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Bioaccumulation of Heavy Metals and Hydrocarbons in Sediment, Shell and Flesh of the Faunas in Qua-Iboe River at Ibeno, Akwa Ibom State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Bioaccumulation of Heavy Metals and Hydrocarbons in Sediment, Shell and Flesh of the Faunas in Qua-Iboe River at Ibeno, Akwa Ibom State, Nigeria was undertaken. The faunas and sediment sample were collected from designated locations and a control location along Ikot-Ibok in dry and wet seasons using standard analytical sampling methods. The samples were analyzed for heavy metals and hydrocarbons content by atomic absorption spectrophotometer and gas chromatography respectively. pH of the samples was assessed. Transfer factor (TF) of the heavy metals between the sediment and the faunas were calculated. Regression models (linear and power equation) were developed to predict the numerical relationship between total petroleum hydrocarbon and total hydrocarbon content (TPH and THC) and heavy metals concentration in shell (predictor) of fauna in relation to their concentration in the flesh (dependent). Results obtained were

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subjected to statistical analysis such as coefficient of variation and mean. The concentration range of the heavy metals of both faunas and sediment was 0.001 – 86. 686 mg/kg. These value are above the World Health Organization and National Environmental Standard and Regulations Enforcement Agency (WHO/NESREA) standards (0.001 -5.0mg/kg). The coefficient of variation (C.V) had a range of 0.0152 – 193.333% which showed variation in stability of the heavy metals. Transfer factor (TF) showed that *Tympanotomus fuscatus* tissue bioaccumulated most heavy metals. Hydrocarbons (TPH and THC) and heavy metals concentration in the flesh of *Ostreidea* and *Tympanomus fuscatus* tissue were predicted from its shells at highly significant level (P - $\leq$ 0.05). This study has provided information on the levels of heavy metals and Hydrocarbons in faunas and sediment. In addition, the study has also developed models for predicting the levels of heavy metals and hydrocarbon content in the flesh from the shell of the faunas studied.

Keywords: Bioaccumulation; heavy metals; anthropogenic; transfer factor; food chain.

1. INTRODUCTION

In nature, aquatic organism are permanently exposed to contaminants such as metals and hydrocarbons due to natural geochemical processes like leaching and rock weathering and anthropogenic activities resulting from increase in urbanization, industrialization, agricultural practices, oil exploration and exploitation activities as characterized in the Niger Delta region of Nigeria [1] and [2]. Often such increases in anthropogenic activities, usually leads to faster releases of chemical contaminants into the aquatic environment which poses deleterious threat to aquatic and man due to their proved toxicity, persistence, bioaccumulation and bio magnification in food chain [2].

The use of biological accumulator species in monitoring and assessing the level of contaminants and pollution of our aquatic environment is a major thrust towards knowing the degree to which the various components of our aquatic ecosystem is impacted. Accumulator species such as mollusc and some bentho-pelagic organism are sedentary dwellers and have capacity to bioaccumulate relatively large amount of certain pollutants, even from much diluted solutions without obvious noxious effects. The bioaccumulation of pollutants in organism is the result of previous uptake from its environment in the past as well as the recent pollution level of the environment in which the organism lives, while the pollutant concentrations in the water only indicate the situation at the time of sampling [3,4]Chemical pollutants are known to have adverse effects on aquatic environments.

A negligible increase in the concentration of chemical pollutants could lead to a drastic effect on the aquatic life. Also, chemicals which would have been harmless on their own may become toxic by interacting in the marine environment [5]. Understanding the dynamic process of Bioaccumulation is very important in protecting human being and other organism from adverse effect of chemical exposure [2]. According to Department of Petroleum Resources (DPR) [6] Bioaccumulation means increase in the concentration of a chemical or substance in a biological organism over time, compared to its concentration in the environment. Meanwhile Bioaccumulation starts with the uptake of chemical pollutants across biological membrane and could be investigated through laboratory and filed study [7]. However, field bio accumulative studies, gives a real situation approach, whereby aquatic organism are exposed to series of inorganic and organic compounds that interplays within the natural environment [8].

The environment is continuously loaded with foreign chemical (Xenobiotic) and inorganic compounds released by urban communities and industries [9]. The aquatic ecosystem is therefore continuously and seriously threatened by these substances as it is the ultimate sink for these contaminants by either due to direct discharges or hydrologic and atmospheric processes [3].

More so, the applications of models such as bivariate linear regression and power equation technique enable predictive equations to be derived as illustrative models based on the responses of concentration of contaminant in flesh as a function of shell totals. It also identified those samples having high accumulation of contaminants in both tissues (flesh) and shell organs. The most valuable contribution of these is not in predicting presence of contaminant as such, but also creating awareness on

the deleterious effect of these pollutants to man [10].

The applicability of regression techniques in the prediction of contaminants concentration in tissues and organs of aquatic biota is well established in literature [11]. The study is aim at determining the inter-relationship models between the contaminant (heavy metals TPH & THC) in the shell and flesh of the faunas (*Osteridae* and *Tympanotomus fuscatus*) in Qua-Iboe River, Akwa Ibom State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study area Qua Iboe River is in Ibeno Local Government Area of Akwa Ibom State. It is a major important hydrographic feature of the Niger Delta. The river is characterized by fine psalmmitic beaches, fringed with tidal mudflats and mangrove swamps. The river is located within latitude $4^{0}30^{-} – 4^{0}45^{-}$ N and longitude $7^{0}30^{-}$ - $8^{0}45^{-}$E on the South-East coastline of Nigeria [12]. However, Ibeno River and other adjoining creeks are subjected to petroleum exploration and exploitation activities as well as use of explosives and chemicals by artisan fishermen. Ibeno River is about 150 km long and empties into Atlantic Ocean [12]. It occupies the largest Atlantic coastline of more than 129 km in Akwa Ibom State [2]. It originated from Umuahia hills and transverse sedimentary terrains and develops into extensive meanders before emptying into Atlantic Ocean. The river flow in a south direction as a first order stream joined by other ributaries to drained Anya River near Umudike. It is linked with a network of creeks and Channel Islands which persist throughout the length of the estuary [13]. Midstream stations are bordered or intercepted by a number of human activities including agriculture, dredging and currently road construction activities. The lower reach of the River is situated close to petrochemical effluent treatment and discharge plant of the Exxon Mobil Company.

The wastes are discharged into Atlantic Ocean but may recycle into the river due to tidal motion. Also regular spills, gas flaring, illegal dumping of untreated wastewaters from Onshore and offshore oil facilities as well as other activities in the upstream of the ecosystem.

2.2 Sample Collection

2.2.1 Fauna

The mature fresh samples of *Tympanotomus fuscatus* (periwinkle) and *Ostreidae* (Oyster) which are highly consumed in the Nigeria Delta Area of Nigeria were collected in triplicate into 1 litre amber glass bottle and polythene bags in an ice cooler, using Quadrate sampling method according to [14], where a series of square (quadrants) were placed in the habitat of interest and the species of interest identified and collected. The samples were collected from five different sites along the river body named; Nditia, Ukpenekang, Mkpanak, Itak-Abasi and Ikot-Ibok (control site) during dry (Dec. 2022, January-February, 2023) and wet (May- July, 2023) seasons.

2.2.2 Sediment

The sediment samples were collected from the five sites stated above, using Van Veen grab sampler. The samples were placed in on litre amber glass bottles and polythene bags previously acid washed with 3M nitric acid to avoid contamination. It was placed in an ice chest with ice before transporting to the laboratory and thereafter kept under refrigerator and protected from light until analysis to avoid photo degradation of the samples [14].

2.3 Determination of Hydrocarbons

2.3.1 Preparation of Total Petroleum Hydrocarbon (TPH) extraction mixture

TPH extraction mixture was prepared using acetone and dichloromethane was measured into a 1000 ml volumetric flask and properly mixed by swirling the mixture [15].

2.3.2 Determination of TPH and THC from faunas

Total Petroleum Hydrocarbon (TPH) and Total Hydrocarbon content (THC) were determined from *Tympanotomus fuscatus* and *Ostreidae* using gas Chorography fitted with flame ionization detector (GC-FID) as reported by Ikpe et al. [2]. Each of the deshelled fresh fauna samples were cut into pieces using a stainless steel knife and then crushed with the help of porcelain mortar and pestle. 10g of each of the crushed samples were weighed into a 100ml beaker and 60ml of TPH extraction mixture was then added. The beaker with its content was

placed on a magnetic stirrer (with thermostated heater) and shaken for about 15mins at 70^0c [16]. The extract was later decanted into a clean round-bottom flask. 30ml of flesh extraction solvent was added and the process of shaking on the magnetic stirrer repeated. 5g of anhydrous sodium sulphate was used to remove water from the extract. The extract was concentrated to 3 ml with rotary evaporator maintained at 20^0c [17].

1.5 ml of the concentrated extract was loaded on silica gel column. The silica gel column was prepared by loading a 2 g glass wool followed by a 30 chromatography silica gel, onto a chromatography column (2cm internal diameter and 10cm long). Each of the bed was conditioned with 40 ml HPLC-hexane to remove any contaminant.

The 1.5 ml concentrated extract was loaded and eluted with 30 ml HPLC hexane into a well labeled 100 ml beaker to get aliphatic hydrocarbon components in the sample. At a point when the hexane was almost getting dried, Hexane was replaced with 20 ml of dichloromethane to elude the aromatic hydrocarbon content into another labeled 100 ml beaker. 2 g of anhydrous sodium sulphate was added to remove any traces of water left in the extract. The extract were reconcentrated using rotary evaporator to about 2 ml. and 0.01ml of the extract was taken and transferred into a well labeled chromatography vial ready for gas chromatography analysis. The samples were stored at a temperature of -4^0c until GC analysis [18].

2.3.3 Determination of TPH and THC from sediment

In the laboratory, sediment samples were dried at ambient temperature in an open container covered lightly with clean paper and then stored in a clean amber bottle. The samples were ground with a porcelain mortar and then passed through a series of graduated strainers to remove stones and vegetable matter. 10 g of the sample was weighed into a 100ml beaker and the above method for fauna's extraction was repeated for sediment samples using acetone/dichloromethane mixture as extraction solvent [16].

2.4 Determination of Heavy Metals

The faunas and sediment were digested after drying at a temperature of 105^0c for 24 hrs according to AOAC [15] methods. The levels of Pb, Cd, Se, Cr, Cu, Ni, Fe and Zn was determined using buck scientific model 210 VAP (Variable Giant Pulse) atomic absorption spectrophotometer with different hollow Cathode lamp at different wavelength. While Hg and As were determined using graphite furnace Atomic absorption spectrophotometer (Perkin Elmer Model 1100B equipped with an HGA-700 graphite furnace, and deuterium background corrector) because of its higher sensitivity.

The modified method by Adewuyi et al. [19]; [20] was used for sample digestion.The samples were grinded using an acid (3m nitric acid) prewashed mortar and pestle, sieved into a well labeled transparent plastic containers by passing them through 1mm mesh, 1g of each of the sieved samples were accurately weighed into different digestion flask, well clamp to a retort stand. 10ml of ratio 10:1 mixture or Nitric (HNO_3) and perchloric ($HClO_4$) acid were added to the sample in each of the clamped digestion flask, swirled and allowed for some minutes for any reaction to subside. The digestion flasks were mounted on a heating mantle and heating began gradually until appearance of whitish dense fumes where a clear solution is obtained. The digestion flask was removed and allowed to cool. 50ml deionized water was added to the digest filtered (using Whatman's filter paper) and made up to mark of 100ml standard volumetric flask with deionized water. Each of the standard volumetric flasks of the digest were corked, labeled and refrigerated ready for AAS analysis. Before the instrumental analysis stock solutions were prepared from which serial dilutions were made for working standards. Calibration curve for each metal was plotted. The working standards were analyzed first followed by the blank before the samples. The results were subjected to descriptive statistics and modeling.

3. RESULTS AND DISCUSSION

3.1 Variation in pH

Aquatic biota is sensitive to extremes of pH [21]. The negative logarithm of hydrogen ion concentration (pH) of the samples under study during dry and wet season were within the range of 4.73-1032 which corroborates with the similar study undertaken by Vaikosen [3] in the Niger Delta. This implies that waste discharge from the operating oil company and other human activities could have possibly influenced this values as was reported by Umanah [21],[4] where the PH was 5.7 at an effluent discharge point. Generally,

the result obtained from the study area, with exception of the control site fell below (acidic) the World Health Organization (WHO) recommended pH of 6.5 – 9.2. This might be attributed to the oil exploration, exploitation, and gas flaring by the operating oil company as well as other anthropogenic sources. These industrial activities releases carbon dioxide which react with atmospheric precipitation to form carbonic acid, as shown in Fig 1.

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad (3.1)$$

The Niger Delta region is noted for high acidity (low pH) in the mangrove swamp areas. The acid infiltrates the biota and sediment thereby reducing the pH of the swamp as reported by Okuo et al. [22]. The values obtained in the wet season was slightly higher than that of the dry season, possibly, due to increase run-off, tidal incursion and flooding during wet season as well as decrease in evaporation rate, which could not reduce the level of the water body. This further corroborates with the research undertaken by Isichie et al. [23] and Moses et al. [14] who reported higher values of pH in wet than dry season in a related study.

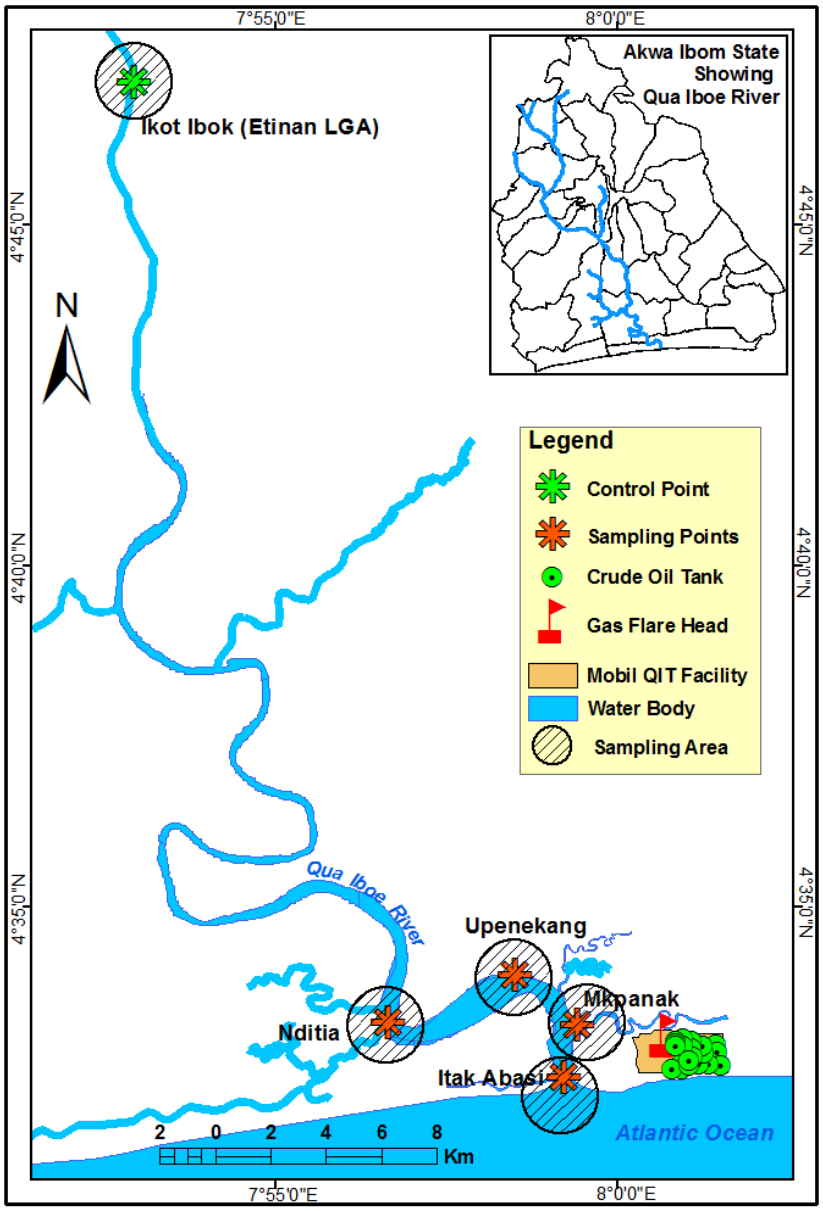

Fig. 1. Location of sampling points along Qua-Iboe river
Source: Ikpe et al., 2023

3.2 Variation in Temperature

The temperature is the degree of hotness or coldness of a body; it is a critical water quality parameter which is directly influence by the amount of dissolved oxygen available to aquatic organism [21].

The temperature ranges of the samples (in-situs) were within the ranges of 27.39 – 28.08c and 26.53 – 27. 62^0c for dry and wet season respectively. The higher values during the dry season could probably be attributed to higher solar radiation [23]. Comparing the values with the World Health Organization [24], it was found to be slightly below the WHO maximum allowable limit of 29.4^0c.

3.3 Descriptive Statistics Showing Heavy Metals Concentration

The descriptive statistics (Tables 2- 3) indicates mean concentration standard error (S.E) and coefficient of variation (C.V) of heavy metals in samples of different sites and seasons.

3.3.1 *Ostreidae* (Oyster)

Heavy metal that exhibited a higher concentration when compared with WHO/ Federal Ministry of Environment [25] standards was Fe > Se > Pb in both seasons. Slight variations indicating higher concentrations noticed in dry than wet seasons. During dry season Fe showed a ranged of 1.0267 – 8.0487 mg/kg, and Pb, 0.0010 – 1.0417 mg.kg. These variations may be due to absorption as a result of reduced level of water in the river as well as seasonal effect of flooding and dilution of trace metal concentration in wet season [13]. These coefficient of variation (CV) showed that the flesh of *Ostreidae* had a high value within the percentage of 0.0144 (Se) to 193.3333% (Pb) across dry and wet seasons which proves stability (low) and instability (high) of the metals in the samples, according to Udosen [26,27]

3.4 *Tympanotomus fuscatus* (Periwinkle)

The presence of some toxic metals in the flesh of *tympanotomus fuscatus* in Table 3. took these sequence across the sites (1-5), during dry season, Cu > Fe > Se > Pb > Zn > Cr > Ni > Hg > Cd > As while in wet season the pattern were: Fe > Se > Cu > Pb > Ni > Cr > Zn > Hg > Cd > As. The seasonal variation of the metals in the samples may be attributed to anthropogenic activities. Adsorption due to reduced level of water body as well as run-off and direction of river flow [28]. Consequently, among the toxic metals available in the samples, mercury toxicity can occur after microbial degradation of mercury to dimethyl mercury. Also human exposure to dimethyl mercury occurs through consumption of contaminated marine or aquatic foods. Gbaruko and Friday [28],[29] reported that Hg affects the central nervous system and brain due to its ability to cross the blood brain barriers. Onianwa *et al.* [30] in a similar study confirms that Hg pollution threat in the river might be attributed to gas flaring, oil exploitation/exploration and from waste discharge by the operating oil company into the river.

The results obtained were higher than the WHO [24] permissible limit of 0.001 – 1.50 mg/kg.

3.5 Sediment

Investigation of sediment (Table 4) indicated the high presence of most of the metals under study. Among such metals are; Fe > Cu > Zn > Ni > Se within both seasons with Fe having the highest mean concentration during wet season, with a value of 86.686 mg/kg which is above WHO/FMEnV (1.0 mg/kg) standard and control (1.0517 mg/kg). The mean concentration of Fe within both seasons could be attributed to run-off during wet season and anthropogenic activities because sediment is at the receiving end, according to Umanah et al. [21] sediment remains pollutant sink. The soluble species of Fe are toxic. It reacts with sulphide in water to form yellow flocculants which could be toxic when picked up by seafood. [32] And [33] in his study suggested that pollution of the environment by Fe cannot be conclusively linked to waste material alone but other natural sources of iron must be taken into consideration. Comparatively, the concentration of iron in sediment in this study exceeded that of previous study by Moses *et al.,* (2015) where 27.04$\pm$ 0.82mg/kg was recorded at Ukpenekang (site 2).

The sediment also exhibited minimal concentration of Arsenic (As) within the mean concentration range of 0.003 – 0.0203mg/kg and a coefficient of variation (CV) of 0.0000 – 193.3333%. The mean concentration of Ni in the sample where slightly less than WHO (0.05 mg/kg) and within the FMEnV (0.2 mg/kg) standard.

Table 1. pH measurement for fauna and sediment during dry & wet seasons

				Dry Season					Wet Season				
S/N	**Sample**	**Biological name**	**Common name**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1.	*Ostreidae*	(Flesh)	Oyster	5.79±0.001	5.81±0.002	5.70±0.006	5.96±0.002	7.90±0.004	5.81±0.001	5.82±0.004	5.71±0.003	5.99±0.000	7.91±0.000
	Ostreidae	(Shell)		8.75±0.002	8.77±0.003	8.09±0.003	9.51±0.003	9.00±0.003	8.78±0.005	8.89±0.001	8.61±0.001	8.52±0.001	9.02±0.001
2.	*Tympanotomus*	*fuscatus (flesh)*	Periwinkle	9.51±0.001	9.49±0.004	8.30±0.0.	8.00±0.001	9.10±0.003	9.51±0.001	9.53±0.003	8.32±0.004	8.01±0.001	9.20±0.006
		(Shell)		10.28±0.01	10.31±0.01	9.00±0.01	8.00±0.01	10.37±0.01	10.31±0.04	10.32±0.01	9.90±0.04	8.42±0.00	10.40±0.02
3.	Sediment	-	-	5.71±0.02	5.60±0.03	4.72±0.06	5.0±0.04	6.40±0.04	5.30±0.09	5.01±0.03	5.00±0.00	4.76±0.01	6.45±0.018

Site 1= Nditia, Site 2 = Ukpenekang, Site 3 = Mkpanak, Site 4= Itak-Abasi, Site 5 = Ikot-Ibok
Maximum permissible limit for biota = 6.5 – 9.2 [30]

Table 2. Descriptive statistics showing heavy metals concentration in *Ostreidae* flesh during dry and wet season

		Site: 1						Site 2					
Season: Dry					**Wet**			**Dry**			**Wet**		
Metal (mg/kg)		**(WHO)**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**CV**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**C.V**
Pb	→	0.01	1.021	±0.005	0.8705	0.7143	0.310	75.2119	1.0423	0.004	0.7455	1.0140	0.006	1.1114
Cd		0.01	0.001	0.0001	173.2051	0.0023	0.0013	98.9743	0.0007	0.000	82.8571	0.0010	0.000	100.00
Cu		1.50	0.0233	0.004	32.1667	0.0140	0.001	14.2857	0.0207	0.000	2.8019	0.00163	0.0012	12.7607
Se		0.001	4.0153	0.003	0.1371	4.0001	0.0003	0.0144	4.0247	0.0074	0.3165	4.0053	0.0022	0.0946
Zn		0.03	0.0770	0.003	6.8721	0.0517	0.0178	59.6661	0.0893	0.0003	0.6495	0.0810	0.004	8.6419
Cr		0.05	0.0803	0.011	24.0843	0.0787	0.009	19.9513	0.0990	0.000	0.0000	0.0917	0.005	0.0432
Ni		1.0	0.0247	0.005	33.0183	0.023	0.002	15.6763	0.0343	0.000	1.6909	0.0287	0.003	20.4181
Hg		0.001	0.0950	0.002	3.7953	0.0783	0.009	20.7945	0.06997	0.300	74.3447	0.0923	0.005	9.7075
As		0.05	0.0033	0.0001	45.8258	0.0013	0.0000	43.3013	0.0037	0.0000	15.6757	0.0013	0.0000	44.6153
Fe		1.00	4.7280	1.8760	68.7283	7.0600	0.0202	0.4962	7.3990	0.3000	7.0345	8.0030	0.0002	0.0432

Table 2. Contd

Site 3 Dry					**Wet**			**Site 4 Dry**					**Wet**
Metal (mg/kg)								**Dry**					
		Mean	**S.E**	**C.V**	**Mean**	**S.E**	**CV**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**C.V**
Pb	→	1.0953	0.003	0.5031	1.0417	0.0012	0.1997	1.0607	0.001	0.001	0.7163	0.318	76.8142
Cd		0.0020	0.0016	50.0000	0.0033	0.001	46.3636	0.0017	0.001	67.6471	0.0027	0.001	77.0370
Cu		0.0507	0.005	16.5483	0.0486	0.004	15.4209	0.0370	0.001	2.8019	0.00163	0.0012	12.7607
Se		4.0403	0.000	0.0143	4.0273	0.0122	0.5247	4.0123	0.001	0.0381	4.0253	0.011	0.5021

Site 3 Dry				Wet			Site 4 Dry			Wet		
Metal (mg/kg)							Dry					
	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Zn	0.0967	0.0012	2.1509	0.0733	0.1729	40.8458	0.0930	0.001	1.0753	0.0680	0.017	44.1912
As	0.0257	0.001	5.9533	0.0237	0.001	10.63291	0.0207	0.001	7.3913	0.0207	0.001	7.3913
Cr	1.0743	0.002	0.2690	1.0700	0.006	0.9009	1.0613	0.001	0.1084	1.0640	0.004	0.6776
Fe	8.04317	0.0038	0.0827	8.0447	0.003	0.0707	7.0580	0.001	0.0283	8.0367	0.0087	0.1864
Ni	1.0317	0.000	0.0562	1.0317	0.001	0.1482	1.0217	0.001	0.0568	1.0270	0.0020	0.3369
Hg	1.0240	0.0200	3.3828	0.6880	0.3155	79.4273	1.0423	0.001	0.1468	0.6850	0.317	80.1547

Table 2. Contd

Site 5 Dry				Wet		
Metal (mg/kg)						
	Mean	S.E	C.V	Mean	S.E	CV
Pb →	0.0003	0.000	193.3333	0.0010	0.0000	0.0000
Cd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cu	0.0027	0.0000	21.481	0.0013	0.000	44.6154
Se	0.0030	0.0058	33.3333	0.0023	0.0023	25.2174
Zn	0.0120	0.0010	14.4167	0.0123	0.000	12.4390
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cr	0.0017	0.00033	34.1177	0.0010	0.000	0.0000
Fe	1.0267	0.0015	0.2454	1.0250	0.0021	0.3522
Ni	0.0010	0.001	100.0000	1.0247	0.001	0.2029
Hg	0.0010	0.0000	0.0000	0.0010	0.0000	0.0000

Table 3. Descriptive statistics showing heavy metals concentration in *Tympanotomus fuscatus* (Tissue) during dry and wet season

Site: 1 Season: Dry					Wet			Site 2 Dry				Wet	
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Pb		1.0533	0.0093	1.5347	1.0366	0.0129	2.1576	1.0710	0.0000	0.0000	1.3580	0.3218	40.044
Cd		0.0006	0.0006	173.2051	0.0023	0.0012	89.2142	0.0000	0.000	0.000	0.0297	0.02867	167.1710
Cu		0.0036	0.0008	41.6597	0.0016	0.0003	34.6410	0.0057	0.0008	26.8421	3.3387	3.3356	173.0470
Se		4.0666	0.0103	0.4407	3.7206	0.3393	15.7994	4.0903	0.0003	0.1041	4.4063	0.3273	12.8681
Zn		1.0506	1.0146	167.2711	0.0346	0.0023	11.6580	1.3933	1.3483	167.6150	0.0427	0.0066	27.1428
As		0.0153	0.0128	145.0018	0.3546	0.3531	172.4726	0.0173	0.0133	133.6416	0.0193	0.01129	101.2951
Cr		1.0813	0.0057	0.9263	3.0546	2.4995	141.7276	1.0900	0.0005	0.0917	1.0853	0.0084	1.3424
Fe		9.013	0.002	0.0384	6.0363	2.9997	86.0727	9.0210	0.0005	0.0110	9.0407	0.0179	0.3443
Ni		0.0696	0.0081	20.1639	0.0553	0.0031	9.9534	0.0797	0.0093	20.4015	0.3770	0.3235	148.6361
Hg		0.0533	0.0039	12.7628	0.0403	0.0097	41.8070	0.0603	0.0003	0.9618	0.2213	0.1448	113.4021

Table 3. Contd

Site: 3 Season: Dry					Wet			Site 4 Dry			Wet		
Metal (mg/kg)	**(WHO)**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**CV**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**C.V**
Pb		2.0007	0.0003	0.0289	1.4013	0.3043	37.6165	1.6997	0.3008	30.656	1.3923	0.3038	37.8038
Cd		0.0880	0.0015	3.0113	0.0503	0.0182	2.9423	0.0800	0.0086	18.6625	0.0487	0.0239	85.0102
Cu		10.0113	0.0008	0.0152	0.0113	0.0014	22.3008	10.0097	0.0024	0.04156	3.3427	3.3311	172.6075
Se		5.0627	0.0016	0.05770	5.0587	0.0003	0.0114	5.0573	0.0063	0.216914	5.0430	0.0011	0.0396
Zn		0.0557	0.0033	1.0412	0.0547	0.0014	4.6069	0.0543	0.0016	5.3222	0.0517	0.0006	2.2243
As		0.0143	0.0003	4.0559	0.0133	0.0003	4.3609	0.0133	0.0012	15.6391	0.0113	0.0003	5.1327
Cr		1.0990	0.0000	0.0000	1.0910	0.0037	0.6012	1.0907	0.0083	1.3230	1.0830	0.0058	0.9372
Fe		9.0450	0.0005	0.0110	9.0430	0.0020	0.0399	9.0380	0.0075	0.1438	9.0343	0.0059	0.1135
Ni		1.0257	0.0008	0.1491	1.2233	0.1988	28.1525	1.0233	0.0031	0.5384	1.0217	0.0029	0.4923
Hg		0.7003	0.3006	74.3638	0.6983	0.3026	75.0723	0.6930	0.3080	76.9798	0.3923	0.3048	134.6138

Table 3. Contd

Site: 3 Season: Dry					Wet			Site 4 Dry			Wet		
Metal (mg/kg)	**(WHO)**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**CV**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**C.V**
Pb		2.0007	0.0003	0.0289	1.4013	0.3043	37.6165	1.6997	0.3008	30.656	1.3923	0.3038	37.8038
Cd		0.0880	0.0015	3.0113	0.0503	0.0182	2.9423	0.0800	0.0086	18.6625	0.0487	0.0239	85.0102
Cu		10.0113	0.0008	0.0152	0.0113	0.0014	22.3008	10.0097	0.0024	0.04156	3.3427	3.3311	172.6075
Se		5.0627	0.0016	0.05770	5.0587	0.0003	0.0114	5.0573	0.0063	0.216914	5.0430	0.0011	0.0396
Zn		0.0557	0.0033	1.0412	0.0547	0.0014	4.6069	0.0543	0.0016	5.3222	0.0517	0.0006	2.2243
As		0.0143	0.0003	4.0559	0.0133	0.0003	4.3609	0.0133	0.0012	15.6391	0.0113	0.0003	5.1327
Cr		1.0990	0.0000	0.0000	1.0910	0.0037	0.6012	1.0907	0.0083	1.3230	1.0830	0.0058	0.9372
Fe		9.0450	0.0005	0.0110	9.0430	0.0020	0.0399	9.0380	0.0075	0.1438	9.0343	0.0059	0.1135
Ni		1.0257	0.0008	0.1491	1.2233	0.1988	28.1525	1.0233	0.0031	0.5384	1.0217	0.0029	0.4923
Hg		0.7003	0.3006	74.3638	0.6983	0.3026	75.0723	0.6930	0.3080	76.9798	0.3923	0.3048	134.6138

Table 3. Contd

Site: 5 Season: Dry					Wet			Site Dry			Wet		
Metal (mg/kg)	**(WHO)**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**CV**	**Mean**	**S.E**	**C.V**	**Mean**	**S.E**	**C.V**
Pb		0.0017	0.0006	67.6470	0.0017	0.0003	34.1176						
Cd		0.000	0.0000	0.0000	0.0000	0.0000	0.0000						

Site: 5 Season: Dry					Wet			Site Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Cu		0.0013	0.0003	44.6153	0.0010	0.0000	0.0000						
Se		0.0023	0.0003	44.6153	0.0010	0.0000	0.0000						
Zn		0.0183	0.0003	3.1693	0.0147	0.0013	15.7142						
As		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000						
Cr		0.0013	0.0003	44.6153	0.0010	0.0000	0.0000						
Fe		1.0313	0.0003	0.0563	1.0189	0.0081	1.3828						
Ni		0.0017	0.0006	67.6470	1.02383	0.0006	0.1118						
Hg		0.0030	0.0000	0.0000	0.0010	0.0000	0.0000						

Table 4. Descriptive statistics showing heavy metals concentration in sediment during dry and wet season

Site: 1 Season: Dry					Wet			Site 2 Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Pb		1.7323	0.6338	63.3730	1.3993	0.3033	37.5459	2.3447	0.3321	24.5383	2.0038	0.0033	0.2880
Cd		0.0523	0.0056	18.7546	0.0413	0.0110	46.3060	0.0650	0.0023	6.1538	0.2220	0.1843	143.8108
Cu		0.0170	0.0040	41.1764	1.0360	0.5746	96.0769	3.3777	3.3561	172.1008	1.3393	0.6621	85.6350
Se		1.4103	0.3153	38.7275	1.3883	0.3059	38.1735	2.0037	0.0013	0.1152	2.0037	0.0017	0.1527
Zn		5.7060	0.3291	9.9912	5.6876	0.3218	9.8009	6.0390	0.0138	0.3977	6.0153	0.0027	0.0786
As		0.0030	3.0731	1.7731	0.0053	0.0033	109.8650	0.0037	0.0003	15.6756	0.0037	0.0003	15.6756
Cr		0.0186	0.0014	13.4818	0.0156	0.0008	9.7501	0.0203	0.0008	7.5369	0.0177	0.0003	3.2768
Fe		52.7239	6.5515	21.5226	49.1050	4.5153	16.2830	62.7007	0.3483	0.9623	60.3493	0.8766	2.5159
Ni		0.0190	0.0015	13.9250	0.0170	0.0030	30.5656	0.0210	0.0005	4.7619	0.01503	0.0647	74.5979
Hg		1.0193	0.0118	2.0208	0.0600	0.0299	86.3294	1.0163	0.0129	2.2011	0.3950	0.3025	132.6456

Table 4. Contd

Site: 3 Season: Dry					Wet			Site 4 Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Pb		2.0263	0.0063	0.5438	2.0087	0.0014	0.1254	2.0153	0.0041	0.3587	1.6977	0.3088	31.5085
Cd		0.0083	0.0008	2.2401	0.0270	0.0017	11.1111	0.0287	0.0018	11.1846	0.0267	0.0017	11.4606
Cu		10.0193	0.0038	0.0664	10.0197	0.0051	0.0894	10.0163	0.0013	0.0230	0.0180	0.0045	43.3888
Se		3.0273	0.0013	0.0763	3.3687	0.3287	16.9014	2.0077	0.0008	0.0762	3.3670	0.3275	16.8500
Zn		8.0383	0.0023	0.0502	8.0350	0.0023	0.0497	8.0240	0.0011	0.0249	6.3973	0.3343	9.0528

Site: 3 Season: Dry					Wet			Site 4 Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
As		0.0207	0.0003	2.8019	0.0203	0.0008	7.5369	0.0317	0.0191	104.8265	0.0190	0.0011	10.5263
Cr		2.0523	0.0003	0.0282	2.0547	0.0032	0.2769	2.0570	0.0011	0.0972	2.0533	0.0033	0.2853
Fe		73.6910	6.6670	15.6702	86.6860	0.3340	0.6673	62.7010	0.3449	0.9529	27.3510	0.3325	2.1057
Ni		5.0413	0.0008	0.0303	5.0413	0.0008	0.0303	5.0380	0.0010	0.0343	5.0397	0.0003	0.0115
Hg		1.0530	0.0015	0.2516	1.0510	0.0011	0.1902	1.0540	0.0035	0.5768	1.0500	0.0005	0.0952

Table 4. Contd

Site: 3 Season: Dry					Wet			Site 4 Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Pb		2.0007	0.0003	0.0289	1.4013	0.3043	37.6165	1.6997	0.3008	30.656	1.3923	0.3038	37.8038
Cd		0.0880	0.0015	3.0113	0.0503	0.0182	2.9423	0.0800	0.0086	18.6625	0.0487	0.0239	85.0102
Cu		10.0113	0.0008	0.0152	0.0113	0.0014	22.3008	10.0097	0.0024	0.04156	3.3427	3.3311	172.6075
Se		5.0627	0.0016	0.05770	5.0587	0.0003	0.0114	5.0573	0.0063	0.216914	5.0430	0.0011	0.0396
Zn		0.0557	0.0033	1.0412	0.0547	0.0014	4.6069	0.0543	0.0016	5.3222	0.0517	0.0006	2.2243
As		0.0143	0.0003	4.0559	0.0133	0.0003	4.3609	0.0133	0.0012	15.6391	0.0113	0.0003	5.1327
Cr		1.0990	0.0000	0.0000	1.0910	0.0037	0.6012	1.0907	0.0083	1.3230	1.0830	0.0058	0.9372
Fe		9.0450	0.0005	0.0110	9.0430	0.0020	0.0399	9.0380	0.0075	0.1438	9.0343	0.0059	0.1135
Ni		1.0257	0.0008	0.1491	1.2233	0.1988	28.1525	1.0233	0.0031	0.5384	1.0217	0.0029	0.4923
Hg		0.7003	0.3006	74.3638	0.6983	0.3026	75.0723	0.6930	0.3080	76.9798	0.3923	0.3048	134.6138

Table 4. Contd

Site: 5 Season: Dry					Wet			Site Dry			Wet		
Metal (mg/kg)	(WHO)	Mean	S.E	C.V	Mean	S.E	CV	Mean	S.E	C.V	Mean	S.E	C.V
Pb		0.0560	0.0000	0.0000	0.0527	0.0008	2.9032						
Cd		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000						
Cu		0.0020	0.00058	50.0000	0.0017	0.0003	34.1176						
Se		0.0033	0.0006	34.8484	0.0023	0.0003	25.2173						
Zn		0.0230	0.0015	11.5217	0.0890	0.0655	127.4719						
As		0.0003	0.0003	193.3333	0.0000	0.0000	0.0000						
Cr		0.0050	0.0035	121.6000	0.0010	0.0000	0.0000						
Fe		1.0517	0.0017	0.2909	1.0497	0.0014	0.2400						
Ni		0.0037	0.0008	41.3513	0.0047	0.0003	12.3404						
Hg		0.0013	0.0003	44.6153	0.0017	0.0003	34.1176						

On the whole the mean values recorded in wet were slightly higher than in dry season, this may be due to run-off, tidal incursion and flooding. This corroborated with the research undertaken by Vaikosen *et al.* [3] who reported a higher value of heavy metals in wet than dry season. Moreso, the study is in consistent with the result of other studies [28] and [8]. Furthermore, Arsenic (As) is not an essential element for human physiology, but it is regularly found in tissue in very small quantity. Environment pollution by Arsenic may arise from agriculture practices (Weed, Killer, Fungicides, rodenticides and insecticides) and from industries. [24] Confirmed that Arsenic and Arsenical compounds are found in waste waters of metallurgical industry, glassware, ceramic production, tannery operations, dye, herbicides and pesticides manufactured. Other industrial sources include the organic chemicals and petroleum refining industries. Arsenic has serious effect on health and environment inorganic arsenic can produce acute and chronic effect in the respiratory organs, gastrointestinal tract, skin, cardiovascular system, nervous system and blood forming organ due to detrimental effect pose by this heavy metal there is urgent need for remediation, routine monitoring and legislation on waste dumping into the river.

3.6 TRANSFER FACTOR (T.F)

TRANSFER FACTOR (T.F) is a powerful tool for processing the bioaccumulation information for sediment and biota [35]. In support of this Olanescu [36] came up with an equation to established the heavy metal transfer from sediment in biota to be;

$$TF = MB/Ms$$

Where;

TF - Transfer factor

MB - Metal content in biota (fauna or flora)

Ms -mental content in sediment (mg/kg)

The transfer factor (Table 5–6) has appropriately assessed the fauna and sediment during dry and wet season, most of the metals have shown a transfer factor greater than 1 in samples, which calls for concerned. This confirmed bioaccumulation of the metals from sediment. These observations are in line with data of [35], who research on heavy metal content in water, sediment and fish from lagoon system. The variability of the transfer factor in the samples was further confirmed through a research carried-out by Nasir and Al-Najare [36].

3.7 Predictive Modeling of Heavy Metals, TPH and THC in Qua Iboe River

The applicability of regression techniques in the prediction of contaminants concentration in tissues and organs of aquatic biota is well established in literature [11]. This applicability stems from the fact that a regression technique derives a relationship between pairs of variables, in that it predicts the value of one (dependent) from the other (predictor) [37]. This is evident in this study. However, the prediction of hydrocarbons (TPH & THC) and heavy metals concentrations in the flesh of *Ostreidae* and *Tympanotomus fuscatus* from its shell concentration at highly significant statistical level ($P-\leq 0.05$) shown in Table 7 – 10 is an indication that the shell concentration is a good indicator of concentration of this pollutant in the flesh.

According to the models in Table 7, it showed that the power model best predict the relationship between Pb, Se, Zn, Cr, Ni and Hg in the shell in comparison with the flesh. Linear model best predict the relationship between Cd and As in the shell in comparison with the flesh.

Table 5. Transfer factor for *Ostreidae* flesh during dry and wet season

Site	1		2		3		4		5	
Metal (mg/kg)	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Pb	0.5395	0.5105	0.4445	0.5062	0.5905	0.5186	0.5263	0.4219	0.0054	0.0190
Cd	0.0191	0.0564	0.0108	0.0045	0.0293	0.1222	0.0592	0.1011	0.0000	0.0000
Cu	1.3706	0.0135	0.0061	0.0122	0.0051	0.0049	0.0037	2.000	1.3500	0.7647
Se	2.8471	2.8816	2.0086	1.9990	1.3346	1.1955	1.9985	1.1955	0.9091	1.0000
Zn	0.0135	0.0091	0.0148	0.0135	0.0120	0.0091	0.0116	0.0106	0.5217	0.1382
As	1.1009	0.0624	1.0000	0.3514	1.2415	1.1675	0.5630	1.089	0.0000	0.0000
Cr	4.3034	5.0212	4.8768	5.1808	0.5235	0.5208	0.5159	0.5182	0.3400	1.0000
Fe	0.0897	0.1438	0.1180	0.1326	0.1092	0.0928	0.1126	0.2938	0.9762	0.99765
Ni	1.2983	1.3539	1.6333	0.1910	0.2046	0.2046	0.2038	0.2038	0.2703	218.0212
Hg	0.00939	1.3056	0.6885	0.02337	0.9725	0.6546	0.9889	0.6424	0.7692	0.5880

None of the three models were able to predict the relationship between the metal concentration of Cu and Fe in flesh and shell of *Ostrediae* (oyster) which could be attributed to similar concentration of the metal at different stations of study [13].

Fig. 2 – 13. Showed the plot of the measured and the predicted concentration of metals and THC/TPH in the fauna. Positive correlation exists between the measured and the predicted values. The line plot explained the same pattern for the measured and the predicted levels of heavy metals, TPH and THC. This is an indication that the developed models performed well.

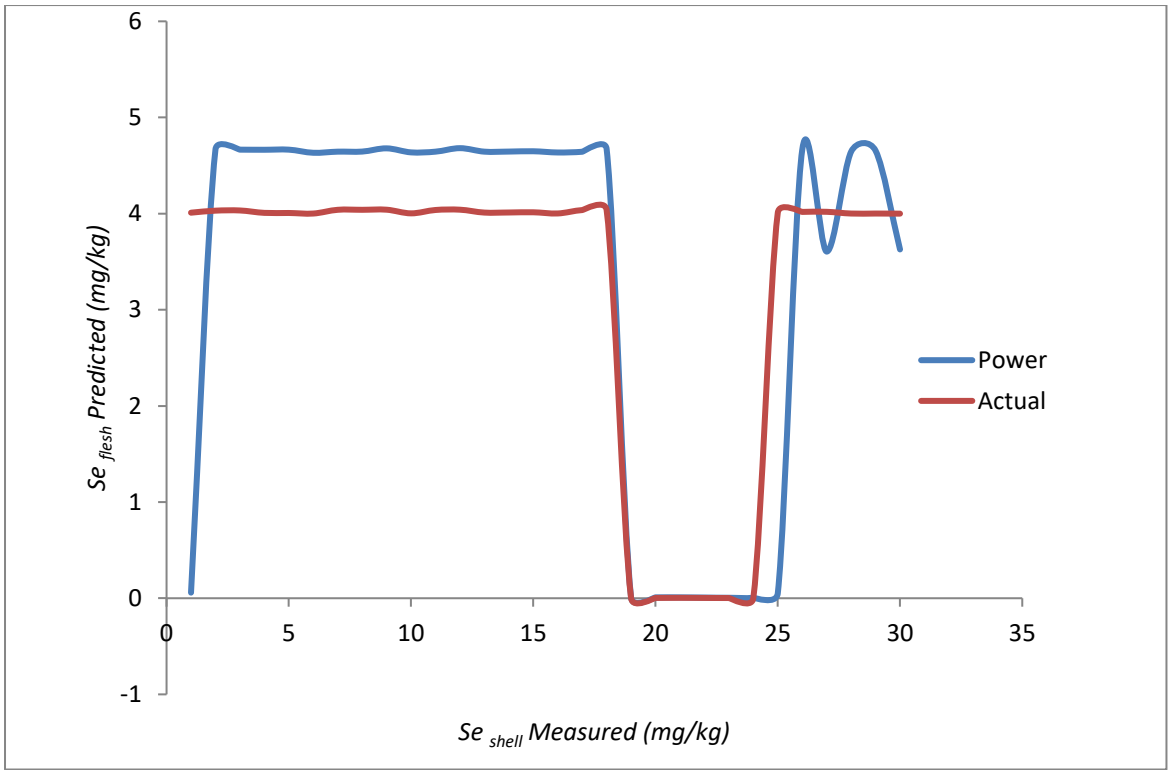

Fig. 2. Graphical pattern of predicted Se conc. in *Ostreidae* flesh against measured value

Table 6. Transfer factor for *Tympanotomus fuscatus* flesh during dry and wet season

Site	1		2		3		4		5	
Metal (mg/kg)	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Pb	0.6080	0.7408	0.4568	0.6779	0.9874	0.6976	0.8434	0.8201	0.0304	0.323
Cd	0.0127	0.0564	0.0000	0.1338	1.2884	1.8630	2.7875	1.8240	0.0000	0.0000
Cu	0.2157	0.0016	0.0017	2.4929	0.9992	0.0011	2.9993	185.7056	0.6500	0.5882
Se	2.8835	2.67100	2.0414	2.1991	1.6723	1.5017	2.5190	1.4978	0.6970	0.7391
Zn	0.1841	0.0061	0.2307	0.0071	0.0069	0.0068	0.0068	0.0081	0.7057	0.1652
As	5.1110	66.5042	4.6757	5.2162	0.6908	0.6552	0.4196	0.5947	0.0000	0.0000
Cr	57.9275	194.9746	53.6946	61.3164	0.5355	0.5310	0.5302	0.5274	0.2600	1.000
Fe	0.1709	0.1229	0.1439	0.1498	0.1227	0.1043	0.1441	0.3303	0.9806	0.9707
Ni	3.6667	3.2549	3.7952	2.5083	0.2035	0.2427	0.2031	0.2027	0.4595	218.7872
Hg	0.0527	0.6722	0.0593	0.5603	0.6651	0.6644	0.6575	0.3736	2.3077	0.5882

Table7. Comparison of different regression models predicting heavy metals concentrations of the flesh of the Oyster from the shell concentration

Linear			Power			Exponential		
Equation	R^2	P	Equation	R^2	p	Equation	R^2	P
$Pb_{flesh} = 0.36 + 0.62Pb_{shell}$	0.461	0.000	$Pb_{flesh} = 1.09(Pb_{shell})^{0.91}$	0.842	0.000	$Pb_{flesh} = 0.02e^{3.90Pb\_shell}$	0.505	0.000
$Cd_{flesh} = 0.001 + 0.16Cd_{shell}$	0.444	0.001	$Cd_{flesh} = 0.02(Cd_{shell})^{0.38}$	0.319	0.009	$Cd_{flesh} = 0.001e^{59.66Cd_{shell}}$	0.341	0.007
$Cu_{flesh} = 0.03 - 0.001Cu_{shell}$	0.002	0.832	$Cu_{flesh} = 0.16(Cu_{shell})^{0.57}$	0.507	0.000	$Cu_{flesh} = 0.02e^{0.09Cu_{shell}}$	0.003	0.789
$Se_{flesh} = 1.03 + 0.001Se_{shell}$	0.679	0.000	$Se_{flesh} = 1.33(Se_{shell})^{0.90}$	0.834	0.000	$Se_{flesh} = 0.02e^{1.38Se_{shell}}$	0.677	0.000
$Zn_{flesh} = 0.04 + 0.60Zn_{shell}$	0.375	0.000	$Zn_{flesh} = 0.50(Zn_{shell})^{0.65}$	0.408	0.000	$Zn_{flesh} = 0.03e^{13.60Zn_{shell}}$	0.309	0.001
$As_{flesh} = -0.001 + 0.90As_{shell}$	0.847	0.000	$As_{flesh} = 0.44(As_{shell})^{0.88}$	0.694	0.000	$As_{flesh} = 0.002e^{103.95As_{shell}}$	0.751	0.000
$Cr_{flesh} = 0.03 + 0.79Cr_{shell}$	0.682	0.000	$Cr_{flesh} = 0.68(Cr_{shell})^{0.84}$	0.694	0.000	$Cr_{flesh} = 0.01e^{3.57Cr_{shell}}$	0.567	0.000
$Fe_{flesh} = 6.00 + 0.001Fe_{shell}$	0.006	0.689	$Fe_{flesh} = 4.15(Fe_{shell})^{0.13}$	0.061	0.189	$Fe_{flesh} = 4.66e^{0.00Fe_{shell}}$	0.009	0.619
$Ni_{flesh} = 0.38 + 0.29Ni_{shell}$	0.154	0.035	$Ni_{flesh} = 0.61(Ni_{shell})^{0.69}$	0.520	0.000	$Ni_{flesh} = 0.07e^{1.23Ni_{shell}}$	0.153	0.036
$Hg_{flesh} = 0.10 + 0.899Hg_{shell}$	0.759	0.000	$Hg_{flesh} = 1.29(Hg_{shell})^{1.03}$	0.930	0.000	$Hg_{flesh} = 0.02e^{3.93Hg_{shell}}$	0.503	0.000

Table 8. Comparison of different regression models predicting heavy metals concentrations of the flesh of the periwinkle from the shell concentration

Linear			Power			Exponential		
Equation	R^2	P	Equation	R^2	p	Equation	R^2	P
$Pb_{flesh} = 0.03 + 1.00Pb_{shell}$	0.910	0.000	$Pb_{flesh} = 1.02(Pb_{shell})^{1.00}$	0.998	0.000	$Pb_{flesh} = 0.01e^{3.61Pb_{shell}}$	0.719	0.000
$Cd_{flesh} = 0.001 + 0.90Cd_{shell}$	0.743	0.000	$Cd_{flesh} = 0.46(Cd_{shell})^{0.81}$	0.807	0.000	$Cd_{flesh} = 0.002e^{47.14Cd_{shell}}$	0.846	0.000
$Cu_{flesh} = 0.39 + 0.96Cu_{shell}$	0.800	0.000	$Cu_{flesh} = 0.65(Cu_{shell})^{0.98}$	0.766	0.000	$Cu_{flesh} = 0.004e^{0.77Cu_{shell}}$	0.754	0.000
$Se_{flesh} = 0.54 + 1.06Se_{shell}$	0.902	0.000	$Se_{flesh} = 1.17(Se_{shell})^{1.07}$	0.995	0.000	$Se_{flesh} = 0.008e^{1.64Se_{shell}}$	0.767	0.000
$Zn_{flesh} = -0.002 + 1.18Zn_{shell}$	0.980	0.000	$Zn_{flesh} = 0.58(Zn_{shell})^{0.76}$	0.768	0.000	$Zn_{flesh} = 0.03e^{1.54Zn_{shell}}$	0.875	0.000
$As_{flesh} = 0.009 + 2.20As_{shell}$	0.071	0.209	$As_{flesh} = 1.00(As_{shell})^{1.02}$	0.715	0.000	$As_{flesh} = 0.005e^{38.96As_{shell}}$	0.487	0.000
$Cr_{flesh} = 0.62 + 0.35Cr_{shell}$	0.038	0.301	$Cr_{flesh} = 0.67(Cr_{shell})^{1.04}$	0.926	0.000	$Cr_{flesh} = 0.007e^{2.92Cr_{shell}}$	0.616	0.000

$Fe_{flesh} = 4.39 + 0.54Fe_{shell}$	0.344	0.001	$Fe_{flesh} = 1.52(Fe_{shell})^{0.89}$	0.377	0.000	$Fe_{flesh} = 2.03e^{0.17Fe_{shell}}$	0.256	0.004
$Ni_{flesh} = 0.009 + 1.02Ni_{shell}$	0.957	0.000	$Ni_{flesh} = 1.11(Ni_{shell})^{1.05}$	0.971	0.000	$Ni_{flesh} = 0.032e^{3.30Ni_{shell}}$	0.792	0.000

Table 9. Comparison of different regression models predicting THC of the shell and flesh of Oyster from TPH

Linear			Power			Exponential		
Equation	**R^2**	**P**	**Equation**	**R^2**	**p**	**Equation**	**R^2**	**P**
$THC_{shell} = 11.96 + 2.13TPH_{shell}$	0.956	0.000	$THC_{shell} = 2.75(TPH_{shell})^{0.96}$	0.980	0.000	$THC_{shell} = 92.07e^{0.007TPH_{shell}}$	0.940	0.000
$THC_{flesh} = 23126.73 + 2.27TPH_{flesh}$	0.746	0.000	$THC_{flesh} = 0.03(TPH_{flesh})^{1.41}$	0.831	0.000	$THC_{flesh} = 2474.92e^{6.14E-05TPH_{flesh}}$	0.612	0.000

Table 10. Comparison of different regression models predicting THC of the shell and flesh of Periwinkle from TPH

Linear			Power			Exponential		
Equation	**R^2**	**P**	**Equation**	**R^2**	**p**	**Equation**	**R^2**	**P**
$THC_{shell} = 8.62 + 1.88TPH_{shell}$	0.909	0.000	$THC_{shell} = 8.87(TPH_{shell})^{0.76}$	0.968	0.000	$THC_{shell} = 133.00e^{0.003TPH_{shell}}$	0.989	0.000
$THC_{flesh} = 663.15 + 1.28TPH_{flesh}$	0.832	0.000	$THC_{flesh} = 292.94(TPH_{flesh})^{0.23}$	0.701	0.000	$THC_{flesh} = 716.690e^{0.001TPH_{flesh}}$	0.846	0.000

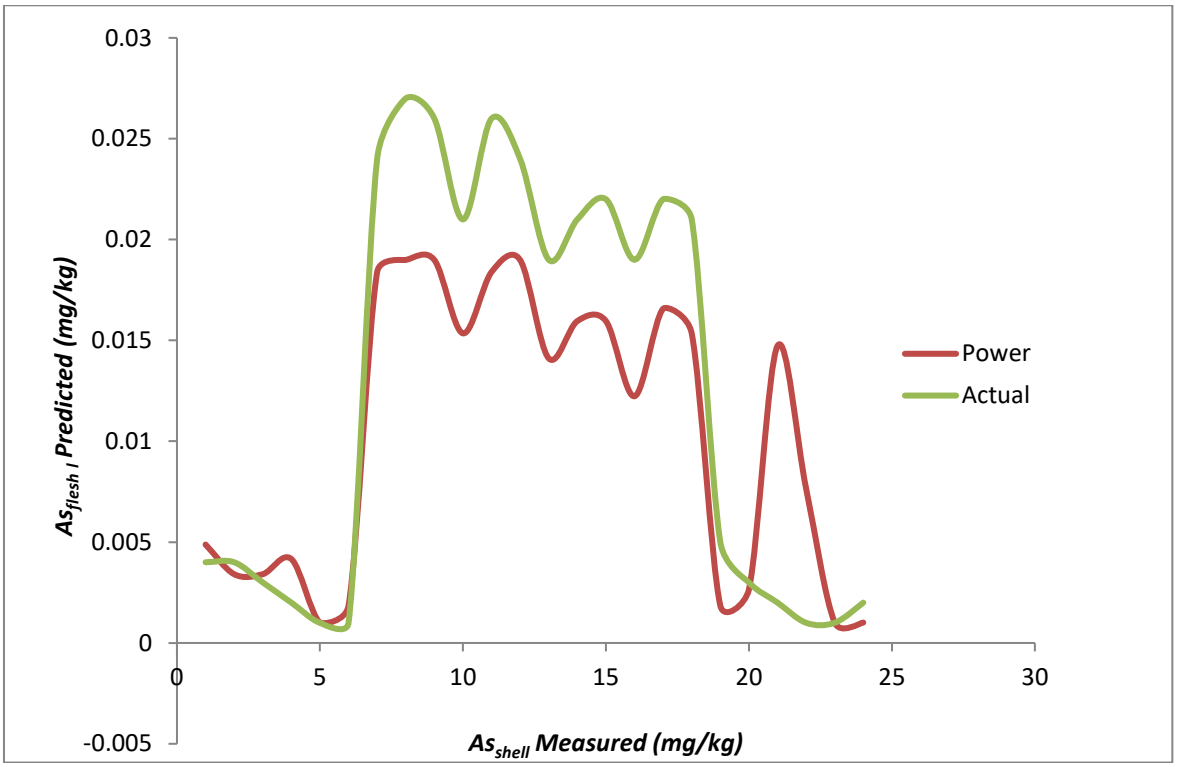

Fig. 3. Graphical pattern of predicted As conc. in *Ostreidae* flesh against measured value

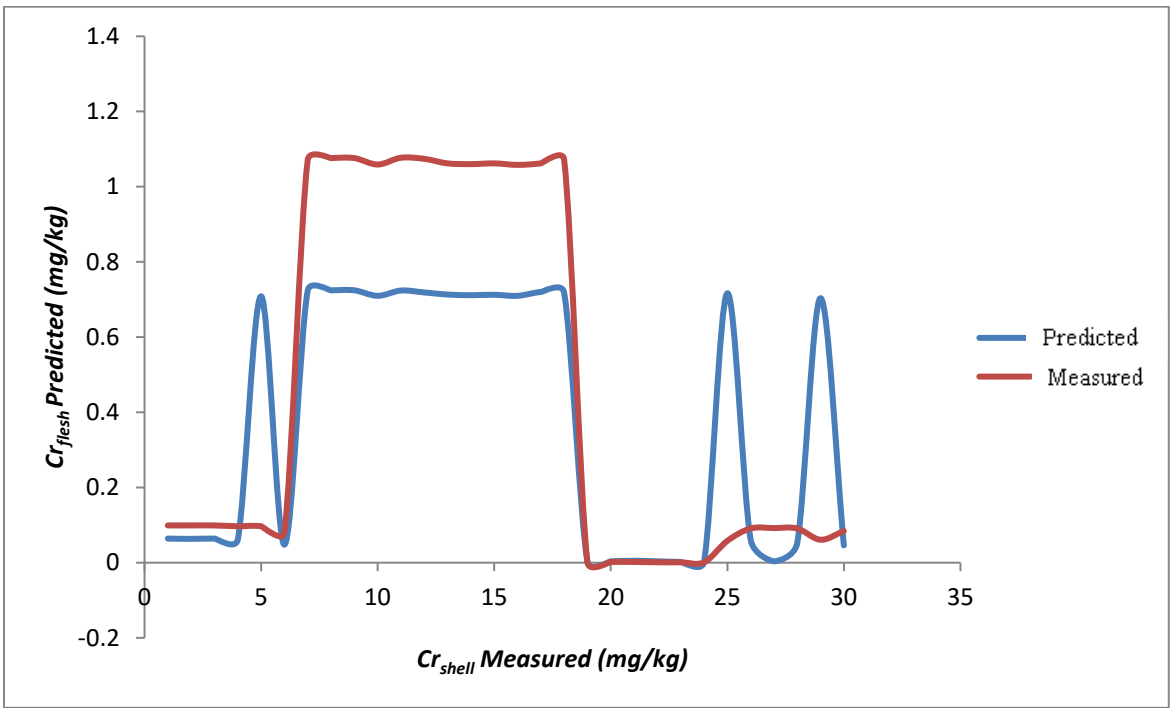

Fig. 4. Graphical pattern of predicted Cr conc. in *Ostreidae* flesh against measured value

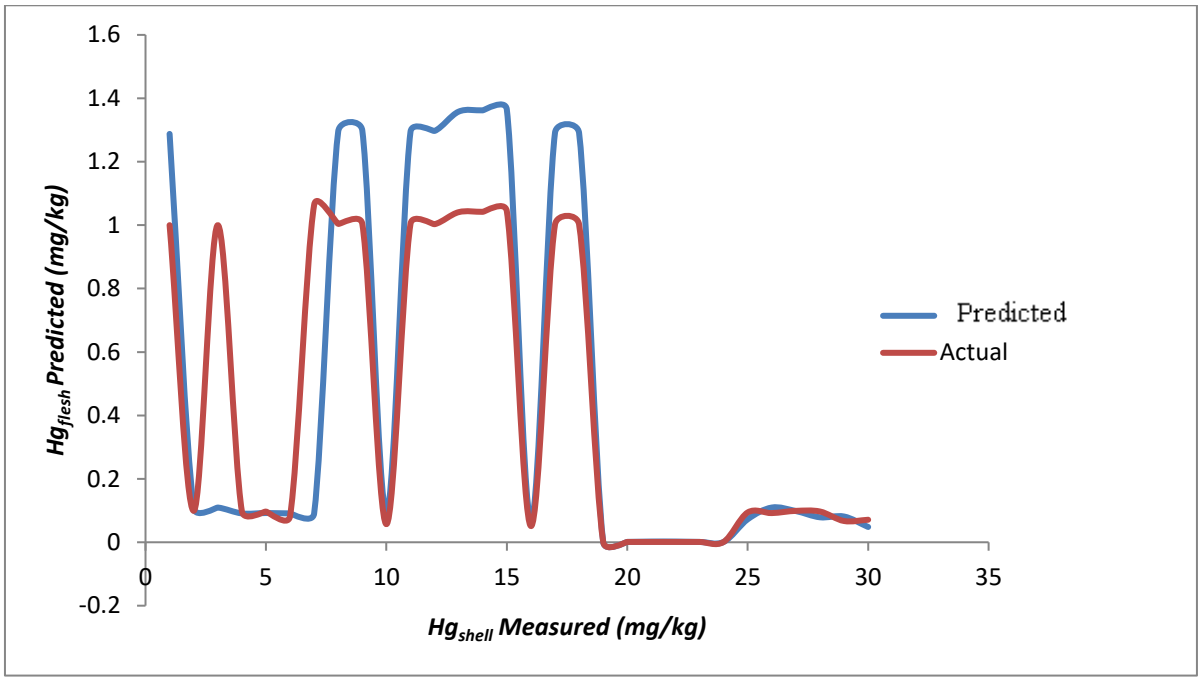

Fig. 5. Graphical pattern of predicted Hg conc. in *Ostreidae* flesh against measured value

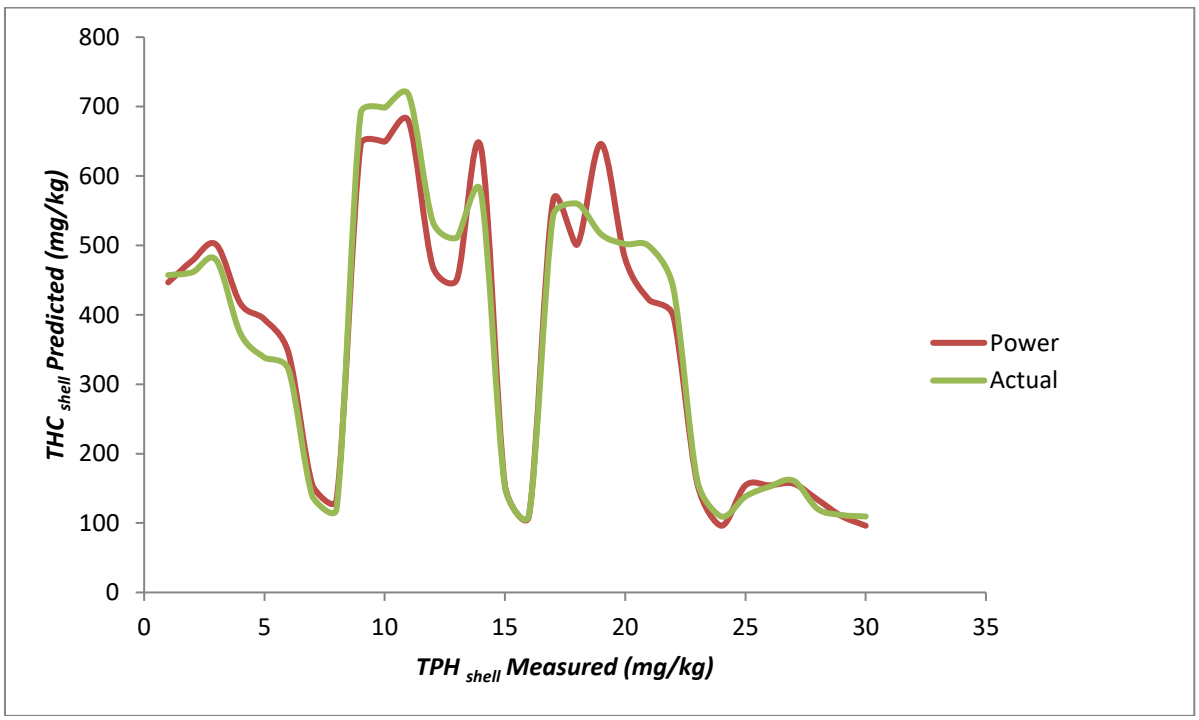

Fig. 6. Graphical pattern of predicted THC shell conc. in *Ostreidae* flesh against measured value

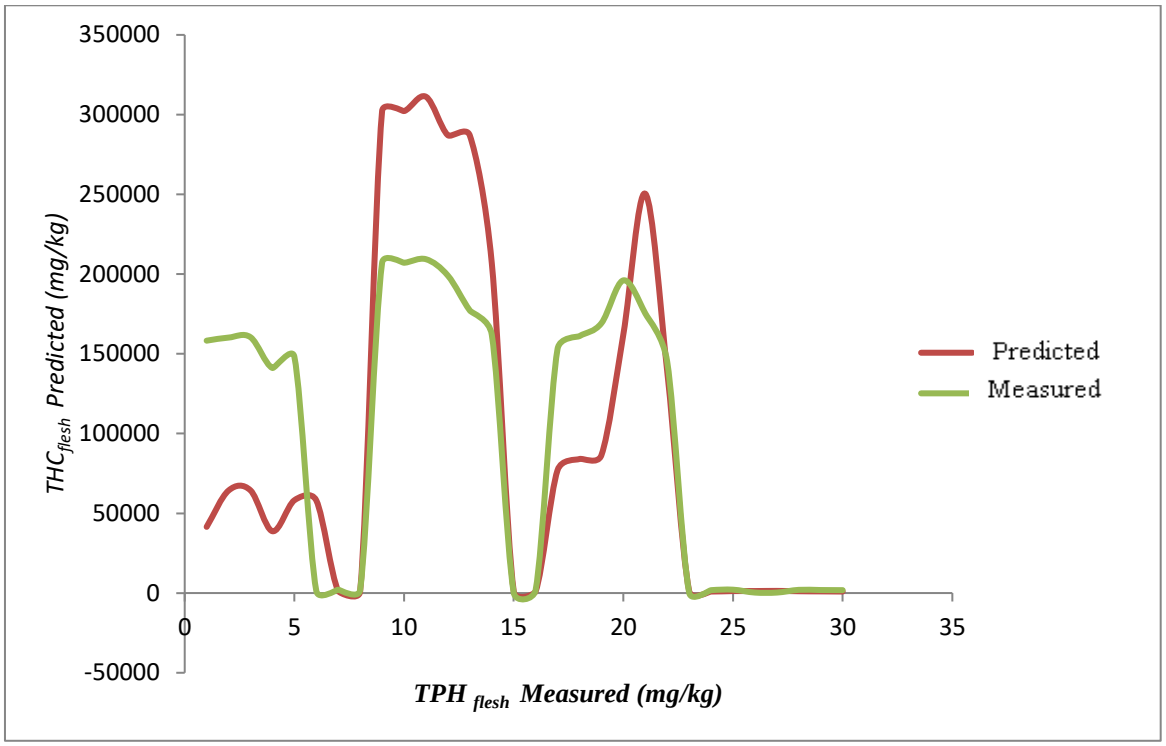

Fig. 7. Graphical pattern of predicted THC flesh conc. in *Ostreidae* flesh against measured value

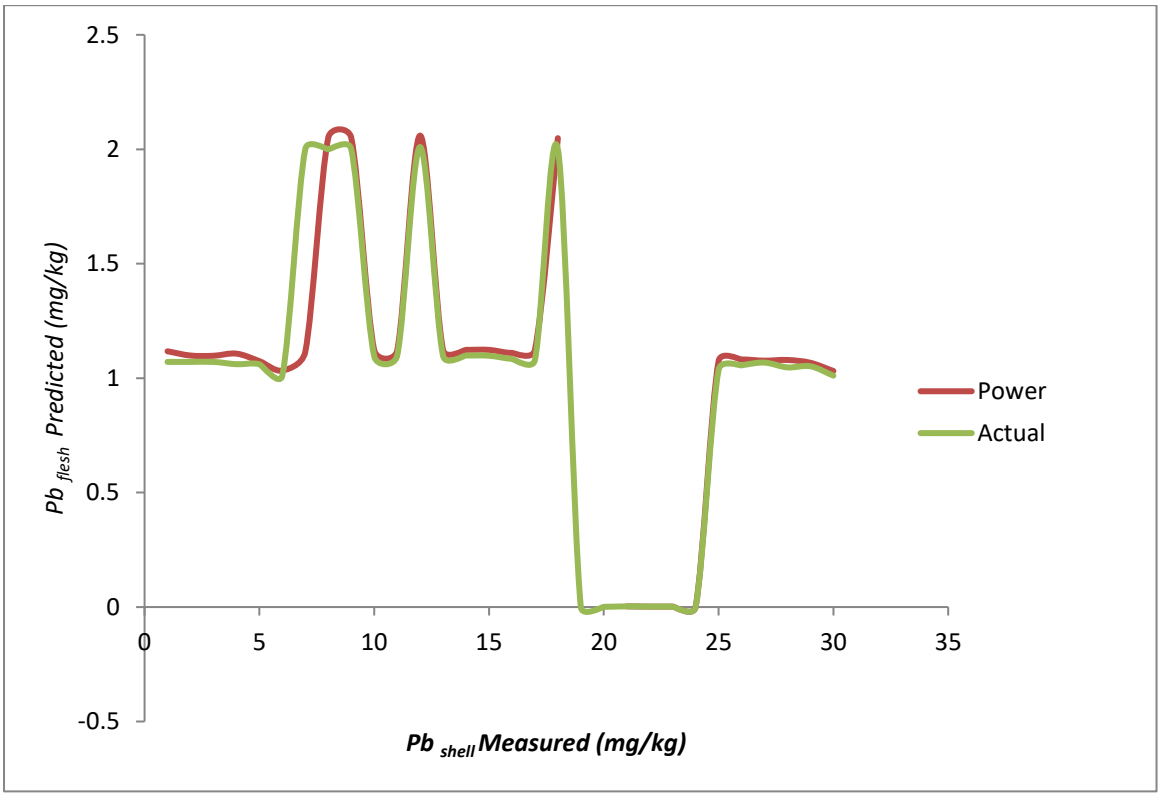

Fig. 8. Graphical pattern of predicted Pb conc. in *Tympanotomus fuscatus* flesh against measured value

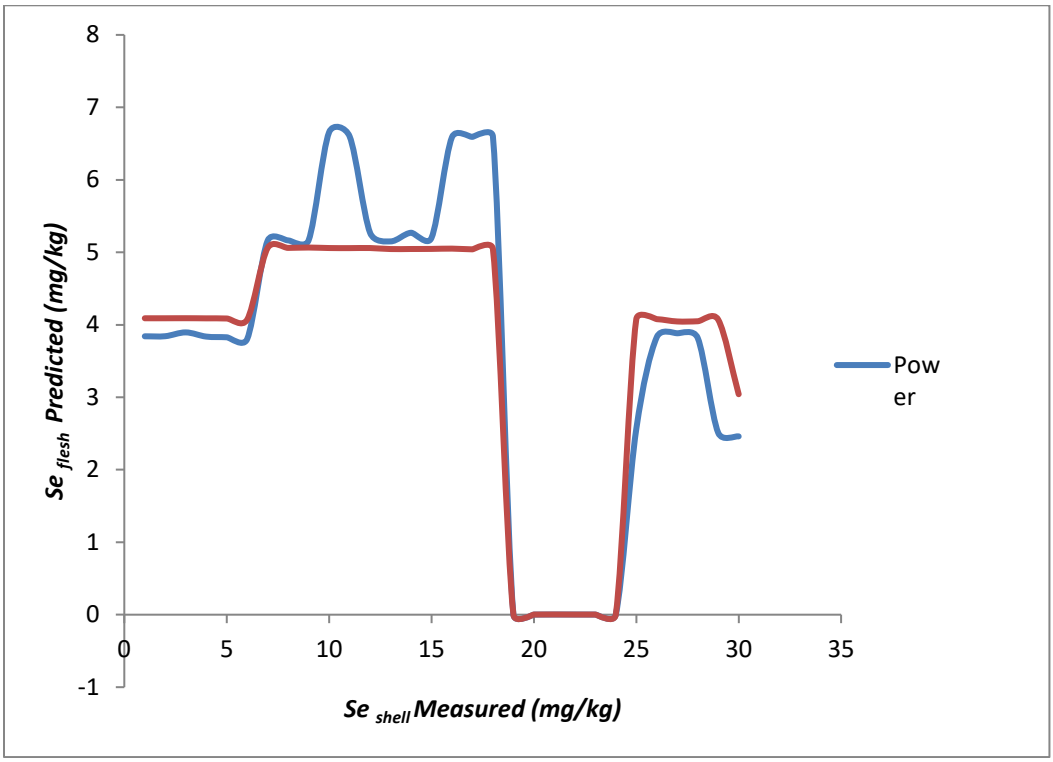

Fig. 9. Graphical pattern of predicted Se conc. in *Tympanotomus fuscatus* flesh against measured value

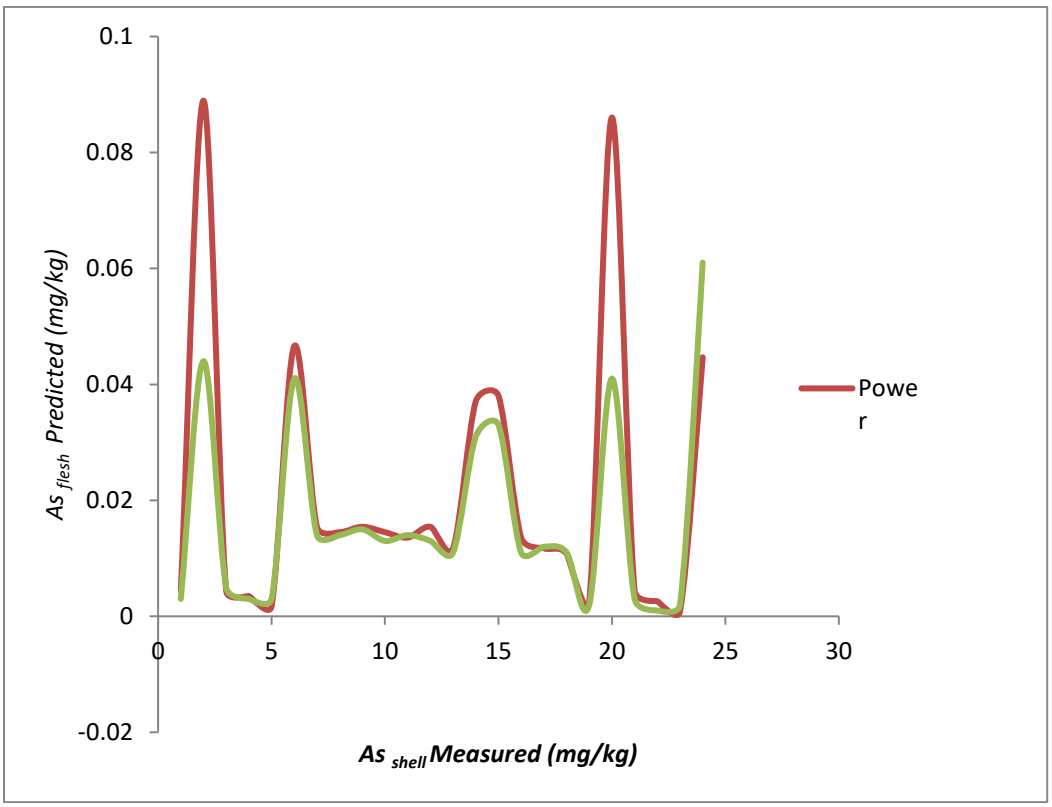

Fig. 10. Graphical pattern of predicted As conc. in *Tympanotomus fuscatus* flesh against measured value

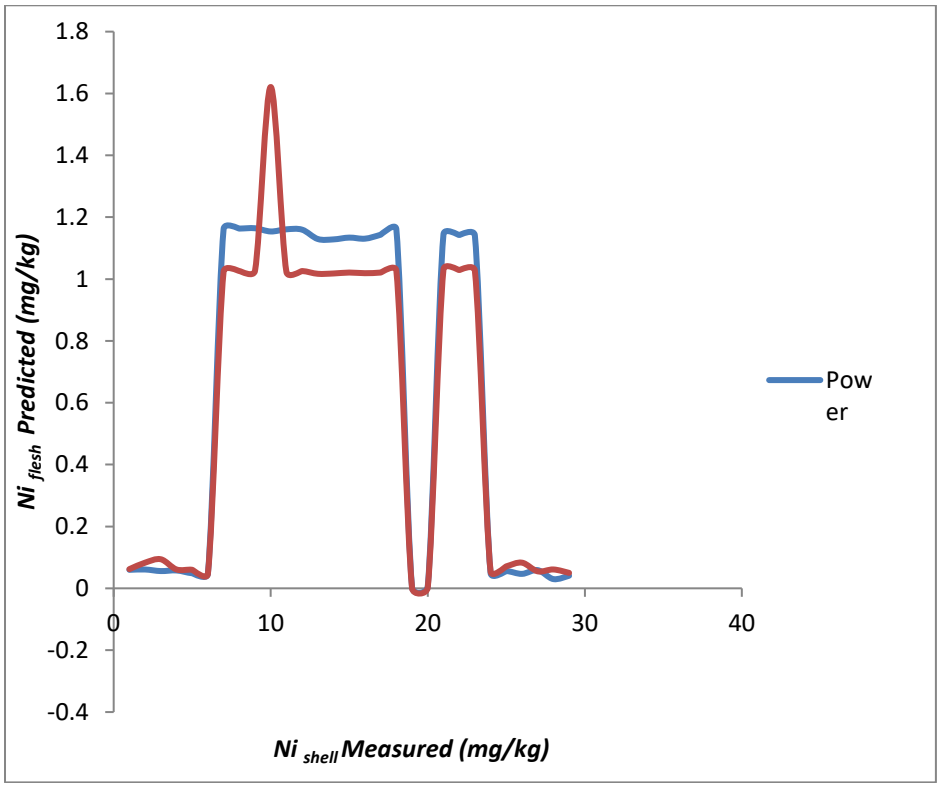

Fig. 11. Graphical pattern of predicted Ni conc. in *Tympanotomus fuscatus* flesh against measured value

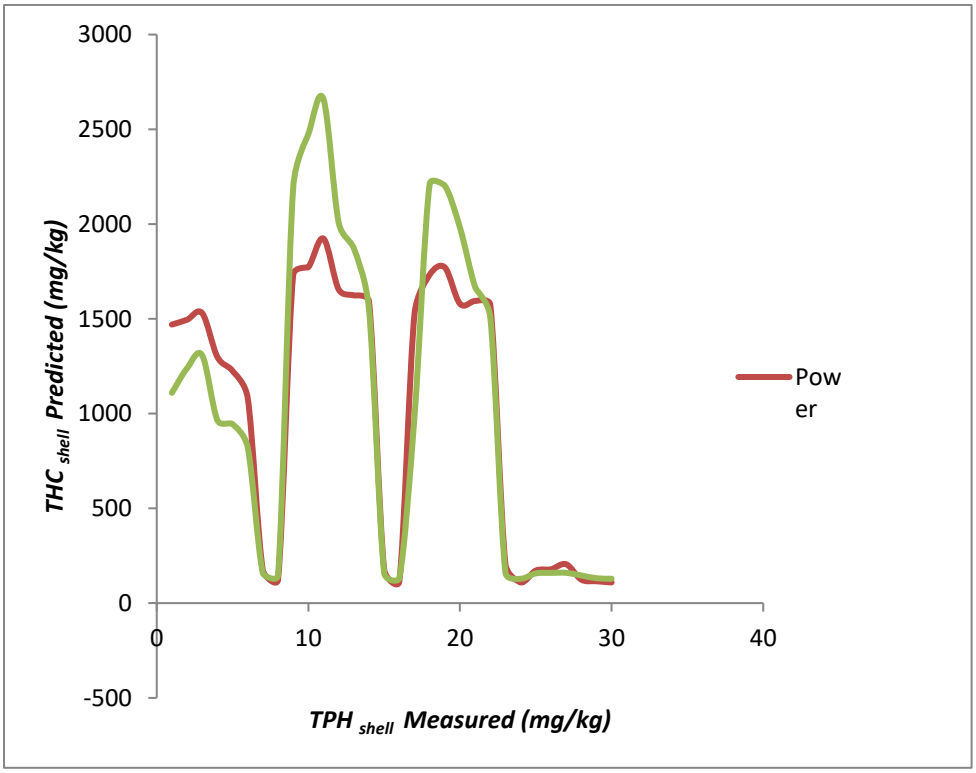

Fig. 12. Graphical pattern of predicted THC shell conc. in *Tympanotomus fuscatus* flesh against measured value

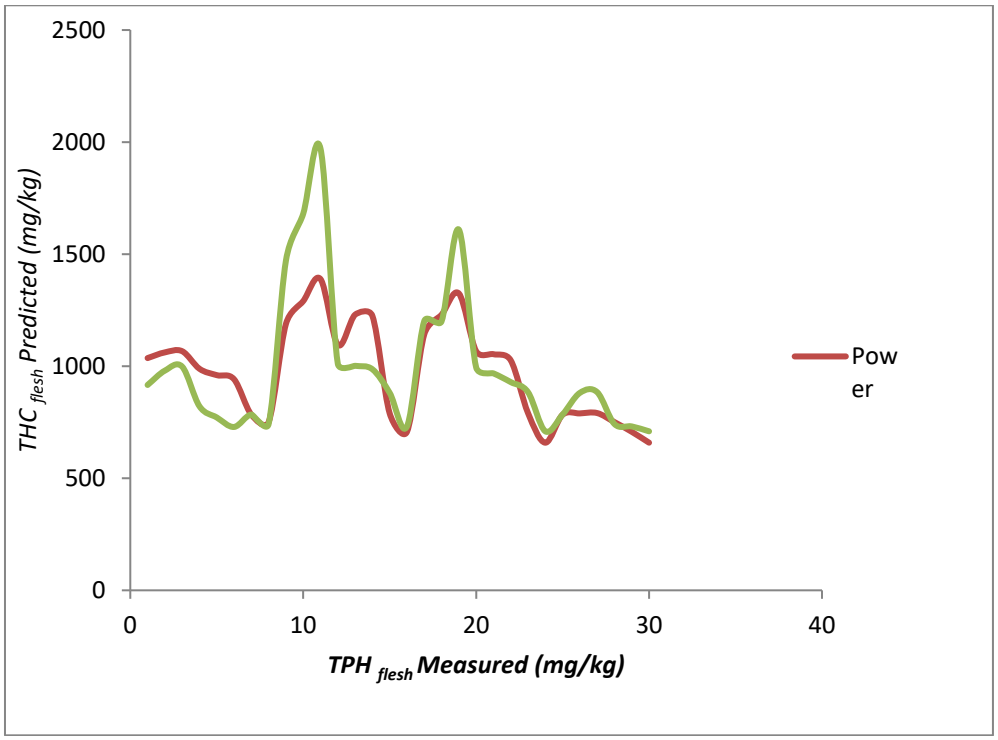

Fig. 13. Graphical pattern of predicted THC flesh conc. in *Tympanotomus fuscatus* flesh against measured value

4. CONCLUSION

The result presented from this study has helped in ascertaining the quality of fauna for human consumption and aquaculture. More so it has created an awareness which has provided up-to-date information on the distribution assessment of TPH, THC and heavy metals, as well as the effect of petroleum exploitation and heavy metals on marine environment. This study has provided models for predicting heavy metals concentration in flesh from shell of faunae; it also provided models for predicting THC from TPH in fauna from Qua-Iboe River.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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