RESEARCH ARTICLE

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Determination and Risk Associated with Phthalic Esters Distribution from the Ekpan River, Effurun, Delta State, Nigeria

Oghenekohwiroro Edjere, Daniel O. Igiegie, and Akpofure Rim-Rukeh

ABSTRACT

Phthalates are additives or plasticizers added to make plastics soft. However, they could leach into the environment and cause harm to human health when contacted. Sites along the Ekpan river have been used for open dumping of refuse. The river also serves as a point source for the disposal of effluents from the Warri Refinery and Petrochemical Company Limited (WRPC). Hence, the need for a preliminary study of phthalates across the river system. Surface water samples were collected from six points along the Ekpan river. Phthalates were extracted using USEPA standard method 3535 and EPA method 8061. Gas Chromatography-Mass Spectrometer (GC-MS) was used for the analysis of six PAEs including di-n-butyl phthalate (DnBP or DPX), butyl benzyl phthalate (BBP), di(2-Ethylhexyl) phthalate (DEHP), di-n-octyl phthalate (D-n-OP)), Dimethyl phthalate (DMP), and Diethyl phthalate (DEP) in the river system. Analysis of phthalates in the Ekpan river system showed that DEP across the Effurun river system ranged from 4.22 – 13.81 µg/L, DPX; 3.03 – 11.5 µg/L, BBP; 0.11–1.39 µg/L, DEHP; 0.12 – 3.33 µg/L. D-n-OP and DMP were below the limit of detection of the analytical instrument used (0.1 µg/L). The distribution of PAEs along the network of the river revealed that the sampling sites in the urban region were more contaminated with PAEs due to urbanization and an increase in population across the river network. Human health risk assessment revealed that the hazard quotient (HQ) for DEP, DPX, DEHP, and D-i-NP were below 1, indicating an acceptable risk of PAEs via ingestion or bathing of the river water. In addition, the Hazard Index (HI) via ingestion and bathing of the river water was less than 1 indicating acceptable risks. According to this study, these PAEs congeners are safe for toddlers, adolescents, and adults to eat and bathe in tap water. Even DEHP, the only PAEs congener designated as a carcinogenic agent by WHO, was shown to have a tolerable cancer risk. These findings indicate that there is no harm to children, adolescents, and adults from DEHP in the river water studied.

Keywords: Cancer, DEP, DPX, Endocrine-Disruption, Ekpan River.

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I. Introduction

Phthalate esters (PAEs) are a family of synthetic organic chemicals [1]. PAEs are used as plasticizers (additives incorporated into a plastic product to make it pliable and durable) [2]. Plastics, rubber, polyvinyl chloride (PVC) pipes and other polyethylene goods all employ PAEs as plasticizers. This is done to enhance the materials' pliability, workability, and long-term durability [3]–[5]. Plastics are used for bottling water for consumption. However, due to indiscriminate disposal, these plastics can find their way into the environment. PAEs can leach into the environment depending on several environmental factors. PAEs are all around us, and their resistance to degradation means that they have the potential to build up in aquatic ecosystems [1], [2]. Due to the harm, they may do to aquatic organisms, and humans, PAEs could harm aquatic ecosystems and health-related diseases. A growing body of evidence indicates that PAEs are among those hormone-disrupting chemical substances most responsible for inhibiting endocrine processes [2], [6], [7].

Dimethyl phthalate (DMP), Di (2-ethyl hexyl phthalate) (DEHP), and Di n octyl phthalate (Di-n-OP) are some of the PAEs that have been designated "priority pollutants" in several nations [2], [8]. It has been shown that phthalates can be found in many different environmental matrices including air [9], surface water [10], tap water [11], sediments [12], and benthic animals and humans [12]–[15]. PAEs in a riverine setting are now receiving worldwide interest for their distribution, source, migration, and possible ecological hazards [2], [15]. In Nigeria, Phthalates have been revealed to be in varying concentrations in river systems [16]–[21]. Other human-caused chemical compounds, including point and non-point wastewater discharge, surface runoff, and air deposition are also possible entry points for PAEs [2], [22], [23].

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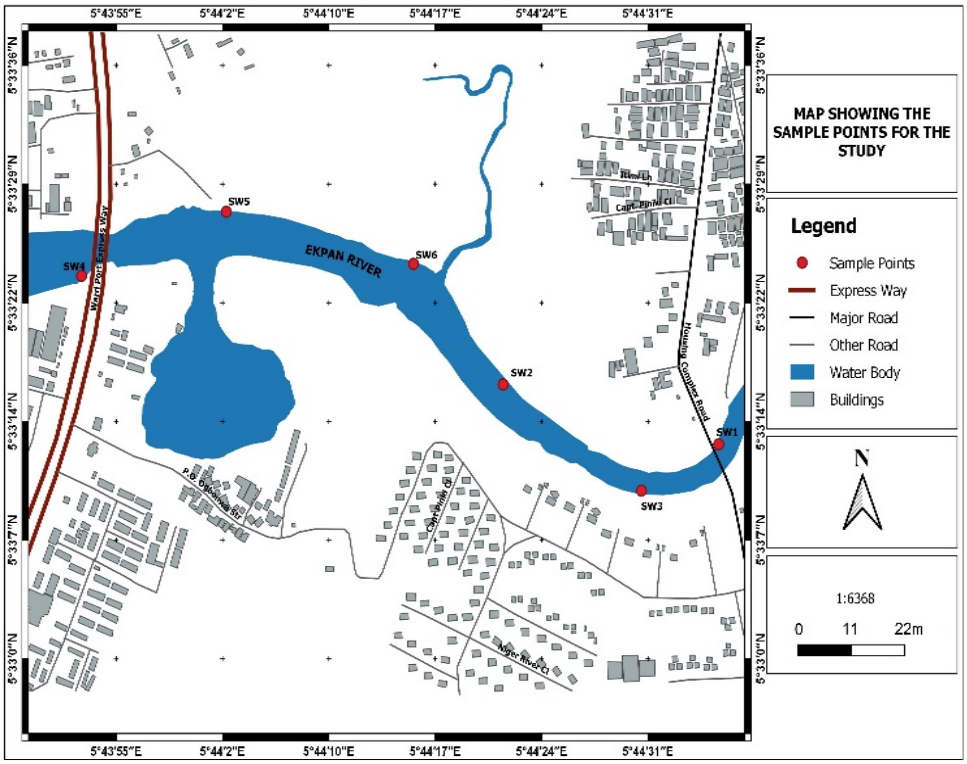

Fig. 1. Map showing sample collection points along the Ekpan river.

Determination of phthalate concentration along the Ekpan river is necessary to aid decision-makers with baseline data, and to aid residents who live along the river's path that may get exposed to PAEs via ingestion or dermal contact when swimming in the water.

II. Study Area

The Ekpan river is a tributary of the Effurun river that flows across the western Niger Delta. The Effurun river is situated in, Delta State, Nigeria. Its source is located in Ndokwa LGA and runs to Agbarho, Warri, Ekpan, and ultimately empties into the Atlantic Ocean from the rainforest zone of Forcados. Various human activities including farming, sand dredging, and fish aquaculture have left the river distinctively muddy. In addition to accepting garbage from Warri Refining and Petrochemicals Limited (WRPC) in the Warri metropolis, it acts as a primary drainage canal for the region handling household and processed industrial waste. Fig. 1 below indicates the locations for the six sampling sites (SW1, SW2, etc. through SW6) where surface water samples were collected.

III. Methodology

This involved collection of water samples from six points along the Ekpan river using amber glass bottles. No special preservation of samples was used. Samples were stored in an ice chest with a temperature reading of -4 ^{O}C and transported to the laboratory. Samples were prepared using USEPA standard method 3535 and EPA method 8061 as detailed in [24]–[25]. Solvents used for this work included HPLC grades of Hexane, methanol, acetone, deionized water. Phthalate standards included: Phthalate Ester Mix 0.2 mg/ml in Methanol (AccuStandard M606), Phthalate and Adipate Esters Mix1 100 (ng/ul), Anhydrous Sodium Sulphate Oven heated at 400 °C. An Agilent 6890N GCM-5973 MSD (Agilent Technologies, U.S.A.), an HP-5 MS in selective ion monitoring mode, and a functional electron influence were used to analyze all of the samples. A human health risk assessment (HHRA) was conducted using approaches as described by Fatoki *et al.*, [26], the United States Environmental Protection Agency (USEPA) [27s], and Hu *et al.*, [28] were implemented with slight modification for human health risk assessment (Table I, Table II, and Table III).

The average daily exposure concentration was referred to as average daily dose (ADD) and was computed using Equation (1).

$$\text{ADD} = \frac{Cmean\ x\ IR\ x\ Fc\ x\ ED}{BW\ x\ AT} \quad (1)$$

Cmean is the concentration of PAEs in the polluted river water samples collected from four waterworks in the study area; IR represents the average daily consumption rate; ED is referred to the exposure period (in years); Fc simply means the fraction contaminated; BW simply means the average body weight; AT represents the average lifetime of exposure (mg/kg/day).

Carcinogenic risk assessment as a result of lifetime exposure was evaluated by using Equation (2).

$$\text{LADD ingestion} = \frac{ADDingestion\ x\ ED}{Lft} \quad (2)$$

Where LADD is referred to as the average daily dose of lifetime exposure; L_{ft} means the lifetime Dermal absorption dose (DAD) was evaluated by using Equation (3)

$$DADdermal = \frac{Cmean\ x\ SA\ x\ SL\ ABS\ x\ EF\ x\ ED}{BW\ x\ AT} \quad (3)$$

TABLE I: EXPOSURE PARAMETERS USED FOR NONCARCINOGENIC RISK AND CARCINOGENIC RISK

Parameter		Value
Reference dose (RfD)	BBP	0.2 mg/kg/day
–	DEHP	0.02 mg/kg/dy
–	DPX	0.02 mg/kg/day
–	DMP	0.1 mg/kg/day
–	DiNP	0.115 [b] mg/kg/day
Concentration of PAEs (C)	Mean value of PAEs	–
Intake rates (IR)	Adults	1.5
Exposure frequency (EF)	Adults	365 years
Exposure duration (ED)	Adults	30 years
Exposure duration (ED)	Adolscents	10 years
Exposure duration (ED)	Children	6 years
Body weight (BW)	Adults	60 kg
–	Adolscent	30 kg
–	Children	15kg
Average time (AT)	Noncancer risk	365 x ED
	Cancer risk	365x 70
Slope factor (SF)	DEHP	0.014 mg/kg/day

Source: [27], [29].

TABLE II: EXPOSURE PARAMETERS USED TO GENERATE EXPOSURE ESTIMATE OF PAES

Exposure parameter	Unit
Drinking water	365 events/year, 2L/event (adult), 1L/event (children); 100% portion of contaminated tap water
Dermal absorption	365 events/year; 12 min/event, 6 min/event; 5700cm^2 skin surface (adult), 2800 cm^{2}skin surface (children); Skin adherence factor = 0.7 mg/cm^2/day; ABS is dermal absorption factor = 0.1 for all PAEs congeners

Source: [7], [26].

TABLE III: ESTABLISHED HEALTH LIMIT OF DAILY INTAKE OF PAES, TDI AND RFD

PAEs compound	TDI µg/kg/day	RfD mg/kg/day	References
DEP	10	100	[30]
DEHP	50	20	[30]
DiNP	150	–	[29]
DPX	150	–	[29]
BBP	500	200	[30]

SA simply represents the skin surface area; SL is skin adherence factor = 0.7 mg cm−2 day−1; ABS is referred to as, the dermal absorption factor; EF is exposure frequency Risk characterization

The risk of cancer development as a result of human exposure to DEHP detected in tap water was estimated based on the assumption that humans are exposed to DEHP concentration in the Ekpan river water via ingestion and bathing on regular basis. In addition, chronic exposure to PAEs via these pathways has been observed to be injurious to humans. For DEHP that have the potential for causing cancer, the carcinogenic risk was calculated using Equation (4).

$$Risk\ ingestion = \beta \times LADD\ ingestion \quad (4)$$

Where Risk digestion is the potential risk due to ingestion of contaminated water; LADD is lifetime average daily dose; β is oral potency factor/slope.

Children are the most vulnerable group that is susceptible to a potential risk of PAEs mainly because they are in the developmental stage of their lives. In addition, their immune systems are not fully developed to combat disease or disorder-causing agents which include environmental pollutants like PAEs.

In this work, an exposure and risk assessment tool was applied to estimate the exposure and risk of PAEs to children, adolescents, and adults via ingestion and dermal contact of contaminated river water.

IV. DISCUSSION OF RESULTS

A. Phthalates In the Ekpan River System

The concentration of the six targeted PAE congeners, including Dimethyl phthalate (DMP), Diethyl phthalate (DEP), Dibutyl phthalate (DPX), Benzyl butyl phthalate (BBP), Bis 2-ethyl hexyl phthalate (DEHP), and Di-n-Octyl phthalate (Di-n-OP) in surface water samples of the Ekpan river are shown in Fig. 2.

The total concentration of PAEs in water samples ranged from non-detectable (ND) to 14 µg/L. Fig. 2, indicates that DMP was below the limit of detection (LOD) of the equipment used for analysis in all the samples (LOD – 0.1 µg/L). Similarly, D-n-OP was also below LOD of the equipment in all samples analyzed. However, DEP, BBP, DPX and DEHP were all detected in all the samples analyzed.

DEP across SW_1, SW_2, SW_3, SW_4, SW_5, and SW_6 was in concentration of 9.66 µg/L, 7.11 µg/L, 6.53 µg/L, 7.74 µg/L, 13.81 µg/L, and 4.22 µg/L respectively.

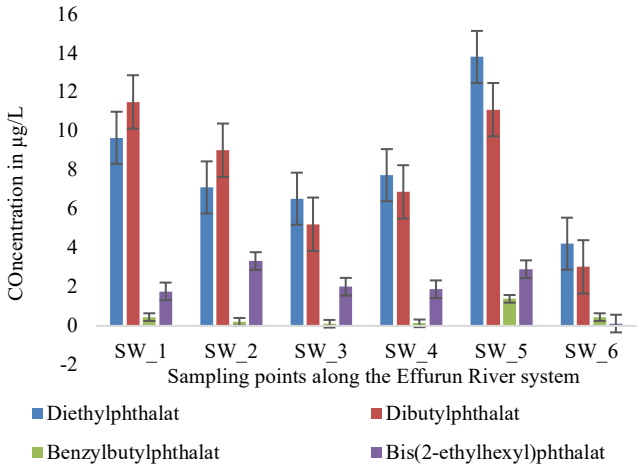

Fig. 2. Concentration of phthalates in the Ekpan river system.

DPX across SW_1, SW_2, SW_3, SW_4, SW_5, and SW_6 was in concentration of 11.5 µg/L, 9.02 µg/L, 5.22 µg/L, 6.88 µg/L, 11.1, and 3.03 µg/L respectively. BBP across SW_1, SW_2, SW_3, SW_4, SW_5, and SW_6 was at 0.13 µg/L, 1.39 µg/L and 0.45 µg/L repectively. DEHP concentration levels along SW_1, SW_2, SW_3, SW_4, SW_5, and SW_6 was 1.77 µg/L, 3.33 µg/L, 2.01 µg/L, 1.88 µg/L, 2.91 µg/L and 0.12 µg/L respectively.

The distribution patterns of PAEs in the Ekpan river system are mainly controlled by various factors including the hydrodynamic state of the river system, the properties of concentration levels of 0.45 µg/L, 0.21 µg/L, 0.11 µg/L, the suspended solid particles, the physicochemical properties of the PAEs themselves, and the level of urbanization [12].

The differences in distribution patterns of PAEs in the Ekpan river suggested that there might be a variation in

pollution sources along with the river network. Among the sampling sites in the river system, SW_5 had the highest total concentration of PAEs, with DPX showing concentrations of 13.81 µg/L, 9.66 µg/L, 7.74 µg/L, 7.11 µg/L, 6.53 µg/L. DPX also had concentrations ranging as high as 11.5 µg/L, 11.1 µg/L, 9.02 µg/L, and 6.88 µg/L.

This site is one of the sites that are characterized by high open waste disposal due to a high population, industrialization, and urbanization along the Ekpan river system, housing many residential, and commercial hubs. Moreso, there is a major refinery upstream that deposits its wastewater into the river, which highlights the fluctuation downstream of phthalates along the river system.

DMP and Di-n-OP were below the limit of detection across all samples taken along the Ekpan river system. DEP was highest in SW_5 with values of 13.81 µg/L, while SW_1 had 9.66 µg/L. SW_2 had 7.11 µg/L, and SW_3 had. were one order of magnitude lower than DEP (241 ng/l), DBP (250 ng/l), and DEHP (514 ng/l). Further, the percentage composition of phthalates (DEHP, DEP, DBP, BBP, and DOP) observed in this study indicates their usage as mentioned in Olujimi *et al.* [7].

As indicated by the data in Fig. 2, the Effurun river has a higher total PAEs concentration in its water than those of Cianjhen river in Taiwan [31] and Jiulong river estuary in China [10], though it is lower than the values reported elsewhere, Kaoshiung Harbor, Taiwan [32], and Garda Sedimentation facility in Sweden [33], but comparable with PAEs levels reported for Jiulong river, China [10].

Similarly, Wang *et al.* [34] observed that discharge from the industrial areas is the main cause of high concentrations of PAEs in the riverine sediment of the Yangtze River, in Southern Jiangsu, China. Moreover, Chen *et al.* [35] documented that the high concentration of PAEs in the rivers of Love River was mainly due to the influx of industrial effluents, domestic sewage, and surface runoffs along the riverbank. Furthermore, discharge from Urban and agricultural areas was indicated to be the main contributor for an elevated concentration of PAEs in rivers of the Persian Gulf, in Iran [36]. Therefore, the relatively high total PAEs levels in rivers of the Ekpan river might be ascribed to the incessant discharging of wastewater from industries and residential areas, effluent from agricultural fields and aquaculture ponds as well as surface runoffs from nearby municipal solid waste sites, especially during flooding [37].

B. Source Correlation Analysis of PAEs concentration

The spearman correlations matrix (SCM) in Table IV showed the relationship between the levels of DEP, DPX, BBP, and DEHP with the concentrations of total PAEs in the water samples.

As seen, there is a significant correlation between ΣPAEs and DPX as well as DEHP, suggesting the significant role played by DPX and DEHP in total concentrations of PAEs in the investigated river water.

However, the contribution of DEHP to a total concentration of PAEs congeners was higher than DPX, thus, can be used as a marker to predict the concentration of other PAEs congeners in the investigated source water.

DEHP is the most commonly used PAEs and accounts for approximately 50% of the total industrial PAEs output in several countries, including Malaysia, Canada, Nigeria, South Africa, and China [6], [38]–[40]. This study observed that DEHP is the most predominant PAEs congener in raw water due to its high production, consumption volume, and low degradation rate. In addition, the legislation regulating the discharge of industrial and domestic wastewater in Nigeria does not specify limits for PAEs congeners into the aquatic environment [41]. In this study, DEHP is the most predominant PAEs in water, which is consistent with those of previous studies [6], [41]–[43].

TABLE IV: SPEARMAN CORRELATION MATRIX OF INDIVIDUAL PAES CONCENTRATION

Spearman Correlation Matrix				
	DEP	DPX	BBP	DEHP
DEP	1	–	–	–
DPX	0.20003	1	–	–
BBP	0.011	0.565*	1	–
DEHP	0.301	0.723	0.98	1
∑PAEs	0.518	0.798**	0.702**	–

* Correlation is significant at the 0.05 level *(*2-tailed*)*.

** Correlation is significant at the 0.01 level *(*2-tailed*)*.

C. Human Health Risk Assessment of PAEs in the Ekpan River Water

To evaluate the potential and harmful effects of PAEs in humans via exposure to contaminated river water, quality guidelines for source water and tolerable daily intake (TDI) were used. The result of this present study indicated that the mean concentration of DEP and DPX were slightly above the reference dose (RfD) of 8.0 µg/L and 3.0 µg/L respectively, for the surface water quality of China. Similarly, the mean concentration of DEHP and BBP in source water did not exceed the RfD values of 16 µg/L and 8.0 µg/L of the environmental quality standards of surface water in Canada and Korea, respectively.

Nevertheless, PAEs have been classified as endocrine-disrupting organic chemical pollutants (EDCs). EDCs are chemicals that can adversely affect the normal functioning of endocrine systems in humans as well as wildlife. These effects may not appear until the exposure becomes chronic or prolonged and may also be irreversible.

According to the result of this work, PAEs were detected in the Ekpan river water, which may be constantly ingested in daily life through swimming, suggesting that the source water is a significant source or pathway of human exposure to these endocrine-disrupting organic contaminants.

The human health risk assessment of PAEs via ingestion and bathing of river water is presented in Table V and Table X. While Table XI and Table XVI showed the hazard index of PAEs in children, adolescents, and adults.

D. Hazard Index (HI) Of PAEs via Ingestion and Bathing of the Ekpan River Water

Using the formula HI = ∑ HQ, the HI of PAEs health risk of combined effects or mixture effects of PAEs via ingestion and bathing with tap water. Results of HI of PAEs via ingestion and bathing in the Ekpan river are shown in Table XI, Table XII, Table XIII, Table XIV, Table XV, and Table XVI.

Using the value of the concentration of each PAEs in the river water, the HQ for DEP, DPX, BBP, and DEHP were below 1, indicating an acceptable risk of PAEs via drinking and bathing in the Effurun river water. This implies that none of these PAEs congeners will cause any bad health effects on adults, adolescents, and children through ingestions or dermal contact. Similarly, in the cancer risk evaluated for DEP, the only PAEs congener classified as a carcinogenic agent was lower than $1+10^{-6}$ indicating acceptable risk as stipulated by WHO [44]. This suggests that the level of DEP in the investigated tap water collected from the Effurun river system cannot trigger cancer risk in both children, adolescents, and adults via ingestion or dermal contact. Moreover, the HI index of PAEs was evaluated to assess the cumulative effects of PAEs from both ingestion and bathing of the river water on children, adolescents, and adults. The result indicated that the HI in all the waterworks was less than one, suggesting that the concentration of PAEs in tap water can not constitute a cumulative health risk on children, adolescents, and adults. However, DEP poses higher health risk effects on humans when compared to DEHP, DPX, and BBP.

TABLE V: HEALTH RISK ASSESSMENT OF PAES IN ADULTS VIA INGESTION OF THE EKPAN RIVER WATER

Sample Location	PAEs	Concentration *(µg/L)*	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.75×10^{-5}	1.10×10^{-5}	0.1	0.00017	–	–
	DPX	2.15	3.19×10^{-5}	1.05×10^{-5}	0.02	0.00198	0.014	5.161×10^{-7}
	DEP	9.66	3.95×10^{-3}	2.15×10^{-5}	0.005	0.00591		
	DEHP	1.77	2.29×10^{-5}	2.28×10^{-5}	0.115	0.000271	–	–
SW_2	BBP	0.21	0.34×10^{-5}	1.08×10^{-5}	0.1	0.000148	–	–
	DPX	9.02	3.14×10^{-5}	2.95×10^{-5}	0.02	0.00127	0.014	3.220×10^{-7}
	DEP	7.11	2.35×10^{-5}	0.45×10^{-5}	0.04	0.00119		
	DEHP	3.33	2.77×10^{-5}	1.60×10^{-5}	0.115	0.000260	–	–
SW_3	BBP	0.11	2.33×10^{-5}	1.70×10^{-5}	0.88	0.000233	–	–
	DPX	5.22	7.33×10^{-5}	2.59×10^{-5}	0.02	0.00178	0.014	3.626×10^{-7}
	DEP	6.53	4.12×10^{-5}	7.33×10^{-5}	0.17	0.02190		
	DEHP	2.01	3.10×10^{-5}	2.99×10^{-5}	0.115	0.000356	–	–
SW_4	BBP	2.20	3.43×10^{-5}	2.63×10^{-5}	0.1	0.000360	–	–
SW_5	DPX	4.15	5.29×10^{-5}	3.86×10^{-5}	0.02	0.00265	0.014	2.404×10^{-7}
	DEP	7.74	8.18×10^{-5}	7.54×10^{-5}	0.37	0.046		
SW_6	DEHP	2.36	3.11×10^{-5}	2.64×10^{-5}	0.234	0.00076	0.014	1.404×10^{-7}
	BBP	1.39	3.16×10^{-5}	2.07×10^{-5}	0.0012	0.00017		
	DPX	11.1	3.86×10^{-5}	2.34×10^{-5}	0.1110	0.000789		
	DEP	13.81	2.46×10^{-5}	1.81×10^{-5}	0.110	0.0456		
	DEHP	2.91	1.45×10^{-5}	2.88×10^{-5}	0.008	0.005708		5.404×10^{-7}
	BBP	0.45	0.62×10^{-5}	1.89×10^{-5}	0.30042	0.000765	0.014	
	DPX	3.03	1.46×10^{-5}	1.56×10^{-5}	0.115	0.00037		
	DEP	4.22	1.86×10^{-5}	4.33×10^{-5}	0.115	0.00045		
	DEHP	0.12	0.26×10^{-5}	2.3×10^{-5}	0.115	0.000767		

TABLE VI: HEALTH RISK ASSESSMENT OF PAES IN CHILDREN VIA INGESTION OF THE EKPAN RIVER WATER

Sample Location	PAEs	Concentration (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.5×10^{-5}	1.10×10^{-5}	0.1	0.00102	–	–
	DPX	2.15	3.19×10^{-5}	2.15×10^{-5}	0.02	0.00176	0.014	5.161×10^{-7}
	DEP	9.66	3.95×10^{-3}	2.15×10^{-5}	0.005	0.00492	–	–
	DEHP	1.77	2.29×10^{-5}	2.28×10^{-5}	0.115	0.000206	–	–
SW_2	BBP	0.21	0.34×10^{-5}	1.08×10^{-5}	0.1	0.000132	–	–
	DPX	9.02	3.14×10^{-5}	2.95×10^{-5}	0.02	0.00101	0.014	3.220×10^{-7}
	DEP	7.11	2.35×10^{-5}	0.45×10^{-5}	0.04	0.00108	–	–
	DEHP	3.33	2.77×10^{-5}	1.60×10^{-5}	0.115	0.00024	–	–
SW_3	BBP	0.11	2.33×10^{-5}	1.70×10^{-5}	0.88	0.000213	–	–
	DPX	5.22	7.33×10^{-5}	2.59×10^{-5}	0.02	0.00149	0.014	3.626×10^{-7}
	DEP	6.53	7.33×10^{-5}	7.33×10^{-5}	0.17	0.0021	–	–
	DEHP	2.01	3.10×10^{-5}	2.99×10^{-5}	0.115	0.000236	–	–
SW_4	BBP	2.2	3.43×10^{-5}	2.63×10^{-5}	0.1	0.00014	–	–
	DPX	4.15	5.29×10^{-5}	3.86×10^{-5}	0.02	0.002654	0.014	2.404×10^{-7}
	DEP	7.74	8.18×10^{-5}	7.54×10^{-5}	0.37	0.023	–	–
	DEHP	2.36	3.11×10^{-5}	1.89×10^{-5}	0.234	0.00034	–	–
SW_5	BBP	1.39	3.16×10^{-5}	0.34×10^{-5}	0.0012	0.00012	0.014	1.404×10^{-7}
	DPX	11.1	3.86×10^{-5}	2.67×10^{-5}	0.115	0.00023	–	–
	DEP	13.81	2.46×10^{-5}	4.45×10^{-5}	0.11	0.0321	–	–
	DEHP	2.91	1.45×10-5	1.75×10^{-5}	0.008	0.004508	–	–
SW_6	BBP	0.45	0.62×10^{-5}	0.54×10^{-5}	0.30042	0.000465	–	5.404×10^{-7}
	DPX	3.03	2.01×10^{-5}	1.69×10^{-5}	0.115	0.000157	0.014	–
	DEP	4.22	2.13×10^{-5}	1.85×10^{-5}	0.115	0.000257	–	–
	DEHP	0.12	1.60×10^{-5}	0.29×10^{-5}	0.115	5.23E-05	–	–

TABLE VII: HEALTH RISK ASSESSMENT OF PAES IN ADOLESCENTS VIA INGESTION OF THE EKPAN RIVER WATER

Sample Location	PAEs	Mean (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.32×10^{-5}	1.23×10^{-5}	0.1	0.00151	–	–
	DPX	2.15	2.89×10^{-5}	2.76×10^{-5}	0.02	0.0011	0.014	5.210×10^{-7}
	DEP	9.66	4.17×10^{-5}	2.32×10^{-5}	0.005	0.0062	–	–
	DEHP	1.77	2.58×10^{-5}	2.54×10^{-5}	0.115	0.00031	–	–
SW_2	BBP	0.21	1.34×10^{-5}	1.54×10^{-5}	0.1	0.000132	–	–
	DPX	9.02	3.58×10^{-5}	3.23×10^{-5}	0.02	0.00023	0.014	3.150×10^{-7}
	DEP	7.11	3.88×10^{-5}	1.34×10^{-5}	0.04	0.00181	–	–
	DEHP	3.33	2.98×10^{-5}	1.76×10^{-5}	0.115	0.00034	–	–
SW_3	BBP	0.11	2.89×10^{-5}	1.89×10^{-5}	0.88	0.000301	–	–
	DPX	5.22	6.34×10^{-5}	2.86×10^{-5}	0.02	0.00161	0.014	3.89×10^{-7}
	DEP	6.53	6.65×10^{-5}	7.43×10^{-5}	0.17	0.0032	–	–
	DEHP	2.01	3.43×10^{-5}	3.23×10^{-5}	0.115	0.000251	–	–
SW_4	BBP	2.2	3.23×10^{-5}	2.89×10^{-5}	0.1	0.00021	–	–
	DPX	4.15	4.78×10^{-5}	3.98×10^{-5}	0.02	0.002811	0.014	2.56×10^{-7}
	DEP	7.74	7.24×10^{-5}	7.65×10^{-5}	0.37	0.0109	–	–
	DEHP	2.36	3.89×10^{-5}	1.98×10^{-5}	0.234	0.00039	–	–
SW_5	BBP	1.39	3.64×10^{-5}	0.76×10^{-5}	0.0012	0.00021	0.014	1.510×10^{-7}
	DPX	11.1	3.45×10^{-5}	2.76×10^{-5}	0.115	0.000321	–	–
	DEP	13.81	2.78×10^{-5}	4.65×10^{-5}	0.11	0.0211	–	–
	DEHP	2.91	1.86×10^{-5}	1.87×10^{-5}	0.008	0.00521	–	–
SW_6	BBP	0.45	1.23×10^{-5}	0.53×10^{-5}	0.30042	0.000389	–	5.386×10^{-7}
	DPX	3.03	2.56×10^{-5}	1.45×10^{-5}	0.115	0.000189	0.014	–
	DEP	4.22	2.89×10^{-5}	1.97×10^{-5}	0.115	0.000267	–	–
	DEHP	0.12	1.78×10^{-5}	0.79×10^{-5}	0.115	0.0000499	–	–

TABLE VIII: HEALTH RISK ASSESSMENT OF PAES IN ADULTS VIA BATHING IN THE EKPAN RIVER WATER

Sample Location	PAEs	Concentration (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.4×10^{-5}	0.89×10^{-5}	0.1	0.00132	–	–
	DPX	2.15	2.34×10^{-5}	2.01×10^{-5}	0.02	0.00156	0.014	5.171×10^{-7}
	DEP	9.66	4.45×10^{-3}	2.89×10^{-5}	0.005	0.00462	–	–
	DEHP	1.77	2.45×10^{-5}	2.86×10^{-5}	0.115	0.000306	–	–
SW_2	BBP	0.21	0.57×10^{-5}	1.54×10^{-5}	0.1	0.000232	–	–
	DPX	9.02	3.45×10^{-5}	3.01×10^{-5}	0.02	0.00181	0.014	3.210×10^{-7}
	DEP	7.11	2.54×10^{-5}	0.86×10^{-5}	0.04	0.00178	–	–
	DEHP	3.33	1.56×10^{-5}	1.89×10^{-5}	0.115	0.00036	–	–
SW_3	BBP	0.11	3.67×10^{-5}	1.90×10^{-5}	0.88	0.000623	–	–
	DPX	5.22	7.56×10^{-5}	2.67×10^{-5}	0.02	0.00049	0.014	3.636×10^{-7}
	DEP	6.53	6.98×10^{-5}	7.67×10^{-5}	0.17	0.00119	–	–
	DEHP	2.01	6.19×10^{-5}	3.02×10^{-5}	0.115	0.000136	–	–
SW_4	BBP	2.2	2.67×10^{-5}	2.89×10^{-5}	0.1	0.00022	–	–
	DPX	4.15	4.56×10^{-5}	3.94×10^{-5}	0.02	0.002244	0.014	2.446 x10-7
	DEP	7.74	4.87×10^{-5}	7.68×10^{-5}	0.37	0.0232	–	–
	DEHP	2.36	3.98×10^{-5}	1.94×10^{-5}	0.234	0.00014	–	–
SW_5	BBP	1.39	2.76×10^{-5}	0.89×10^{-5}	0.0012	0.00032	0.014	1.491×10^{-7}
	DPX	11.1	2.98×10^{-5}	2.67×10^{-5}	0.115	0.00033	–	–
	DEP	13.81	3.98×10^{-5}	4.67×10^{-5}	0.11	0.0234	–	–
	DEHP	2.91	0.98×10^{-5}	1.86×10^{-5}	0.008	0.00208	–	–
SW_6	BBP	0.45	1.01×10^{-5}	0.68×10^{-5}	0.30042	0.000465	–	5.451×10^{-7}
	DPX	3.03	1.98×10^{-5}	2.02×10^{-5}	0.115	0.002157	0.014	–
	DEP	4.22	2.98×10^{-5}	1.58×10^{-5}	0.115	0.002125	–	–
	DEHP	0.12	0.98×10^{-5}	0.67×10^{-5}	0.115	0.002123	–	–

TABLE IX: HEALTH RISK ASSESSMENT OF PAES IN CHILDREN VIA BATHING OF THE EKPAN WATER

Sample Location	PAEs	Mean (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.34×10^{-5}	1.32×10^{-5}	0.1	0.00102	–	–
	DPX	2.15	3.39×10^{-5}	2.15×10^{-5}	0.02	0.00176	0.014	5.161×10^{-7}
	DEP	9.66	3.46×10^{-3}	2.15×10^{-5}	0.005	0.00492		
	DEHP	1.77	2.34×10^{-5}	2.28×10^{-5}	0.115	0.000206		
SW_2	BBP	0.21	0.33×10^{-5}	1.08×10^{-5}	0.1	0.000132		
	DPX	9.02	3.23×10^{-5}	2.95×10^{-5}	0.02	0.00101	0.014	3.220×10^{-7}
	DEP	7.11	2.45×10^{-5}	0.45×10^{-5}	0.04	0.00108	–	–
	DEHP	3.33	2.74×10^{-5}	1.60×10^{-5}	0.115	0.00024	–	–
SW_3	BBP	0.11	2.22×10^{-5}	1.70×10^{-5}	0.88	0.000213	–	–
	DPX	5.22	7.45×10^{-5}	2.59×10^{-5}	0.02	0.00149	0.014	3.626×10^{-7}
	DEP	6.53	7.32×10^{-5}	7.33×10^{-5}	0.17	0.0021	–	–
	DEHP	2.01	3.43×10^{-5}	2.99×10^{-5}	0.115	0.000236	–	–

TABLE IX: HEALTH RISK ASSESSMENT OF PAES IN CHILDREN VIA BATHING OF THE EKPAN WATER (CONT.)

Sample Location	PAEs	Mean (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_4	BBP	2.2	3.32×10^{-5}	2.63×10^{-5}	0.1	0.00014	–	–
	DPX	4.15	5.56×10^{-5}	3.86×10^{-5}	0.02	0.002654	0.014	2.404×10^{-7}
	DEP	7.74	8.32×10^{-5}	7.54×10^{-5}	0.37	0.023	–	–
	DEHP	2.36	3.35×10^{-5}	1.89×10^{-5}	0.234	0.00034	–	–
SW_5	BBP	1.39	3.45×10^{-5}	0.34×10^{-5}	0.0012	0.00012	0.014	1.404×10^{-7}
	DPX	11.1	3.6×10^{-5}	2.67×10^{-5}	0.115	0.00023	–	–
	DEP	13.81	2.4346×10^{-5}	4.45×10^{-5}	0.11	0.0321	–	–
	DEHP	2.91	$1.48\text{x}10^{-5}$	1.75×10^{-5}	0.008	0.004508	–	–
SW_6	BBP	0.45	0.98×10^{-5}	0.54×10^{-5}	0.30042	0.000465	–	5.404×10^{-7}
	DPX	3.03	2.84×10^{-5}	1.6×10^{-5}	0.115	0.000157	0.014	–
	DEP	4.22	2.45×10^{-5}	1.85×10^{-5}	0.115	0.000257	–	–
	DEHP	0.12	1.65×10^{-5}	0.29×10^{-5}	0.115	0.000523	–	–

TABLE X: HEALTH RISK ASSESSMENT OF PAES IN ADOLESCENTS VIA BATHING OF THE EKPAN RIVER WATER

Sample Location	PAEs	Mean (µg/L)	ADD	LADD	RfD mg/kg/d	HQ	Slope factor	Cancer Risk
SW_1	BBP	0.45	1.21×10^{-5}	1.43×10^{-5}	0.1	0.00159	–	–
	DPX	2.15	2.23×10^{-5}	2.98×10^{-5}	0.02	0.00023	0.014	5.10×10^{-7}
	DEP	9.66	3.46×10^{-3}	2.52×10^{-5}	0.005	0.0043	–	–
	DEHP	1.77	2.15×10^{-5}	2.34×10^{-5}	0.115	0.00043	–	–
SW_2	BBP	0.21	1.14×10^{-5}	1.73×10^{-5}	0.1	0.000141	–	–
	DPX	9.02	3.28×10^{-5}	3.11×10^{-5}	0.02	0.00023	0.014	3.130×10^{-7}
	DEP	7.11	3.58×10^{-5}	1.34×10^{-5}	0.04	0.00172	–	–
	DEHP	3.33	2.38×10^{-5}	1.98×10^{-5}	0.115	0.00038	–	–
SW_3	BBP	0.11	2.29×10^{-5}	1.93×10^{-5}	0.88	0.000322	–	–
	DPX	5.22	6.14×10^{-5}	2.73×10^{-5}	0.02	0.00182	0.014	3.73 x10-7
	DEP	6.53	6.23×10^{-5}	7.82×10^{-5}	0.17	0.0031	–	–
	DEHP	2.01	3.23×10^{-5}	3.45×10^{-5}	0.115	0.000252	–	–
SW_4	BBP	2.2	3.14×10^{-5}	2.95×10^{-5}	0.1	0.00025	–	–
	DPX	4.15	4.28×10^{-5}	4.02×10^{-5}	0.02	0.00292	0.014	2.67×10^{-7}
	DEP	7.74	7.01×10^{-5}	7.64×10^{-5}	0.37	0.001	–	–
	DEHP	2.36	3.37×10^{-5}	2.01×10^{-5}	0.234	0.00041	–	–
SW_5	BBP	1.39	3.49×10^{-5}	0.93×10^{-5}	0.0012	0.00024	0.014	1.570×10^{-7}
	DPX	11.1	3.45×10^{-5}	2.89×10^{-5}	0.115	0.00034	–	–
	DEP	13.81	2.54×10^{-5}	4.42×10^{-5}	0.11	0.022	–	–
	DEHP	2.91	1.91×10^{-5}	1.96×10^{-5}	0.008	0.005301	–	–
SW_6	BBP	0.45	1.65×10^{-5}	0.72×10^{-5}	0.30042	0.0003	–	5.401×10^{-7}
	DPX	3.03	2.65×10^{-5}	1.53×10^{-5}	0.115	0.000191	0.014	–
	DEP	4.22	2.32×10^{-5}	1.87×10^{-5}	0.115	0.00027	–	–
	DEHP	0.12	1.82×10^{-5}	0.85×10^{-5}	0.115	3.81E-05	–	–

TABLE XI: HAZARD INDEX OF PAES IN ADULTS VIA INGESTION OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.43×10^{-5}	0.1	0.000151
	DEHP	1.77	3.02×10^{-5}	0.02	0.00147
	DPX	11.5	2.95×10^{-6}	0.02	0.00147
	DEP	9.66	2.56×10^{-5}	0.8	0.000271
	Hazard Index of PAEs		–	–	0.001892
SW_2	BBP	0.21	1.61×10^{-5}	0.1	0.000148
	DEHP	3.33	1.45×10^{-5}	0.02	–
	DPX	9.02	2.11×10^{-5}	0.02	0.00127
	DEP	7.11	1.77×10^{-5}	0.8	0.00026
	Hazard Index of PAEs		–	–	0.001678
SW_3	BBP	0.11	2.12×10^{-5}	0.1	0.000233
	DEHP	2.01	3.45×10^{-5}	0.02	0.00178
	DPX	5.22	1.65×10^{-5}	0.02	0.00054
	DEP	6.53	2.89×10^{-5}	0.8	0.000356
	Hazard Index of PAEs		–	–	0.002369
SW_4	BBP	0.13	3.67×10^{-5}	0.1	0.00036
	DEHP	1.88	4.87×10^{-5}	0.02	0.00265
	DPX	6.88	4.01×10^{-5}	0.115	0.000287
	DEP	7.74	3.11×10^{-6}	0.8	0.000562
Hzard Index of PAEs		–	–	–	0.000537
SW_5	BBP	1.39	1.45×10^{-6}	0.1	0.00065
	DEHP	2.91	2.89×10^{-6}	0.02	0.00643
	DPX	11.1	7.11×10^{-4}	0.02	0.0053
	DEP	13.81	2.60×10^{-3}	0.8	0.00008
	Hazard Index of PAEs		–	–	0.003367
SW_6	BBP	0.45	2.89×10^{-5}	0.1	0.000445
	DEHP	0.12	8.11×10^{-7}	0.02	0.0053
	DPX	3.03	4.64×10^{-6}	0.02	0.000532
	DEP	4.22	5.54×10^{-5}	0.8	0.00089
Hazard Index of PAEs		–	–	–	0.000278

TABLE XII: HAZARD INDEX OF PAES IN ADULTS VIA BATHING OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.32×10^{-5}	0.1	0.000141
	DEHP	1.77	3.43×10^{-5}	0.02	0.00127
	DPX	11.5	3.01×10^{-6}	0.02	0.00107
	DEP	9.66	2.76×10^{-5}	0.8	0.000293
	Hazard Index of PAEs		–	–	0.00192
SW_2	BBP	0.21	1.72×10^{-5}	0.1	0.000151
	DEHP	3.33	1.76×10^{-5}	0.02	0.00031
	DPX	9.02	2.64×10^{-5}	0.02	0.00134
	DEP	7.11	1.89×10^{-5}	0.8	0.00029
	Hazard Index of PAEs		–	–	0.00153
SW_3	BBP	0.11	2.43×10^{-5}	0.1	0.000247
	DEHP	2.01	3.89×10^{-5}	0.02	0.00178
	DPX	5.22	1.83×10^{-5}	0.02	0.00831
	DEP	6.53	2.94×10^{-5}	0.8	0.000412
	Hazard Index of PAEs		–	–	0.00041
SW_4	BBP	0.13	3.57×10^{-5}	0.1	0.00042
	DEHP	1.88	4.43×10^{-5}	0.02	0.00301
	DPX	6.88	4.01×10^{-5}	0.115	0.000249
	DEP	7.74	3.43×10^{-6}	0.8	0.000521
Hzard Index of PAEs		–	–	–	0.000497
SW_5	BBP	1.39	1.42×10^{-6}	0.1	0.00293
	DEHP	2.91	2.92×10^{-6}	0.02	0.00043
	DPX	11.1	7.43×10^{-4}	0.02	0.000032
	DEP	13.81	2.68×10^{-3}	0.8	0.000023
	Hazard Index of PAEs		–	–	0.00212
SW_6	BBP	0.45	2.23×10^{-5}	0.1	0.000032
	DEHP	0.12	8.56×10^{-7}	0.02	0.0045
	DPX	3.03	4.32×10^{-6}	0.02	0.00054
	DEP	4.22	5.587×10^{-5}	0.8	0.00093
Hazard Index of PAEs		–	–	–	0.000021

TABLE XIII: HAZARD INDEX OF PAES IN CHILDREN VIA INGESTION OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.15×10^{-5}	0.1	0.00075
	DEHP	1.77	3.14×10^{-5}	0.02	0.0043
	DPX	11.5	3.23×10^{-6}	0.02	0.00181
	DEP	9.66	2.54×10^{-5}	0.8	0.000301
	Hazard Index of PAEs		–	–	0.0021
SW_2	BBP	0.21	1.82×10^{-5}	0.1	0.00019
	DEHP	3.33	1.89×10^{-5}	0.02	0.00028
	DPX	9.02	2.84×10^{-5}	0.02	0.00141
	DEP	7.11	1.93×10^{-5}	0.8	0.00031
	Hazard Index of PAEs		–	–	0.00161
SW_3	BBP	0.11	2.51×10^{-5}	0.1	0.000212
	DEHP	2.01	3.72×10^{-5}	0.02	0.00458
	DPX	5.22	1.63×10^{-5}	0.02	0.00791
	DEP	6.53	2.38×10^{-5}	0.8	0.000391
	Hazard Index of PAEs		–	–	0.00032
SW_4	BBP	0.13	3.35×10^{-5}	0.1	0.000391
	DEHP	1.88	4.32×10^{-5}	0.02	0.00049
	DPX	6.88	4.16×10^{-5}	0.115	0.00045
	DEP	7.74	3.52×10^{-6}	0.8	0.00065
Hzard Index of PAEs	–	–	–	–	0.000454
SW_5	BBP	1.39	1.35×10^{-6}	0.1	0.00271
	DEHP	2.91	2.74×10^{-6}	0.02	0.000392
	DPX	11.1	7.53×10^{-4}	0.02	0.000039
	DEP	13.81	2.73×10^{-3}	0.8	0.000027
	Hazard Index of PAEs		–	–	0.00261
SW_6	BBP	0.45	2.29×10^{-5}	0.1	0.000038
	DEHP	0.12	8.34×10^{-7}	0.02	0.0048
	DPX	3.03	4.14×10^{-6}	0.02	0.00062
	DEP	4.22	5.87×10^{-5}	0.8	0.00089
Hazard Index of PAEs		–	–	–	0.000032

TABLE XIV: HAZARD INDEX OF PAES IN CHILDREN VIA BATHING OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.19×10^{-5}	0.1	0.00075
	DEHP	1.77	3.24×10^{-5}	0.02	0.0041
	DPX	11.5	3.56×10^{-6}	0.02	0.0016
	DEP	9.66	2.24×10^{-5}	0.8	0.000351
	Hazard Index of PAEs		–	–	0.00251
SW_2	BBP	0.21	1.93×10^{-5}	0.1	0.000139
	DEHP	3.33	1.65×10^{-5}	0.02	0.00021
	DPX	9.02	2.95×10^{-5}	0.02	0.00138
	DEP	7.11	1.79×10^{-5}	0.8	0.000331
	Hazard Index of PAEs		–	–	0.0018

TABLE XIV: HAZARD INDEX OF PAES IN CHILDREN VIA BATHING OF THE EKPAN RIVER WATER (CONT.)

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_3	BBP	0.11	2.45×10^{-5}	0.1	0.000281
	DEHP	2.01	3.68×10^{-5}	0.02	0.00462
	DPX	5.22	1.45×10^{-5}	0.02	0.0065
	DEP	6.53	2.21×10^{-5}	0.8	0.000541
	Hazard Index of PAEs		–	–	0.00045
SW_4	BBP	0.13	3.21×10^{-5}	0.1	0.000401
	DEHP	1.88	4.21×10^{-5}	0.02	0.00042
	DPX	6.88	4.34×10^{-5}	0.115	0.00038
	DEP	7.74	3.45×10-6	0.8	0.000591

TABLE XIV: HAZARD INDEX OF PAES IN CHILDREN VIA BATHING OF THE EKPAN RIVER WATER (CONT.)

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
Hzard Index of PAEs		–	–	–	0.00039
SW_5	BBP	1.39	1.45×10^{-6}	0.1	0.00311
	DEHP	2.91	2.65×10^{-6}	0.02	0.000323
	DPX	11.1	7.47×10^{-4}	0.02	0.0000269
	DEP	13.81	2.84×10^{-3}	0.8	0.000031
	Hazard Index of PAEs		–	–	0.00321
SW_6	BBP	0.45	2.38×10^{-5}	0.1	0.000032
	DEHP	0.12	8.53×10^{-7}	0.02	0.0032
	DPX	3.03	4.09×10^{-6}	0.02	0.00051
	DEP	4.22	5.38×10^{-5}	0.8	0.00078
Hazard Index of PAEs		–	–	–	0.000039

TABLE XV: HAZARD INDEX OF PAES IN ADOLESCENTS VIA INGESTION OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.53×10^{-5}	0.1	0.000564
	DEHP	1.77	$3.237x10^{-5}$	0.02	0.0036
	DPX	11.5	4.87×10^{-6}	0.02	0.0045
	DEP	9.66	2.45×10^{-5}	0.8	0.000401
	Hazard Index of PAEs		–	–	0.00287
SW_2	BBP	0.21	1.97×10^{-5}	0.1	0.000167
	DEHP	3.33	1.87×10^{-5}	0.02	0.00028
	DPX	9.02	3.10×10^{-5}	0.02	0.00167
	DEP	7.11	2.65×10^{-5}	0.8	0.00038
	Hazard Index of PAEs		–	–	0.00201
SW_3	BBP	0.11	2.37×10^{-5}	0.1	0.000262
	DEHP	2.01	3.75×10^{-5}	0.02	0.00421
	DPX	5.22	1.67×10^{-5}	0.02	0.0059
	DEP	6.53	2.86×10^{-5}	0.8	0.000391
	Hazard Index of PAEs		–	–	0.000498
SW_4	BBP	0.13	3.89×10^{-5}	0.1	0.000329
	DEHP	1.88	4.67×10^{-5}	0.02	0.000391
	DPX	6.88	4.48×10^{-5}	0.115	0.000418
	DEP	7.74	3.23×10^{-6}	0.8	0.000614
Hzard Index of PAEs		–	–	–	0.00041
SW_5	BBP	1.39	1.65×10^{-6}	0.1	0.00389
	DEHP	2.91	2.89×10^{-6}	0.02	0.000356
	DPX	11.1	7.13×10^{-4}	0.02	2.38E-05
	DEP	13.81	2.98×10^{-3}	0.8	0.000032
	Hazard Index of PAEs		–	–	0.00431
SW_6	BBP	0.45	2.12×10^{-5}	0.1	0.000034
	DEHP	0.12	8.32×10^{-7}	0.02	0.0038
	DPX	3.03	4.34×10^{-6}	0.02	0.000491
	DEP	4.22	5.23×10^{-5}	0.8	0.00071
	Hazard Index of PAEs		–	–	0.000035

TABLE XVI: HAZARD INDEX OF PAES IN ADOLESCENTS VIA BATHING OF THE EKPAN RIVER WATER

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_1	BBP	0.45	1.48×10^{-5}	0.1	0.00063
	DEHP	1.77	3.34×10^{-5}	0.02	0.0041
	DPX	11.5	4.54×10^{-6}	0.02	0.0052
	DEP	9.66	2.65×10^{-5}	0.8	0.00045
	Hazard Index of PAEs		–	–	0.0036
SW_2	BBP	0.21	1.65×10^{-5}	0.1	0.000187
	DEHP	3.33	1.56×10^{-5}	0.02	0.00031
	DPX	9.02	3.18×10^{-5}	0.02	0.00171
	DEP	7.11	2.87×10^{-5}	0.8	0.00041
	Hazard Index of PAEs		–	–	0.0021
SW_3	BBP	0.11	2.54×10^{-5}	0.1	0.000273
	DEHP	2.01	3.89×10^{-5}	0.02	0.00432
	DPX	5.22	1.54×10^{-5}	0.02	0.0043
	DEP	6.53	2.54×10^{-5}	0.8	0.000343
	Hazard Index of PAEs		–	–	0.000421

TABLE XVI: HAZARD INDEX OF PAES IN ADOLESCENTS VIA BATHING OF THE EKPAN RIVER WATER (CONT.)

Sampling point	PAEs	Concentration (µg/L)	ADD	RfD mg/kg/d	HQ
SW_4	BBP	0.13	3.94×10^{-5}	0.1	0.000342
	DEHP	1.88	4.54×10^{-5}	0.02	0.00033
	DPX	6.88	4.57×10^{-5}	0.115	0.000398
	DEP	7.74	3.54×10^{-6}	0.8	0.00067
Hzard Index of PAEs	–	–	–	–	0.00048
SW_5	BBP	1.39	1.435×10^{-6}	0.1	0.00354
	DEHP	2.91	2.33×10^{-6}	0.02	0.000316
	DPX	11.1	7.98×10^{-4}	0.02	0.0000212
	DEP	13.81	2.54×10^{-3}	0.8	0.000038
Hazard Index of PAEs			–	–	0.0046
SW_6	BBP	0.45	2.65×10^{-5}	0.1	0.000038
	DEHP	0.12	8.43×10^{-7}	0.02	0.0032
	DPX	3.03	4.54×10^{-6}	0.02	0.000421
	DEP	4.22	5.98×10^{-5}	0.8	0.00064
Hazard Index of PAEs			–	–	0.000043

V. CONCLUSION

In conclusion, the study revealed that the Ekpan river system was contaminated with DEP, DPX, BBP, and DEHP to some extent. The levels of PAEs in the river water posed acceptable health risks of both carcinogenic and noncarcinogenic risks. The endocrine disruptive effect of PAEs has the potential to cause infertility to aquatic animals, especially fishes, shrimps, and crabs which are abundant there. To prevent negative impacts on the local economy and food security, both point source and nonpoint source of PAEs should be strictly regulated and monitored continuously.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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