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Spatio-temporal variations of benzene, toluene, ethylbenzene, xylene (BTEX) in water, sediment and health risk assessment of three fin-fishes from three lagoons in Lagos, Nigeria

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ABSTRACT: Adverse effects of exposure of human to benzene, toluene, ethylbenzene and xylene (BTEX) are enormous. Therefore, this study was conducted to examine and compare BTEX in water, sediment and fishes (*Chrysichthys nigrodigitatus*, *Oreochromis niloticus* and *Ilishia africana)* from Badagry, Ojo and Ologe Lagoons in Lagos State, Nigeria, and to investigate if consumption of the fish has any human health risks problem. Fish, water and sediment samples were collected for three months (May - July 2023) using standard procedures. Data were computed using Statistical Package for Social Sciences (SPSS version 22) and analyzed with analysis of variance while the differences in mean were separated using Least Significant Difference at $p<0.05$ being considered significant. There were no significant ($p>0.05$) spatial variations in the BTEX concentration in the water column, sediment and fish collected from Badagry, Ojo and Ologe Lagoons. Levels of BTEX in water, sediment and fish across the three sampling Lagoons were lower than the standard maximum permissible levels. Benzene with 3.57×10^{-8}, 3.57×10^{-8} and 7.13×10^{-8} represent the highest hazard quotient (HQ) in *C. nigrodigitatus* from Badagry, Ojo and Ologe Lagoons respectively. Similarly, benzene with 7.13×10^{-8}, 7.13×10^{-8} and 1.07×10^{-7} had the highest HQ in *O. niloticus* from Badagry, Ojo and Ologe Lagoons respectively. For *I. africana*, same value of benzene (3.57×10^{-8}) was obtained as the highest HQ across Badagry, Ojo and Ologe Lagoons. Xylene had the least HQ in *C. nigrodigitatus* (Badagry and Ologe), *O. niloticus* (Ologe and Ojo) and *I. Africana* (Badagry and Ojo). However, HQ of toluene was the least for *C. nigrodigitatus* (Ojo), *O. niloticus* (Badagry), while ethylbenzene had lowest HQ in *I. africana* from Ologe lagoon. The estimated hazard index (HI) which ranged from 4.14×10^{-8} in *C. nigrodigitatus* (from Badagry lagoon) to 1.14×10^{-7} in *O. niloticus* (from Ologe lagoon) inferred no likelihood of non-carcinogenic and carcinogenic incidents when the fish species are consumed. Hence, the examined fishes are safe for human consumption.

Keywords: Safety assessment, BTEX, aquatic habitat, *C. nigrodigitatus*, *I. africana, O. niloticus.*

INTRODUCTION

Benzene, toluene, ethylbenzene and xylene (BTEX) are compounds that enter the surface and groundwater via accidental releases of industrial effluents as well as leaks and spills of oil and pipelines (Costa *et al*., 2012). Whitaker and Penn (2018) have noted that the three main sources of BTEX in natural waters were sewage discharge, water transport, and oil leaks. BTEX compounds are known to be airborne and could be readily carried into natural water bodies through rainfall (Zhang *et al.,* 2012). Although BTEX usually evaporates rapidly into the air, yet, have the tendency to pollute water resources (Chen *et al.,* 2011). BTEX chemicals have been found in a wide range of home products such as cleaners, herbicides, insecticides, personal hygiene products, and medications to mention but a few (Fayemiwo *et al.,* 2017).

The levels of BTEX in natural waterways are affected by different factors. For instance, as the temperature and water discharge increase in the seas along the Mediterranean coast, lower amounts of BTEX pollutants were seen (Moliner-Martínez *et al*., 2013) while low wind speeds and strong sun irradiation were associated with the highest BTEX concentrations (Moliner-Martínez *et al*., 2013).

Wendelaar-Bonga and Lock (2008) and Akinsanya *et al.* (2020) have avowed that pollutants, when introduced into water, can lead to adverse effects such as sickness and mortality of organisms as they bio-accumulate up the food chain. It can also prevent the regulation of hydro-minerals at the gills of fish. As a result, fish are likely to absorb less oxygen because branchial function will be significantly reduced. Oxygen pressure gradient will also be impacted, and there may be a reduction or increase in the mean blood-to-water or mean water-to-blood diffusion distance.

The detection of BTEX in aquatic environments has become a worry due to the possibility of bioaccumulation and bio-magnification of these pollutants. Therefore, this study aims to investigate the presence as well as compare the concentration of BTEX in water, sediment, and fish (*Chrysichthys nigrodigitatus*, *Oreochromis niloticus* and *Ilishia africana)* across Badagry, Ologe and Ojo Lagoons in Lagos State, Nigeria with a view of determining the safety status of the afore-mentioned fishes for human consumption.

MATERIALS AND METHODS

Study area and sampling stations

The study area is Lagos State which is situated within the geographical coordinates of latitude 6°25’0”N and 6°32’30”N and longitudes 3°20’0”E and 3°25’0”E. Lagos is located in the low-lying coastal zone of Nigeria with rivers, creeks, lagoons and estuaries being dominant in this coastal landscape. Three sampling stations (Badagry, Ojo and Ologe Lagoons) were selected for this study. Badagry Lagoon is on latitude 6.411566°N and longitude 2.882037°E, Ojo Lagoon is on latitude 6°55’60”N and longitude 3°24’0”E while Ologe Lagoon is on latitude 6°28’14”N and longitude 3°4’59”E as shown in Figure 1.

Collection of water, sediment and fish samples

The water and sediment samples were collected from three (3) different points of each sampling station (Badagry, Ojo, and Ologe Lagoons) fortnightly for 3 months (May - July, 2023) following procedures of APHA (1998) and Mekuleyi *et al*. (2021). A total of 18 water and 18 sediment samples were collected from the three sampling stations with the aid of 2.5L polycarbonate bottles and corer respectively. A total of twenty seven (27) samples of fish were collected at landing from the fishermen from the three sampling stations. Precisely, three (3) samples each of *Chrysichthys nigrodigitatus*, *Oreochromis niloticus* and *Ilishia africana* were collected from each sampling station for 3 months and they were identified by fisheries experts in Lagos State University, Ojo. These fish species were selected for this study due to their relative abundance in the sampled lagoons as well as their notable economic and commercial importance to fisherfolks and fish consumers within Badagry Division in Lagos State.

Reagents, standard solutions and calibration standards stock solutions

All experiments were conducted using analytical and Gas Chromatography (GC)-pesticide grade compounds. The following reagents were used for this study: Silica gel 60-120 mesh, baked at 130°C for 8 hours, Dichloromethane (DCM Methylene chloride)**,** n-hexane**,** Sodium sulfate Anhydrous**,** Glass wool etc. All reagents were utilized in accordance with the protocols. The equipment utilized includes analytical balance (Gulfex FA 2104)**,** Gas chromatograph (Agilent, 6890 A)**,** Freezer- capable of maintaining 4°C, Hot plate with variable heat settings, Ultrasonic Bath**,** Teflon stop-cocks**,** Rotary Evaporator (Buchi)**,** Oven (Capable of 130°C) and Graduated measuring cylinders. The Calibration standard solutions were prepared in DCM to contain 1.0-10.0 µg/mL of each of the EPA 6-components of BTEX mix while the stock (1000 µg/mL) mix was purchased commercially from AccuStandard, Inc, USA (AOAC, 2016).

Extraction of BTEX in the specimen

Sediment samples were allowed to air dry for an entire night at room temperature (25°C) in the laboratory. Fish samples were homogenised individually in a lab blender at a temperature precisely regulated between 20 and 25 degrees Celsius. Next, the samples were extracted using an ultrasonicator, or ultrasonic bath. Ten grammes of homogenised fish sample and sediment were put into a 50 millilitre (mL) glass vial. Then 25 mL of methylene chloride were sonicated over each sample for 10 minutes while the two phases were separated by standing for 15 minutes. A rotary evaporator was used to concentrate the organic phase down to 2 mL. After that, a 1µL aliquot of the concentrate was injected into the GC.

Using the liquid-liquid extraction method, the water sample was extracted. A 200 mL aliquot of the water sample was extracted with 20 mL of methylene chloride. For phase separation, the extract was left to stand for thirty

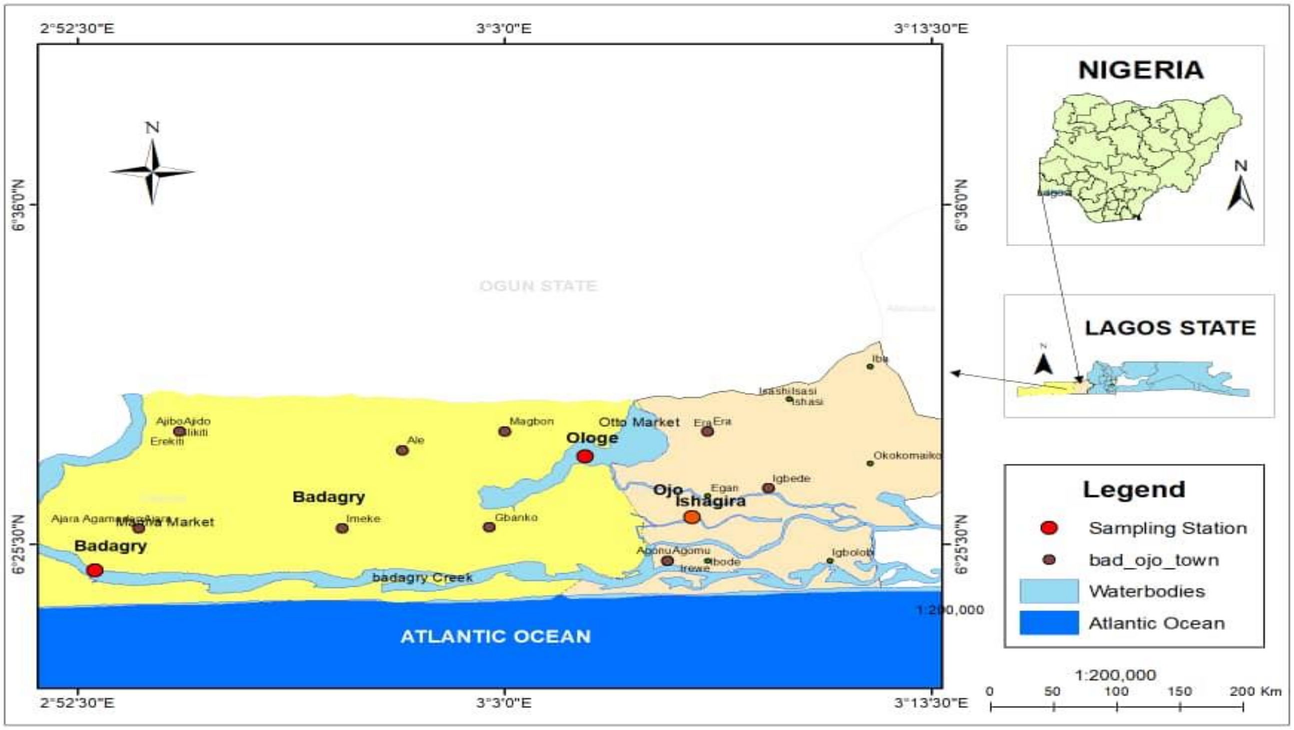

Figure 1. A map showing the location of the three sampling stations (Badagry, Ologe and Ojo Lagoons) in Lagos, Nigeria.

minutes. After being decanted, the organic phase was concentrated to 2 mL. Also, to check for the presence of BTEX compounds, an aliquot of the concentrate was injected into a GC-FID (USEPA, 2007).

Preparation and calibration of standard BTEX

Using the stock standard solution, five BTEX standard solutions (5, 10, 20, 40, and 80 mg/L) were created by appropriately diluting it in a volumetric flask. After injecting an aliquot of the BTEX standard (1 µL) mix into the GC-FID, a calibration curve was produced that could be used to quantify the amounts of BTEX in the samples (AOAC, 2016).

Analysis procedure, Gas Chromatography (GC) set-up conditions for BTEX and BTEX Quantification

The extracts were transferred to labelled GC auto-sampler vials for determination of BTEX by GC/FID following the procedures specified in the standard methods (USEPA, 2007). Thereafter, the BTEX extracts were analyzed using the Agilent GC (Agilent 6890 A, with Flame Ionization Detector (FID) and HP-5 columns. The carrier gas was Helium and the chromatography operating conditions were as follows: Column: DB 5 MS (15 m x 0.25 mm x 0.5 um) capillary column; Oven Program: 40°C, hold 5 minutes, ramped at 7°C/min to 120°C; Detector: Flame Ionisation Detector (FID) 300°C; Carrier Gas: Helium, 1 ml/min; constant flow; Injection Port temperature: 250°C; Injection volume: 1 uL, splitless, (hold 2 min).

A 1µL aliquot of the final solution was injected into the GC, set up for the quantitation of BTEX using the Agilent Chemstation Software. The quantification of compounds was based on the area of the analyte peak, compared with that of the calibration standards.

Calculation of daily intake (DI) of BTEX in fish

Daily intake of BTEX in fish was calculated using the formula by Copat *et al*. (2012) and Mekuleyi *et al.* (2021) with little modification.

$$DI = \frac{EF \times ED \times FIR \times CF \times CB \times 10^{-3}}{WAB \times TA}$$

Where: EF = Exposure frequency taken as 365 days/year; ED = Exposure duration, equivalent to verge lifetime (65 years) (Ali and Hau, 2001); FIR = Fresh food ingestion rate (g/person/day) being taken as 48 g/person/day (Ali and Hau, 2001); CF = Conversion factor = 0.208; CB = BTEX concentration in the fish stuff (mg/kgd^{-w}); WAB = Average body weight (bw) of consumer (adult) taken as 60kg

(Copat *et al.*, 2012; Mekuleyi *et al.*, 2021); TA = Average exposure of time for non-carcinogens which is equal to (EF x ED) as used by Wang *et al*. (2005).

Cancer risks

The possibility of cancer risks in *Chrysichthys nigrodigitatus*, *Oreochromis niloticus* and *Ilishia africana* from Badagry, Ojo, and Ologe Lagoons through intake of carcinogenic BTEX was estimated using the Incremental Lifetime Cancer Risk (ILCR) (Liu *et al*., 2013)

$$ILCR = CDI \times CSF$$

Where CDI is chronic daily intake of chemical carcinogen, mg/kg BW/day which represents the lifetime average daily dose of exposure to the chemical carcinogen and cancer slope factor (CSF) is the risk produced by a lifetime average dose of 1 mg/kg BW/day and is contaminant specific (Bamuwamye *et al.*, 2015).

The CDI value was calculated as:

$$CDI = (EDI \times EF_r \times ED_{tot}) / AT$$

Where EDI is the estimated daily intake of BTEX via consumption of fish; EF_r is the exposure frequency (365 days/year); ED_{tot} is the exposure duration 65years, average lifetime for Nigerian; AT is the period of exposure for non-carcinogenic effects ($EF_r.ED_{tot}$) and 70years life time for carcinogenic effect (Bamuwamye *et al*., 2015).

The cumulative cancer risk as a result of exposure to multiple carcinogenic BTEX due to consumption of a particular type of fish was assumed to be the sum of the individual BTEX increment risks and calculated by the following equation (Liu *et al*., 2013).

$$\sum ILCR = ILCR1 + ILCR2 + \cdots + ILCRn$$

Where n = 1, 2,…,n is the individual carcinogenic BTEX in fish species while the level of acceptable cancer risk (ILCR) for regulatory purposes is considered within the range of 10^{-6} to 10^{-4} (Li and Zhang, 2010; USEPA, 2002).

Non-cancer risks

Non-carcinogenic risks for individual BTEX were evaluated by computing the target hazard quotient (THQ) using the following equation:

$$THQ = CDI/RfD$$ (Bamuwamye *et al.*, 2015)

Where CDI is the chronic daily BTEX and *RfD* is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population via daily exposure (Li and Zhang, 2010). The RfD values of benzene, toluene, ethylbenzene, and xylene are $4x10^{-3}$, $8x10^{-2}$, $1x10^{-1}$ and $2x10^{-1}$ mg/kg/day respectively (USEPA, 2002).

Therefore, to evaluate the potential risk to human health through more than one BTEX, chronic hazard index (HI) is obtained as sum of all hazard quotients (THQ) calculated for individual BTEX.

$$HI = THQ_1 + THQ_2 + \text{----} + THQ_n$$

Where 1, 2, …,n are the individual BTEX in fish species. The calculated HI is compared to standard levels while the population is assumed to be safe when $HI < 1$ and in a level of concern when $1 < HI < 5$ (Guerra *et al.*, 2012).

Statistical analysis

All data for the concentrations of BTEX obtained in water, sediment and fish from the three aquatic stations were tested by one-way analysis of variance (ANOVA) and results expressed as mean standard deviation while the differences in mean were separated using Least Significant Difference at level of significance set at $p<0.05$.

RESULTS

There were no significant ($p>0.05$) spatial variations in the concentrations of Benzene and Xylene in the water column from Badagry, Ojo and Ologe Lagoons as presented in Figure 2. Although, the concentration of ethylbenzene and toluene in the water column seems to be relatively high at Ojo and Ologe Lagoons respectively, however, their spatial variation was not statistically significant ($p>0.05$) when values of these compounds across the sampling lagoons were statistically compared. The concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) in water sample of Badagry, Ojo and Ologe Lagoons respectively are: Benzene (0.000001 ± 0.000001 mg/L, 0.000001 ± 0.000001 mg/L and 0.000002 ± 0.000001 mg/L), Toluene (0.000001 ± 0.000001 mg/L, 0.000001 ± 0.000001 mg/L and 0.00019 ± 0.000001 mg/L), Ethylbenzene (0.000001 ± 0.000001 mg/L, 0.00055 ± 0.000001 mg/L and 0.00041 ± 0.000002 mg/L) and Xylene (0.000002 ± 0.000001 mg/L, 0.000001 ± 0.000001 mg/L and 0.000001 ± 0.000001 mg/L).

The concentration of BTEX recorded in sediment across the sampled aquatic stations is presented in Table 1. There was no significant ($p>0.05$) spatial variation in the level of BTEX obtained in the sediment of Badagry, Ojo and Ologe Lagoons. The distributions of the concentrations of BTEX in the selected fish (*Chrysichthys nigrodigitatus*-

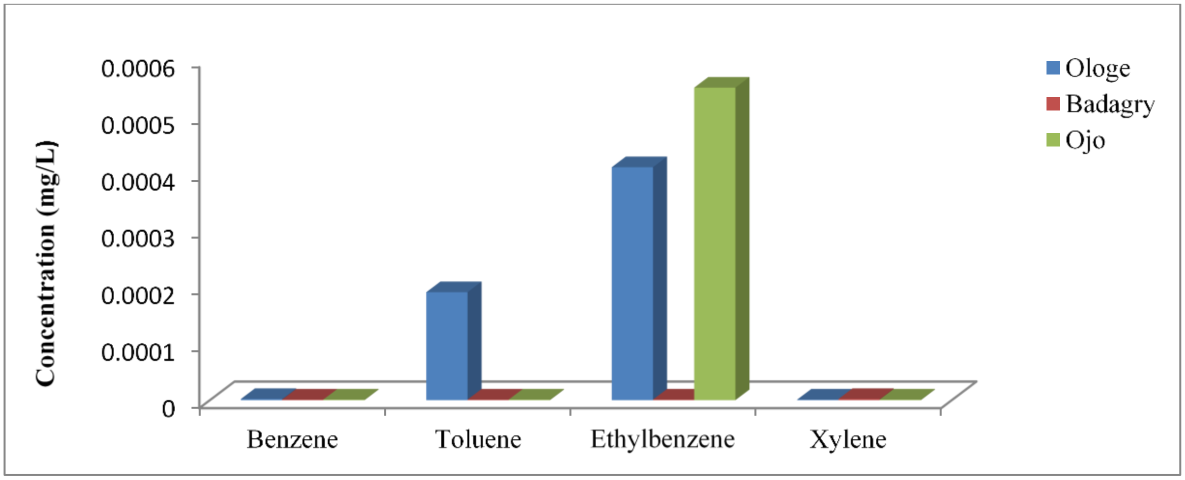

Figure 2. Concentrations of BTEX in water samples from Badagry, Ojo and Ologe Lagoons, Lagos, Nigeria.

Table 1. Concentration of BTEX in sediment from Badagry, Ojo and Ologe Lagoons.

Parameters(mg/kg)	Badagry Lagoon	Ojo Lagoon	Ologe Lagoon
Benzene	8.241±4.764[a]	8.615±7.457[a]	0.501± 0.295[a]
Toluene	7.012±3.329[a]	10.838±7.769[a]	29.277±14.751[a]
Ethylbenzene	14.349± 11.407[a]	47.737± 45.879[a]	30.400± 27.834[a]
Xylene	0.007±0.000[a]	0. 005±0.000[a]	0.005±0.000[a]

All the values of benzene, toluene, ethylbenzene and xylene should be multiplied by10^{-3}. Mean ± STD value with the same superscript across the rows implies no significant difference (p>0.05).

silver catfish, *Oreochromis niloticus* – Nile Tilapia, and *Ilisha africana*–West African ilisha is shown in Figure 3. For the *C. nigrodigitatus* and *I. africana*, ethylbenzene had the highest in term of numerical value and this was recorded at Ologe Lagoon, while benzene had the highest numerical value in *O. niloticus* also from Ologe Lagoon. However, the differences in the concentrations of BTEX obtained in *C. nigrodigitatus, O. niloticus* and *I. africana* across the three sites were not statistically significant (p>0.05). The concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) in *I.africana* from Badagry, Ojo and Ologe Lagoons respectively are: Benzene (0.000001 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000001 ± 0.000001 mg/kg), toluene (0.000001 ± 0.000001 mg/kg, 0.000002 ± 0.000001 mg/kg and 0.000002 ± 0.000001 mg/kg), ethylbenzene (0.000001 ± 0.000001 mg/kg, 0.000002 ± 0.000001mg/kg and 0.000003 ± 0.000001 mg/kg) and xylene (0.000001 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000002 ± 0.000001 mg/kg).

For the *O. niloticus*, the concentrations of BTEX are benzene (0.000002 ± 0.000001 mg/kg, 0.000002 ± 0.000001 mg/kg and 0.000003 ± 0.000001 mg/kg), toluene (0.000002 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000001 ± 0.000001 mg/kg), ethylbenzene (0.000001 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000002 ± 0.000001 mg/kg) and xylene (0.000002 ± 0.000001 mg/L, 0.000001 ± 0.000001 mg/L and 0.000001 ± 0.000001 mg/kg) at Badagry, Ojo and Ologe respectively.

On the other hand, benzene concentrations in *C. nigrodigitatus* from Badagry, Ojo and Ologe were 0.000001 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000002 ± 0.000001 mg/kg respectively. While the toluene levels in *C. nigrodigitatus* from Badagry, Ojo and Ologe respectively were 0.000002 ± 0.000001 mg/kg, 0.000002 ± 0.000002 mg/kg and 0.000001 ± 0.000001 mg/kg; ethylbenzene (0.000001 ± 0.000001 mg/kg, 0.000001 ± 0.000001 mg/kg and 0.000003 ± 0.000002 mg/kg) and xylene (0.000001 ± 0.000001 mg/kg, 0.000002 ± 0.000001 mg/kg and 0.000002 ± 0.000002 mg/kg) were recorded in Badagry, Ojo and Ologe respectively.

The estimated daily intake (DI) of BTEX in *C. nigrodigitatus, O. niloticus* and *I. africana* from Badagry, Ojo and Ologe Lagoons is presented in Table 2. All the values of DI of BTEX in *C. nigrodigitatus*, *O. niloticus* and *I. africana* ranged from 1.426×10^{-10} to 4.280×10^{-10} respectively.

The values of hazard quotient (HQ) and hazard index (HI) of BTEX in *C. nigrodigitatus, O. niloticus* and *I.*

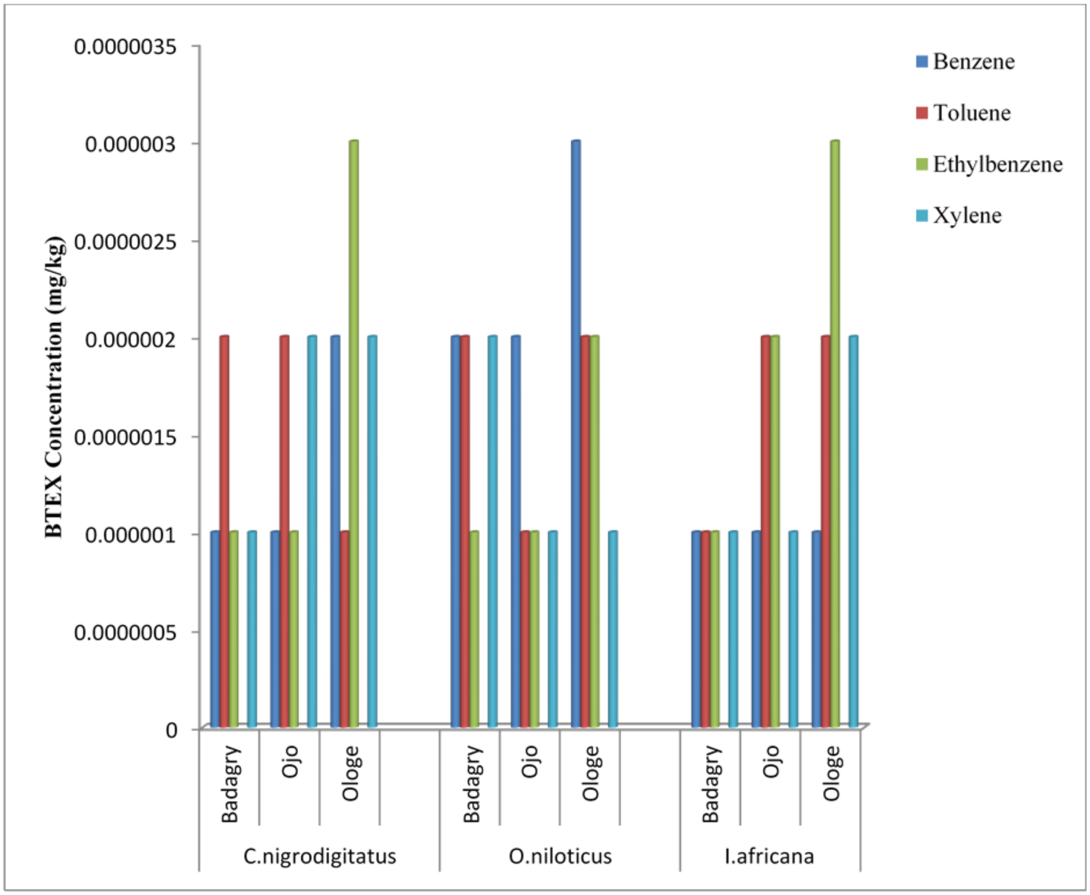

Figure 3. BTEX Concentrations in *C. nigrodigitatus*, *O. niloticus* and *I. africana* from Badagry, Ojo and Ologe Lagoons, Lagos, Nigeria.

Table 2. Estimated Daily Intake (EDI) of BTEX in *C. nigrodigitatus, O. niloticus* and *I. africana* from Badagry, Ojo and Ologe Lagoons.

Location	Fish Species	Benzene	Toluene	Ethylbenzene	Xylene
	C. nigrodigitatus	1.426×10^{-10}	2.853×10^{-10}	1.426×10^{-10}	1.426×10^{-10}
Badagry	*O.niloticus*	2.853×10^{-10}	2.853×10^{-10}	1.426×10^{-10}	2.853×10^{-10}
	I.africana	1.426×10^{-10}	1.426×10^{-10}	1.426×10^{-10}	1.426×10^{-10}
	C. nigrodigitatus	1.426×10^{-10}	2.853×10^{-10}	1.426×10^{-10}	2.853×10^{-10}
Ojo	*O.niloticus*	2.853×10^{-10}	1.426×10^{-10}	1.426×10^{-10}	1.426×10^{-10}
	I.africana	1.426×10^{-10}	2.853×10^{-10}	2.853×10^{-10}	1.426×10^{-10}
	C. nigrodigitatus	2.853×10^{-10}	1.426×10^{-10}	4.279×10^{-10}	1.426×10^{-10}
Ologe	*O.niloticus*	4.280×10^{-10}	2.853×10^{-10}	2.853×10^{-10}	1.426×10^{-10}
	I.africana	1.426×10^{-10}	2.853×10^{-10}	4.279×10^{-10}	2.853×10^{-10}

africana from Badagry, Ojo and Ologe Lagoons is presented in Table 3. Benzene with 3.57×10^{-8}, 3.57×10^{-8} and 7.13×10^{-8} represent the highest HQ in *C. nigrodigitatus* from Badagry, Ojo and Ologe Lagoons, respectively. Similarly, benzene with 7.13×10^{-8}, 7.13×10^{-8} and 1.07×10^{-7} had the highest HQ in *O. niloticus* from Badagry, Ojo and Ologe Lagoons, respectively. For *I. africana*, the same value of benzene (3.57×10^{-8}) was

Table 3. Hazard quotient (HQ) and hazard index (HI) of BTEX in *C. nigrodigitatus, O. niloticus*and *I. africana* from Badagry, Ojo and Ologe Lagoons.

Location	Fish Species	Benzene (HQ)	Toluene (HQ)	Ethylbenzene (HQ)	Xylene (HQ)	HI
Badagry	*C. nigrodigitatus*	3.57×10^{-8}	3.57×10^{-9}	1.43×10^{-9}	7.13×10^{-10}	4.14×10^{-8}
	O.niloticus	7.13×10^{-8}	3.57×10^{-9}	1.42×10^{-9}	1.42×10^{-9}	7.77×10^{-8}
	I.africana	3.57×10^{-8}	1.78×10^{-9}	1.42×10^{-9}	7.13×10^{-9}	4.60×10^{-8}
Ojo	*C. nigrodigitatus*	3.57×10^{-8}	3.57×10^{-9}	1.42×10^{-9}	1.43×10^{-9}	4.21×10^{-8}
	O.niloticus	7.13×10^{-8}	1.78×10^{-9}	1.43×10^{-9}	7.13×10^{-10}	7.52×10^{-8}
	I.africana	3.57×10^{-8}	3.57×10^{-9}	2.85×10^{-9}	7.13×10^{-9}	4.29×10^{-8}
Ologe	*C. nigrodigitatus*	7.13×10^{-8}	1.78×10^{-9}	4.28×10^{-9}	7.13×10^{-10}	7.80×10^{-8}
	O.niloticus	1.07×10^{-7}	3.57×10^{-9}	2.85×10^{-9}	7.13×10^{-10}	1.14×10^{-7}
	I.africana	3.57×10^{-8}	3.57×10^{-9}	4.28×10^{-9}	1.42×10^{-9}	4.50×10^{-8}

obtained as the highest HQ across Badagry, Ojo and Ologe Lagoons.

However, the lowest HQ in *C. nigrodigitatus* from Badagry and Ologe Lagoons was from xylene with value of 7.13×10^{-10} each, while toluene with 3.57×10^{-9} represents the lowest HQ in *C. nigrodigitatus* from Ojo Lagoon. On the other hand, xylene recorded in *O. niloticus* from Ologe and Ojo had the least HQ with the value of 7.13×10^{-10} each, while the lowest HQ in *O. niloticus* from Badagry was found in toluene with the value of 3.57×10^{-10}. For *I. africana*, the same value of xylene (7.13×10^{-9}) was obtained as the least HQ at Badagry and Ojo Lagoons while the lowest HQ in *I. africana* from Ologe Lagoon was found in ethylbenzene with value of 4.28×10^{-9}.

The estimated HI as shown in Table 3 ranged from 4.14×10^{-8} in *C.nigrodigitatus* (from Badagry Lagoon) to 1.14×10^{-7} in *O.niloticus* (from Ologe Lagoon). However, all the values of HI in *C. nigrodigitatus, O. niloticus, I. africana* across the three sampling areas are less than 1.

DISCUSSION

The concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) in the water column and sediment from Badagry, Ojo and Ologe Lagoons had no significant spatio-temporal variation. However, the values of BTEX in sediment and water across the sampling stations in this study were relatively very low in comparison to those reported in Lekki Lagoon by Isibor *et al*. (2020). Unlike the observation in this study as regards the level of BTEX in sediment across Badagry, Ojo and Ologe Lagoons, Isibor *et al*. (2020) reported higher concentrations of BTEX in the sediment medium than in the water which they attributed to the repository nature of the bottom sediment in conjunction with the hydrophobic nature of the contaminants. Similarly, the levels of BTEX in water and sediment in this study were lower than those reported by Akinsanya *et al.* (2022) from Lekki Lagoon. The low level of BTEX in the water and sediment from Badagry, Ojo and Ologe Lagoons may be a result that none of the sampling stations had an oil and gas industry around them and probably the rate of discharge of domestic hazardous wastes across the sampling stations are very low. Adesanya *et al.* (2022) reported that effluents from industries release BTEX into water bodies, as they are being used as solvents especially those that are involved in oil and gas. Also, Doherty and Otitoloju (2016) said that domestic hazardous wastes have been implicated as sources of BTEX while Robinson *et al.* (2005) reported the presence of BTEX in human care products, pesticides, pharmaceuticals, and some detergents. As opined by Mekuleyi *et al*. (2017) and Adesanya *et al*. (2022), anthropogenic activities often made aquatic biota susceptible to environmental stressors (e.g heavy metals, benzene, toluene, ethylbenzene and xylene (BTEX), pharmaceutical effluents etc).

The crucial position which fish holds in nutritional and food security in Nigeria cannot be over-emphasized. In this study, the concentrations of BTEX in the selected fish (*Chrysichthys nigrodigitatus*– silver catfish, *Oreochromis niloticus* – Nile Tilapia, and *Ilisha africana*–West African ilisha had no spatial significance differences across the sampling stations. The levels of BTEX in the afore-mentioned fishes from Badagry, Ojo and Ologe Lagoons were lower than the standard maximum permissible limits of BTEX in fish published by USEPA (1989) expressed as: Benzene-0.000I56 mg/kg, toluene-0.000228mg/kg, ethylbenzene- 0.003905 mg/kg, and xylene- 0.003905 mg/kg. The BTEX recorded in fish for the present study was lower than those reported in *C. nigrodigitatus* from Epe and Lekki Lagoons (Akinsanya *et al.,* 2020; Akinsanya *et al.,* 2022). Unlike the findings in this study, the concentration of *C. nigrodigitatus* recorded at Lekki

Lagoon is unsuitable for consumption as its value exceeds permissible limits. Some studies have pinpointed the negative health effects that result from the consumption of BTEX compounds which include cancer, liver lesions, drowsiness and irritation of organs (Zhang *et al.,* 2012; Tunsaringkarn *et al.,* 2012). Mitra and Roy (2011) and Sogbanmu *et al.* (2016) further reported that human exposure to BTEX compounds over a long period of time could lead to skin and sensory irritation, adverse respiratory health effects and central nervous system irritation. Toluene, ethylbenzene, and xylene are often considered non-carcinogenic compounds, although benzene is known to be carcinogenic (Sogbanmu *et al.,* 2016).

The very low level of BTEX in fish from Badagry, Ojo and Ologe Lagoons may be due to the prevalence of gastrointestinal parasites in these fishes. A study by Bosch *et al.* (2015) has divulged that the concentration of BTEX may be lessened in the host by gastrointestinal parasites accumulating toxins from their host. Microbial activity and photo-degradation lead to the aerobic/anaerobic biodegradation of benzene (Sei and Fathepure, 2009).

All the values of hazard quotient (HQ) and hazard index (HI) in the three fin fishes- silver catfish, Nile Tilapia and West African Ilisha examined in this study were far below 1.0 and this is an indication of a low hazardous exposure of the consumers to BTEX at the current rate of consumption of these fishes. Similar results of HQ and HI of fish being less than 1 have been reported in some fishes in Nigeria (Mekuleyi *et al*., 2021) and Malaysia (Latif *et al.*, 2019). Whenever the HQ value goes beyond 1, the higher the likelihood of the hazard risk on the consumers (USEPA, 1989; Mekuleyi *et al*., 2021). There are reports that prolong exposures to concentrations of the BTEX monoaromatic compounds can cause adverse effects in humans (Liu *et al.*, 2018). For instance, human exposure to high concentration of benzene could result into modified menstrual cycles, decreased immune cells and antibodies, aberrant sperm production and spontaneous abortion (Thurston *et al.,* 2000; Uzma *et al.,* 2010; Ji *et al.,* 2012; Marchetti *et al.,* 2012; Bolden *et al.,* 2015). Human exposure to high concentration of toluene has been linked to reductions in follicle stimulating hormone, testosterone, luteinizing hormone as well as impaired fertility in women (Bolden *et al.,* 2015) while high xylene was attributed to an increased risk of oligomenorrhea (Cho *et al.,* 2001), but effects of exposure to ethylbenzene include an increase in markers of oxidative stress (Chang *et al*., 2011). In an attempt to reduce BTEX in water, Yang *et al.* (2018) noted that the use of adsorption technology as separation method for water treatment compared to traditional approaches like incineration, oxidation, and bioremediation has proven to be both economically viable and efficient in eliminating organic contaminants like BTEX in water sample.

Conclusion

A very low concentration of benzene, toluene, ethylbenzene and xylene (BTEX) in water, sediment and fish (*Chrysichthys nigrodigitatus, Ilishia africana* and *Oreochromis niloticus***)** from Badagry, Ojo and Ologe was established in this study. All the values of BTEX in water, sediment and fish examined in this study were below the standard maximum permissible limits and this further implies that the three lagoons are suitable for the fish. However, there were no significant spatial variations in the concentrations of BTEX in water, sediment and fish samples while the estimated hazard quotient and hazard index of BTEX in *C. nigrodigitatus, O. niloticus* and *I. africana* from the sampling sites which were far below 1 is an indication that carcinogenic and non-carcinogenic risk of BTEX associated with consumption of the fish is not likely to occur. Hence, the examined fish in this study are safe for human consumption.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Adesanya, Y., Atiyeh, H. K., Olorunsogbon, T., Khanal, A., Okonkwo, C. C., Ujor, V. C., Shah, A., & Ezeji, T. C. (2022). Viable strategies for enhancing acetone-butanol-ethanol production from non-detoxified switchgrass hydrolysates. *Bioresource Technology*, *344*, (Part A), 126167.

Akinsanya, B., Ehinlaiye, P. E., Ovioma, G. O., Konofua, C. C., & Isibor, P. O. (2022). A comparative study on bioaccumulation of BTEX and oxidative stress biomarker response in parasitised and non-parasitised *Parachanna obscura* (GUNTHER, 1861) from Lekki Lagoon, Lagos, Nigeria. *Egyptian Academic Journal of Biological Sciences, B. Zoology*, *14*(2), 49-77.

Akinsanya, B., Isibor, P., Emmanuel, A., Dada, E., Saliu, J., & Olasehinde, G. (2020). Accumulation of PCBs and Infections of Parasitic helminthes in *Synodontis filamentosus* (Boulenger, 1901) and *Tilapia zillii* (Gervais, 1848) of Epe Lagoon, Lagos, Nigeria. *Egyptian Journal of Aquatic Biology & Fisheries, 24*(1), 49-63.

Ali, M., & Hau, V. T. B. (2001). Vegetables in Bangladesh: Economic and nutritional impact of new varieties and technologies. Asian Vegetable Research and Development Centre, Technical Bulletin No. 25 AVRDC, Taiwan.

American Public Health Association (APHA) (1998). Standard methods for the examination of water and waste water.14th edition, Washington DC. Pp 1007-1157.

Association of Analytical Chemists (AOAC) (2016). *Official Method of the Association of Analytical Chemists International* 20th Edition; AOAC, Washington, DC; USA. 447pp.

Bamuwamye, M., Ogwok, P., & Tumuhairwe, V. (2015). Cancer and non-cancer risks associated with heavy metal exposures from street foods: evaluation of roasted meats in an urban setting. *Journal of Environment Pollution and Human Health*, *3*(2), 24-30.

Bolden, A. L., Kwiatkowski, C. F., & Colborn, T. (2015). New look at BTEX: are ambient levels a problem? *Environmental Science & Technology*, *49*(9), 5261-5276.

Bosch, M. D., Mannino, M. A., Prendergast, A. L., O'Connell, T. C., Demarchi, B., Taylor, S. M., Niven, L., Van Der Plicht, J., & Hublin, J. J. (2015). Reply to Douka et al.: Critical evaluation of the Ksâr'Akil chronologies. *Proceedings of the National Academy of Sciences*, *112*(51), E7035-E7035.

Chang, F. K., Mao, I. F., Chen, M. L., & Cheng, S. F. (2011). Urinary 8-hydroxydeoxyguanosine as a biomarker of oxidative DNA damage in workers exposed to ethylbenzene. *Annals of Occupational Hygiene*, *55*(5), 519-525.

Chen, Y., Li, J., Lei, C., & Shim, H. (2011). Interactions between BTEX, TPH, and TCE during their bio-removal from the artificially contaminated water. In *Proceedings of the Second International Conference on Bioenvironment, Biodiversity and Renewable Energies* (pp. 33-37).

Cho, S. I., Damokosh, A. I., Ryan, L. M., Chen, D., Hu, Y. A., Smith, T. J., Christiani, D. C., & Xu, X. (2001). Effects of exposure to organic solvents on menstrual cycle length. *Journal of Occupational and Environmental Medicine*, *43*(6), 567-575.

Copat, C., Bella, F., Castaing, M., Fallico, R., Sciacca, S., & Ferrante, M. (2012). Heavy metals concentrations in fish from Sicily (Mediterranean Sea) and evaluation of possible health risks to consumers. *Bulletin of Environmental Contamination and Toxicology*, *88*, 78-83.

Costa, A. S., Romão, L. P. C., Araújo, B. R., Lucas, S. C. O., Maciel, S. T. A., Wisniewski Jr, A., & Alexandre, M. D. R. (2012). Environmental strategies to remove volatile aromatic fractions (BTEX) from petroleum industry wastewater using biomass. *Bioresource Technology*, *105*, 31-39.

Doherty, V. F., & Otitoloju, A. A. (2016). Occurrence and distribution of monocyclic aromatic hydrocarbons (BTEX) and the impact on macrobenthic community structure in Lagos lagoon, Nigeria. *Environmental Monitoring and Assessment*, *188, Article number 571*.

Fayemiwo, O., Moothi, K., & Daramola, M. (2017). BTEX compounds in water–future trends and directions for water treatment. *Water Sa*, *43*(4), 602-613.

Guerra, F., Trevizam, A. R., Muraoka, T., Marcante, N. C., & Canniatti-Brazaca, S. G. (2012). Heavy metals in vegetables and potential risk for human health. *Scientia Agricola*, *69*, 54-60.

Isibor, P. O., Akeredolu, E., Samuel, O. B., Abayomi, A., Olaleru, F., Akinsanya, B., Emezie, P., Are, F. N., & Saliu, J. K. (2020). Comparative Bioaccumulation of PAH and BTEX in Malapterurus electricus (Siluriformes: Malapteruridae) and its enteric parasite, Electrotaenia malopteruri sampled from Lekki Lagoon, Lagos, Nigeria. *Brazilian Journal of Biology*, *81*, 1081-1094.

Ji, Z., Weldon, R. H., Marchetti, F., Chen, H., Li, G., Xing, C., Kurtovich, E., Young, S., Schmid, T. E., Waidyanatha, S., Rappaport, S., Zhang, L., & Eskenazi, B. (2012). Comparison of aneuploidies of chromosomes 21, X, and Y in the blood lymphocytes and sperm of workers exposed to benzene. *Environmental and Molecular Mutagenesis*, *53*(3), 218-226.

Latif, M. T., Abd Hamid, H. H., Ahamad, F., Khan, M. F., Nadzir, M. S. M., Othman, M., Sahani, M., AbdulWahab, M. I., Mohamad, N., Uning, R., Poh, S. C., Fadzil, M. F., Sentian, J., & Tahir, N. M. (2019). BTEX compositions and its potential health impacts in Malaysia. *Chemosphere*, *237*, 124451.

Li, S., & Zhang, Q. (2010). Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China. *Journal of Hazardous Materials, 181*, 1051-1058.

Liu, A., Hong, N., Zhu, P., & Guan, Y. (2018). Understanding benzene series (BTEX) pollutant load characteristics in the urban environment. *Science of the Total Environment*, *619*, 938-945.

Liu, K., Quan, J., Mu, Y., Zhang, Q., Liu, J., Gao, Y., Chen, P., Zhao, D., & Tian, H. (2013). Aircraft measurements of BTEX compounds around Beijing city. *Atmospheric Environment*, *73*, 11-15.

Marchetti, F., Eskenazi, B., Weldon, R. H., Li, G., Zhang, L., Rappaport, S. M., Schmid, T.E., Xing, C., Kurtovich, E., & Wyrobek, A. J. (2012). Occupational exposure to benzene and chromosomal structural aberrations in the sperm of Chinese men. *Environmental Health Perspectives*, *120*(2), 229-234.

Mekuleyi, G. O., Lawson, E. O., & Fakoya, K. A. (2017). Comparative morphometric characters of gladiator swimming crab Callinectes pallidus (Rochebrune, 1883) (Crustacea: Decapoda) from two coastal areas in Lagos Southwest Nigeria. *Brazilian Journal of Biological Sciences*, *4*(7), 157-163.

Mekuleyi, G. O., Yaji, A. J. & Adelere, F. I. (2021). Comparative assessment of wellbeing of *Chrysichthys filamentosus, Kribia nana* and *Pegusa lascaris* from Tomaro, Ajegunle and Badagry Creeks in Lagos, Nigeria. *Bangladesh Journal of Fisheries*, *33*(1), 1-12.

Mitra, S., & Roy, P. (2011). BTEX: A serious ground-water contaminant. *Research Journal of Environmental Sciences*, *5*(5), 394-398.

Moliner-Martínez, Y., Herraez-Hernandez, R., Verdú-Andres, J., Campíns-Falcó, P., Garrido-Palanca, C., Molins-Legua, C., & Seco, A. (2013). Study of the influence of temperature and precipitations on the levels of BTEX in natural waters. *Journal of Hazardous Materials*, *263*, 131-138.

Robinson, H. D., Knox, K., Bone, B. D., & Picken, A. (2005). Leachate quality from landfilled MBT waste. *Waste Management*, *25*(4), 383-391.

Sei, A., & Fathepure, B. Z. (2009). Biodegradation of BTEX at high salinity by an enrichment culture from hypersaline sediments of Rozel Point at Great Salt Lake. *Journal of Applied Microbiology*, *107*(6), 2001-2008.

Sogbanmu, T. O., Nagy, E., Phillips, D. H., Arlt, V. M., Otitoloju, A. A., & Bury, N. R. (2016). Lagos lagoon sediment organic extracts and polycyclic aromatic hydrocarbons induce embryotoxic, teratogenic and genotoxic effects in Danio rerio (zebrafish) embryos. *Environmental Science and Pollution Research*, *23*(14), 14489-14501.

Thurston, S. W., Ryan, L., Christiani, D. C., Snow, R., Carlson, J., You, L., Cui, S., Ma, G., Wang, L., Huang, Y., & Xu, X. (2000). Petrochemical exposure and menstrual disturbances. *American Journal of Industrial Medicine*, *38*(5), 555-564.

Tunsaringkarn, T., Siriwong, W., Rungsiyothin, A., & Nopparatbundit, S. (2012). Occupational exposure of gasoline station workers to BTEX compounds in Bangkok, Thailand. *The International Journal of Occupational and Environmental*

Medicine, 3(3), 117-125.

United States Environmental Protection Agency (USEPA) (1989). Risk assessment guidance for superfund. Human Health Evaluation Manual Part A, Interim final, Vol. 1. Washington DC, United States Environmental Protection Agency; EPA/540/1- 89/002.

United States Environmental Protection Agency (USEPA) (2002). Supplemental guidance for developing soil screening levels for superfund sites. U.S. Environmental Protection Agency, Washington, DC. Pp. 4-24.

United States Environmental Protection Agency (USEPA) (2007). Method 3550C. Ultrasonic Extraction, Washington: US Government Printing Office, 2007.

Uzma, N., Kumar, B. S., & Hazari, M. A. H. (2010). Exposure to benzene induces oxidative stress, alters the immune response and expression of p53 in gasoline filling workers. *American Journal of Industrial Medicine*, *53*(12), 1264-1270.

Wang, X., Sato, T., Xing, B., & Tao, S. (2005). Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. *Science of the Total Environment*, *350*(1-3), 28-37.

Wendelaar-Bonga, S., & Lock, R. A. C. (2008). The osmo-regulatory system, in: R.T.D. Giulio, D.E. Hinton (Eds.), *The Toxicology of Fishes, CRC Press, Florida*. Pp. 401-411.

Whitaker, A. H., & Penn, C. J. (2018). Total petroleum hydrocarbon degradation and BTEX leaching in soils after application of oil-base drilling mud: Impact of application rate, rainfall regime, and time. *Modern Approaches in Oceanography and Petrochemical Sciences, 1*(2), 1-13.

Yang, X., Yi, H., Tang, X., Zhao, S., Yang, Z., Ma, Y., Feng, T., & Cui, X. (2018). Behaviors and kinetics of toluene adsorption-desorption on activated carbons with varying pore structure. *Journal of Environmental Sciences*, *67*, 104-114.

Zhang, Y., Mu, Y., Liu, J., & Mellouki, A. (2012). Levels, sources and health risks of carbonyls and BTEX in the ambient air of Beijing, China. *Journal of Environmental Sciences*, *24*(1), 124-130.