Altwegg, 1991; Koneman *et al.*, 1992). The most common of these in the QIRE communities are gastrointestinal and bronchopulmonary disorders due to incidental swallowing of the estuarine water during swimming and consumption of inadequately cooked shellfishes.

Table 1: Microbial counts in the water and mangrove oyster samples

Sampling location	Water			*Crassostrea tulipa*		
	THBC (x10^4)	TVC (x10^4)	TCC (x10^4)	THBC (x10^6)	TVC (x10^5)	TCC (x10^5)
L1	9.5 (4.98)	2.7 (4.43)	6.8 (4.83)	13.2 (7.12)	5.1 (5.71)	8.9 (5.95)
L2	8.8 (4.94)	2.1 (4.32)	5.6 (4.75)	12.5 (7.10)	3.9 (5.59)	9.2 (5.96)
L3	9.2 (4.96)	3.4 (4.53)	6.6 (4.82)	13.0 (7.66)	5.2 (5.72)	9.7 (5.99)
L4	10.2 (5.01)	2.6 (4.41)	7.2 (4.86)	17.9 (7.25)	4.2 (5.62)	8.9 (5.95)
L5	10.8 (5.03)	3.8 (4.58)	6.8 (4.83)	17.5 (7.24)	4.7 (5.67)	9.4 (5.97)
L6	9.7 (4.99)	3.5 (4.54)	5.2 (4.72)	14.6 (7.16)	5.8 (5.76)	9.6 (5.98)

Values in parenthesis are Log10

Table 2: Correlation between the microbial groups in water and *Crassosstrea tulipa*

	THBw	TVCw	TCCw	THBct	TVCct	TCCct
THBw	1					
TVCw	0.5755^a	1				
TCCw	0.4569^c	0.0607^d	1			
THBct	-0.1104^d	0.4406^c	0.3315^c	1		
TVCct	0.1283^d	0.7209^a	-0.2343^d	0.2838^d	1	
TCCct	-0.1497^d	0.6689^b	-0.3767^c	0.6784^b	0.5839^b	1

w = water sample, ct = *Crassostrea tulipa*

a = high positive correlation, b = moderate positive correlation, c = low positive (negative) correlation, d = little if any correlation

Water and food-borne infections in the QIRE communities of the Niger Delta has continued largely due to the low literacy level, poor hygienic conditions, historical neglect, apathy, pollution, socio-ecological green washing of the exploration and allied companies operating in the region and the abysmal poverty level of the inhabitants who cannot afford clean, safe drinking water and medicare.

The gastrointestinal illnesses prevalent in the area range from mild to severe stomach distress with symptoms including abdominal cramps, frequent diarrhea, occasional vomiting and dehydration. These illnesses although preventable, are often undiagnosed, life threatening, sometimes fatal and unreported. Food borne infection and intoxication in the study area as a result of consumption of sea foods is particularly worrisome because of the unhygienic environment, handling of the harvested aquatic biota and the mild heat applied during the smoking process which could be stimulatory to the microorganisms. The tissue microbial load in the oyster was above the ICMSF (1986) standard of 10^5 cfu/g for fresh and frozen bivalve molluscs. This is indicative of the health hazard susceptible consumers would be exposed to, if the mangrove oyster is not depurated, hygienically prepared or adequately cooked before consumption. Exposure to food borne infection and intoxication is usually more pronounced in avid consumers who are in the habit of eating uncooked oyster harvested from the estuarine ecosystem (personal communication).

The levels of individual PAH quantified in this study ranged from 0.20-1.00 mg/l and 0.20-3.56 mg/kg in the brackish surface water and mangrove oyster with a total PAH concentration of 7.51 mg/l and 11.96 mg/kg respectively as represented in Table 3. These levels may be regarded as baseline concentration and will be useful in comparing the risk factors in the consumption of other aquatic foods. It will be premature to make categorical statements on the residue levels of PAHs in the estuary considering the inflows and inputs from Qua Iboe River, atmospheric deposition, runoffs, sewage, industrial and municipal waste and petroleum E and P activities contributing significantly to the load and the small sample size.

Several PAHs are the most potent carcinogens known to exist, producing tumors in some organism through single exposures to microgram quantities. PAHs act at both the site of application and at organs distant to the site of absorption; their effects have been demonstrated in nearly every tissue and species tested, regardless of the route of administration (Lee and Grant, 1981). This could influence and negatively impact the biodiversity and densities of the biota in the estuary.

Susceptible human population in the Niger Delta would be exposed to PAHs primarily through the consumption of shellfish and other aquatic resources that are essentially an integral component of every diet of the people in this region. In the Douglas creek, much of the PAHs are released into the atmosphere via soots from gas flaring and eventually reaches the water by direct deposition or by deposition on vegetation in addition to inputs from sewage and used motor oil from diffuse sources. The carcinogenic activity of soots, tars and oils to man is beyond dispute. Benzo(a)pyrene, a PAH, was identified as one of the most carcinogenic compound in coal tar (Dipple, 1985). Sewage effluents usually contain measurable levels of PAHs, although extreme variability between and among sites is common (Eisler, 1987). In addition to the skin cancers, higher incidences of respiratory tract and upper gastrointestinal tract tumors

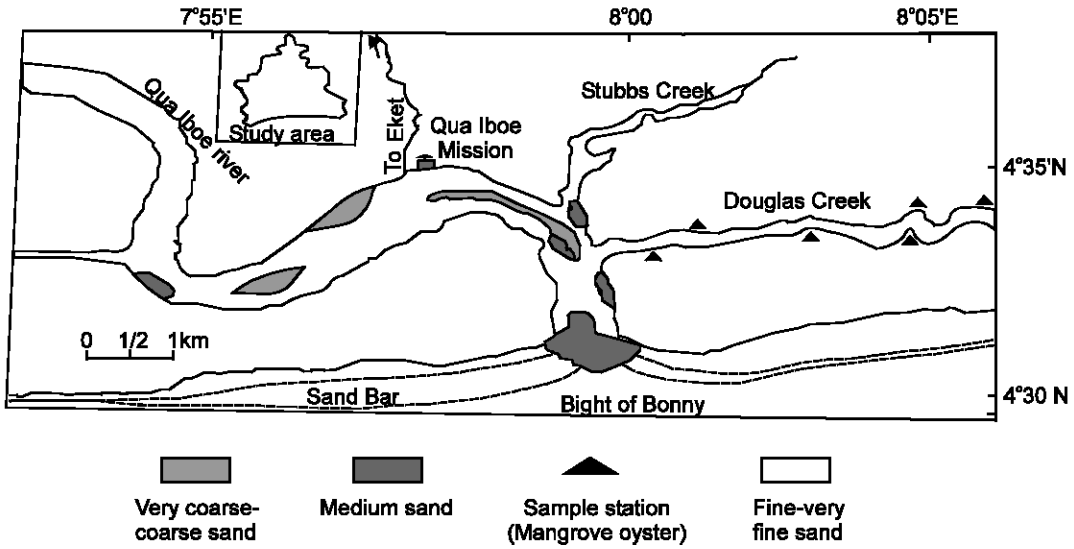

Fig. 1: Map of Qua Iboe River Estuary showing Douglas creek and sampling sites (Inset: Map of Akwa Ibom State)

Table 3: Concentration of polycyclic aromatic hydrocarbon in samples and their Bioconcentration factor

	Concentration		
Parameter	Water (mg/l)	Mangrove Oyster (mg/kg)	BCF
Naphthalene	1.00	1.00	1.00
2-Methylnaphthalene	0.20	0.20	1.00
Acenaphthylene	1.00	1.00	1.00
Acenaphthene	0.70	0.70	1.00
Fluorene	0.70	0.70	1.00
Phenanthrene	0.20	0.67	3.35
Anthracene	0.40	0.40	1.00
Fluoranthene	0.20	0.20	1.00
Pyrene	0.20	0.20	1.00
Benzo(a)anthracene	0.43	0.44	1.02
Chrysene	0.22	0.58	2.64
Benzo(b)fluoranthene	0.49	0.25	0.51
Benzo(k)fluoranthene	0.74	0.82	1.11
Benzo(a)pyrene	0.43	0.36	0.83
Dibenzo(a,h)anthracene	0.20	3.56	17.8
Benzo(g,h,I)perylene	0.20	0.68	3.40
Indeno(1,2,3-d)pyrene	0.20	0.20	1.00
Total PAH	7.51	11.96	1.59

were associated with occupational exposures to these carcinogens (Dipple, 1985). This research finding has strong public health implications although there are no records or data of body burden reflecting exposures of the populace to PAHs or other persistent-lipophilic and bioaccumulative or toxic compounds in the Qua Iboe River Estuary, Nigeria. Apart from microbial causes, gastrointestinal distress prevalent in the area may not be unconnected with direct uptake of PAH through consumption of the aquatic biota.

It has been demonstrated that certain Lower Molecular Weight (LMW), non carcinogenic PAHs, at environmentally realistic levels were acutely toxic to aquatic organisms, or produced deleterious sublethal responses (Neff, 1985). Among the LMW PAH, elevated concentration was recorded for phenanthrene with 0.67 mg/kg above the background level of 0.20 mg/l in water. It is suggestive that the uniform concentration of other low molecular weight PAHs such as 1.00 (naphthalene), 1.00 (acenaphthylene), 0.70 (acenaphthene) and 0.70 (fluorene) in the surface water (mg/l) and those accumulated in the aquatic biota (mg/kg) respectively could have adverse effects on the mangrove biota. The most obvious could be the low population densities of the mangrove oyster compared with other oyster beds in the estuary where the populations of *Rhizophora* and *Avicennia* species in the ecosystem are not asphyxiated. The *Nypa fructican* that proliferate in the study area have a thick and impervious cuticle that seems to excludes the oil from the plant tissues except through direct uptake and does not provide adequate breeding site for the biota. The Douglas creek surface water is darkened with an oily sheen as a result of soot deposition and episodic discharges from oil installations which could have contributed to the accelerated mortality of the mangrove plant by asphyxiation, blocking breathing pores on the mangrove prop roots and pneumatophores of *Avicennia* and by extension the aquatic resources.

Several studies have indicated that bivalve mollusks and some other invertebrates are unable to efficiently metabolize PAHs and excrete them (Neff *et al*., 1976; Jackim and Lake, 1978; Lawrence and Weber, 1984a; Varanasi *et al*., 1985), presumably due to inefficient or missing mixed function oxidase systems (Sirota and Uthe, 1981). Several PAHS are the most potent carcinogens known to exist, producing tumors in some organism through single exposures to microgram quantities. PAHs act at both the site of application and at organs distant to the site of absorption; their effects have

been demonstrated in nearly every tissue and species tested, regardless of the route of administration (Lee and Grant, 1981). There could also be the formation of reactive intermediates such as diol epoxides and phenol epoxides of benzo (a) pyrene both of which are implicated in mammalian mutagenesis and carcinogenesis (Varanasi and Gmur, 1981). The concentration of individual carcinogenic PAH in the mangrove oyster was in the following trend: 0.20 mg/kg [indeno (1,2,3-d) pyrene], 0.25 mg/kg [benzo (b) fluoranthene], 0.36 mg/kg [benzo (a) pyrene], 0.44 mg/kg [benzo (a) anthracene], 0.58 mg/kg (chrysene) and 3.56 mg/kg [dibenzo (a,h) anthracene]. The Bioconcentration Factor (BFC) for most of the PAH were above one order of magnitude in the samples with benzo (b) fluoranthene (0.51) and benzo (a) pyrene (0.83) as the exceptions, having values less the one.

PAHs from drinking water contribute only a small proportion of the average human intake (Harrison *et al*., 1975). The drinking water quality criterion for carcinogenic PAH compounds is based on the assumption that each compound is as potent as benzo (a) pyrene and that the carcinogenic effect of the compound is proportional to the sum of their concentrations (EPA, 1980). Based on an oral feeding study of benzo (a) pyrene in mice, the concentration of this compound estimated to result in additional risk of one additional case for every 100,000 individuals exposed (i.e., 10^5) is 0.028 µg/l. Therefore, with this assumption, the sum of the concentrations of all carcinogenic PAH compounds should be less than 0.028 µg/l in order to keep the lifetime cancer risk below 10^{-4}. The corresponding recommended criteria which may result in an incremental cancer risk of 10^{-6} and 10^{-7} over the lifetime are 0.0028 µg/l and 0.00028 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, the levels are 0.311 (10^{-5}), 0.031 (10^{-6}) and 0.003 (10^{-7}) µg/kg, respectively (EPA, 1980).

Though inhabitants of the study area do not drink the brackish estuarine water with a 0.43 mg/l concentration of benzo(a)pyrene, diffused exposure to PAHs may be during recreational activities such as wading, fishing, water sports and inhalation but significant route of the PAHs exposure would be through consumption of diverse aquatic foods, including most especially the mangrove oyster. The elevated concentration of PAHs in the mangrove oyster tissue (11.96 mg/kg) above the background levels in the surface water (7.51 mg/l) with BCF of 1.57 is both suggestive of bioaccumulation and the chronic cancer risk humans in the study area are exposed to, as a result of oyster consumption since the concentration of individual PAHs in the water and mangrove oyster in this study was above the minimum recommended 0.00028 (10^{-7}) µg/l and 0.003 (10^{-7}) µg/kg respectively.

Conclusion: There is an increasing anthropogenic generation, use and deliberate release of waste containing persistent organic pollutants such as PAHs, and sewage into the Douglas creek of the Qua Iboe River estuary where prohibitions and/or restrictions existing on documents of regulatory agencies are rarely or poorly enforced. The concentration of PAHs in the surface water and mangrove oyster from the Douglas creek should be considered alarming in view of the carcinogenic and mutagenic properties of many individual PAHs. The widespread occurrence of pathogenic microorganisms and PAHs in all the samples is indicative of the local influence of the inhabitants and industrial activities in the area. The PAHs level of accumulation was found to be higher in the mangrove oyster than in the surface water and could be regarded as baseline environmental concentration and bioaccumulation in the mangrove oyster tissues respectively. The PAHs level is considered to be bioavailable since it is present in detectable quantities in the surface water and mangrove oyster tissues. The mangrove oyster (*Crassostrea tulipa*) could serve as a bioindex for microbiological and ecotoxicological risk assessment of the various probabilities of adverse effect of pollutants in the ecosystem and the body burden of microbial and organic pollutants accumulation therefore may provide a good indication of the health of the QIRE mangrove ecosystem.

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