EGYPTIAN ACADEMIC JOURNAL OF
BIOLOGICAL SCIENCES
ZOOLOGY

B

ISSN
2090-0759

WWW.EAJBS.EG.NET

Vol. 16 No. 2 (2024)

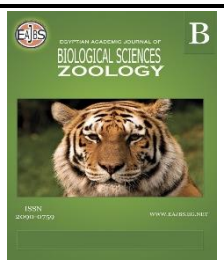
.

www.eajbs.eg.net

Citation: *Egypt. Acad. J. Biolog. Sci. (B. Zoology) Vol. 16(2) pp:159-172 (2024)*
DOI: 10.21608/EAJBSZ.2024.394786

Egypt. Acad. J. Biolog. Sci., 16(2):159-172(2024)

Egyptian Academic Journal of Biological Sciences
B. Zoology
ISSN: 2090 – 0759
http://eajbsz.journals.ekb.eg/



Comparative Bioaccumulation of Polybrominated Diphenyl Ethers (Pbdes) in *Synodontis clarias* and *Tilapia zilli* in Lekki Lagoon, Lagos, Nigeria

Tobi O. Ayoola[1], Akinsanya Bamidele[1], Akeredolu Excellence[1], Sultan O. Junaid[1], Kofoworola, Z. J. Ovioma[1], Godwin Onoriode[2], Zainab A. Otubanjo[1]; Mary Uwayo[1] and Patrick Omoregie[2]

[1]Department of Zoology, faculty of life Sciences, University of Lagos, Nigeria.
[2]Department of Biological Sciences, Covenant University, Ota, Ogun State, Nigeria.
*** E-mail** : bamidele992@gmail.com

ARTICLE INFO
Article History
Received:30/10/2024
Accepted:3/12/2024
Available:7/12/2024

Keywords:
Anthropogenic, runoff, biomagnification, endocrine disruption, lipid profile, turbidity.

ABSTRACT

This study investigates the bioaccumulation of polybrominated diphenyl ethers (PBDEs), specifically PBDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether), in two fish species, *Tilapia zilli* (*T. zilli*) and *Synodontis clarias* (*S. clarias*), within the Lekki Lagoon, Lagos, Nigeria. The study aim to ascertain the effects and magnitude of PBDE bioaccumulation and assess the major effects associated with the consumption of these fishes.. Sampling was conducted in various locations within the lagoon, with specific attention to areas exhibiting different turbidity levels potentially influenced by anthropogenic activities. Tissue samples from the intestines of both fish species were collected and subjected to rigorous biochemical analyses to detect and quantify PBDE concentrations. Notably, T. zilli exhibited significantly higher levels of PBDE-183, measuring 0.02 mg/g, compared to S. clarias. This differential bioaccumulation suggests species-specific susceptibilities, likely influenced by physiological and metabolic differences. The study reveals that elevated turbidity levels, particularly in the habitat of T. zilli, can be attributed to localized anthropogenic disturbances rather than upstream water influx. These disturbances may include industrial effluents, urban runoff, and inadequate waste management practices. Such activities introduce PBDEs into the aquatic environment through various pathways, including direct discharge, stormwater drainage, and improper disposal of PBDE-containing materials. This study underscores the urgent need for improved industrial regulations, effective waste management practices, and public awareness to reduce PBDE contamination. Implementing these measures is crucial to preserve the ecological integrity of Lekki Lagoon and protect its aquatic life. Regular monitoring and further research are recommended to track contamination trends, assess the effectiveness of mitigation strategies, and understand the long-term health impacts on fish populations and human consumers. The findings of this study highlight the significance of species-specific studies in environmental toxicology, providing valuable insights into the differential bioaccumulation of contaminants and their ecological implications. By addressing the anthropogenic sources of PBDEs, we can mitigate their environmental and health impacts, ensuring the sustainability of vital aquatic ecosystems such as Lekki Lagoon.

INTRODUCTION

This contaminant is known as flame retardants and are used in various consumer products, including electronics, textiles, and furniture, to reduce the risk of fire. Chemically, PBDEs consist of two phenyl rings bonded with one to ten bromine atoms, conferring varying degrees of bromination across different congeners (Abdallah and Harrad, 2014). The environmental persistence of PBDEs, combined with their hydrophobic nature, has led to their ubiquitous presence in the environment. These compounds are released through manufacturing processes, product wear and tear, and disposal, subsequently entering air, water, and soil matrices (O'Driscoll *et al.,* 2016; Okoffo *et al.,* 2021; Oloruntoba *et al.,* 2021; Olujimi *et al.,* 2022).

PBDEs pose significant ecological and human health risks as a results of their non-biodegradable nature and ability for long-range atmospheric transport, and bioaccumulative properties. In aquatic systems, they adsorb onto particulate matter and sediments, becoming a persistent source of contamination. The lipophilicity of PBDEs facilitates their accumulation in biota, where they biomagnify through the food web, leading to higher concentrations in apex predators. Chronic exposure to PBDEs has been associated with neurodevelopmental deficits, endocrine disruption, and hepatotoxicity in wildlife and humans (Olutona *et al.,* 2016; Olutona *et al.,* 2017). The environmental burden of PBDEs necessitates comprehensive monitoring and mitigation strategies to minimize their impact. Studying bioaccumulation in aquatic organisms is crucial for understanding the ecological and health risks posed by persistent organic pollutants (POPs) like PBDEs. Bioaccumulation refers to the process by which organisms absorb and retain contaminants from their environment and diet at rates faster than they can eliminate them. In aquatic ecosystems, organisms such as fish, mollusks, and crustaceans are particularly vulnerable due to their direct contact with contaminated water and sediments (Adewuyi and Adeleye, 2013; Luo *et al.,* 2014; McGrath *et al.,* 2018; Margolis *et al.,* 2020).

Bioaccumulation studies provide insight into the trophic transfer of contaminants and the potential for biomagnification, where contaminant concentrations increase at higher trophic levels. This is particularly significant for humans who consume aquatic species, as it directly impacts food safety and public health. Understanding the factors influencing bioaccumulation, including species-specific metabolic capacities, environmental conditions, and chemical properties of the contaminants, is essential for risk assessment and the development of effective regulatory policies. Additionally, bioaccumulation data aids in the conservation of biodiversity and the protection of vulnerable species within aquatic ecosystems (Zhu *et al.,* 2015; Yu *et al.,* 2016; Babayemi, *et al.,* 2018; Zhang *et al.,* 2020).
Lekki Lagoon, located in the southwestern region of Nigeria, is a brackish water body that spans an area of approximately 247 km². It is part of the larger Lagos Lagoon system and is connected to the Atlantic Ocean through a network of waterways, including the Lagos Lagoon and the Ogun River. (Bergayou *et al.,* 2009; Bodin *et al.,* 2011; Bamidele *et al.,* 2020). It involves in nutrient cycling, sediment transport, and maintaining regional hydrological balance. However, the lagoon faces environmental pressures from urbanization, industrialization, and pollution, leading to habitat degradation and water quality deterioration. Understanding and preserving the ecological integrity of Lekki Lagoon is imperative for sustaining its ecological functions, supporting local communities, and enhancing regional environmental health (Bobescu *et al.,* 2021).

The contamination of Lekki Lagoon with polybrominated diphenyl ethers (PBDEs) can be attributed to a variety of anthropogenic activities in the surrounding catchment area. These activities introduce PBDEs into the environment through different pathways, contributing to the overall pollution of the lagoon. Factories producing electronics, textiles, plastics, and other products often use PBDEs as flame retardants. Effluents from these

facilities can contain high levels of PBDEs, which are released directly into water bodies. Improperly treated industrial waste and sewage from treatment plants can be significant sources of PBDEs (Bramwell *et al.,* 2017; Cao *et al.,* 2018)..

The contaminants are found in televisions, computers, mattresses, and upholstered furniture (Guo *et al.,* 2016). Over time, PBDEs can leach from these products into household dust and, through improper waste disposal, into the environment. Washing clothes, especially those treated with flame retardants, and other cleaning activities can release PBDEs into wastewater, which may not be fully removed during sewage treatment. Utilizing water from the lagoon for irrigation purposes can introduce PBDEs into agricultural fields, from where they can re-enter the water system through runoff and soil leaching (Onyeche and Akankali, 2013; Park *et al.,* 2014). Certain agricultural chemicals can be contaminated with PBDEs, adding to the pollution load when these substances are applied to crops. PBDEs released into the atmosphere from various sources can travel long distances before settling into water bodies, including Lekki Lagoon. This process is facilitated by their semi-volatile nature, allowing them to undergo repeated cycles of evaporation and deposition (Pereira *et al.,* 2013; Choi *et al.,* 2014; Pellacani *et al.,* 2014; Ukenye *et al.,* 2016; Tang and Zhai, 2017; Wang *et al.,* 2018).

By understanding these sources, efforts can be directed toward mitigating PBDE contamination through improved waste management practices, stricter industrial regulations, and public awareness campaigns. Addressing these anthropogenic activities is crucial for reducing the environmental and health impacts of PBDEs in Lekki Lagoon and its surrounding areas (Daso *et al.,* 2013; Hahladakis *et al.,* 2018). Effective strategies include enhancing industrial effluent treatment, promoting the proper disposal and recycling of PBDE-containing products, and regulating agricultural practices to prevent contamination. Public education on the environmental impacts of PBDEs can also play a vital role in reducing pollution and protecting the ecological integrity of Lekki Lagoon (Wepener *et al.,* 2012; Chakraborty *et al.,* 2013; Ssebugere, *et al.,* 2014; Doherty *et al.,* 2019).

The primary aim of this study is to ascertain the effects and magnitude of polybrominated diphenyl ethers (PBDEs) bioaccumulation in two key fish species, *Synodontis clarias* and *Tilapia zilli*, inhabiting the Lekki Lagoon in Lagos, Nigeria (Davis *et al.,* 2012; Ge *et al.,* 2014; Su *et al.,* 2018). This investigation seeks to quantify the concentration of PBDEs within the tissues of these species, thereby providing critical data on the level of environmental contamination and the potential risks associated with their bioaccumulation. Specifically, the study will measure and compare the bioaccumulation levels of PBDEs in the tissues of *S. clarias* and *T. zilli*. *S. clarias*, a bottom-dwelling catfish, and *T. zilli*, a widely consumed cichlid, are both significant for their ecological roles and economic value. By evaluating these species, the study aims to offer a comprehensive understanding of how PBDEs distribute within different trophic levels and ecological niches of the lagoon (Dazy *et al.,* 2009; Gonzalez *et al.,* 2013; Guo *et al.,* 2015; Kanaya *et al.,* 2019).

Furthermore, the study aims to determine the safety of consuming these fish species by assessing the PBDE concentrations against established human health guidelines. This aspect is critical for public health, considering that fish from Lekki Lagoon constitute a vital protein source for the local population. The findings will inform risk assessments and guide regulatory policies to ensure food safety and protect the health of consumers (Johnson *et al.,* 2013; Huang *et al.,* 2020; Khan *et al.,* 2022).

This dual-species approach enhances the robustness of the study, providing a broader perspective on the bioaccumulation dynamics of PBDEs in Lekki Lagoon's aquatic ecosystem. The outcomes will contribute to environmental monitoring efforts, supporting the management and conservation of this critical water body.

MATERIALS AND METHODS

Study Area:

The hydrology of Lekki Lagoon is primarily influenced by several river systems. The River Oni flows into the lagoon from the northeast, while the Rivers Oshun and Saga contribute inflows from the northwest. This fluvial input plays a critical role in maintaining the lagoon's ecological balance and supports a diverse array of aquatic and terrestrial species. The interconnected nature of this lagoon system highlights its significance in regional hydrodynamics, nutrient cycling, and as a habitat for various forms of wildlife.

Lekki Lagoon forms a link with other water bodies encompassing lagoons and creeks that trace the southwestern coastline of Nigeria for approximately 200 kilometers. Lekki Lagoon supports diverse range of flora and fauna, including various species of fish, aquatic plants, and birdlife like Oil palms *Elaeis guineensis*, *Cocos nucifera* to mention a few. The lush vegetation and unique ecosystem of the area contribute to its ecological significance.

The Lagoon is a hub of commercial activities. The local communities surrounding the lagoon are engaged in various economic pursuits, such as fishing, aquaculture, and tourism. Fishing is of paramount importance, providing livelihoods for many, and contributing to the local and regional economy. The lagoon's proximity to Lagos, a major economic and industrial hub, also influences trade and commerce activities in the area.

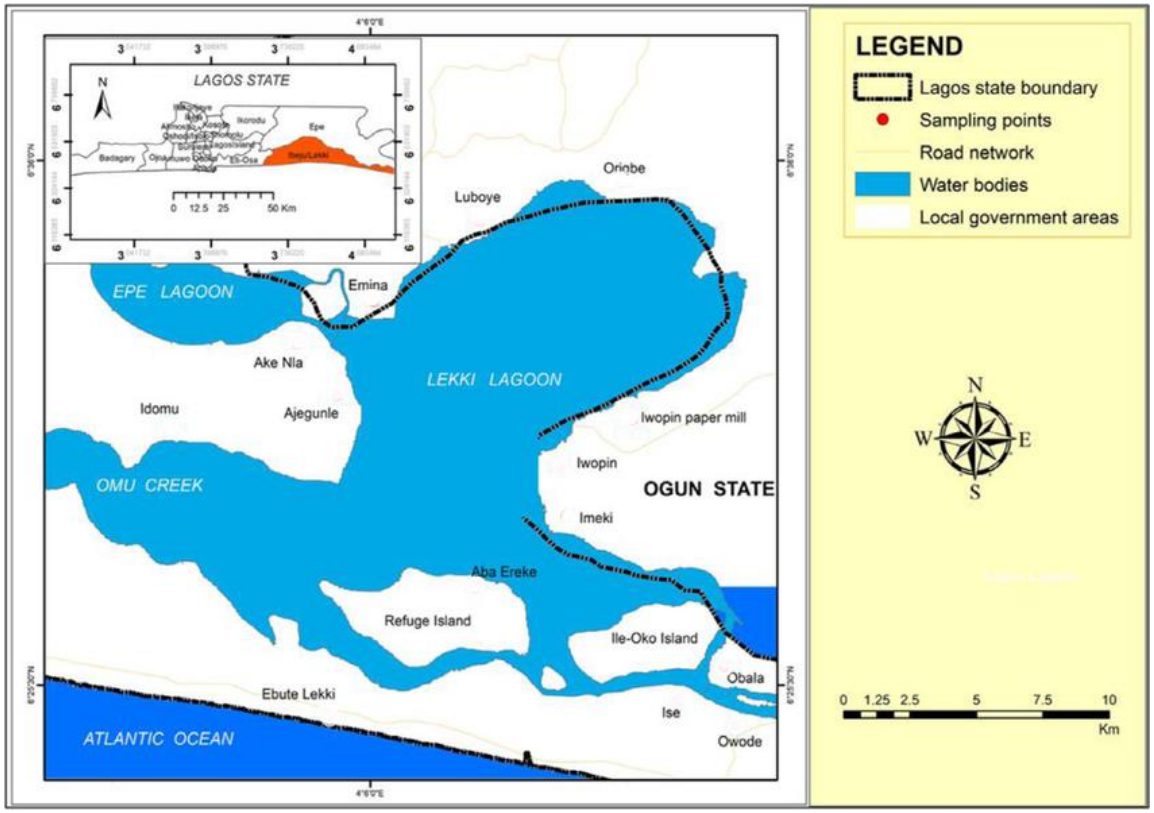


Fig. 1: Map of Lekki-Epe Lagoon, Lagos, Nigeria

Determination of Physicochemical Parameters of Water:

For a comparative analysis, surface water samples were collected from 3 locations of each fish species repeatedly for 3 months; totaling 9 replicates for each of the 2 fish species and 18 surface water samples in total. A handheld multiparameter probe was used to test the Dissolved oxygen (DO), Electrical Conductivity, PH, Salinity, Temperature, Total Dissolved Solids (TDS), and Turbidity were measured using a handheld multiparameter probe (Horiba Water Checker Model U-10). A motorized canoe was used to collect data from the lagoon.

Biochemical Analysis:

-Homogenizing Sample:

The dissected liver and intestine were removed and weighed. The organs were homogenized with 0.1phosphate buffer (PH 7.2) putting the organ each into the mortar and blended with a pestle together. The resulting homogenate was centrifuged at 2500RPM for 15 minutes. The supernatant was decanted and stored at -20°C.

-Determination of Catalase Activity (CAT):

Catalase activity was done according to the method of Sinha (1971). The reaction mixture contains 5% Potassium heptaoxodichromate, 0.2 M Hydrogen Peroxide, Dichromate/acetic acid solution and 0.01 M Phosphate buffer pH 7.0. 0.1 ml of sample will be mixed with 4.9 ml of distilled water to give a 1 in 5 dilution of the sample.

-Determination of Reduced Glutathione (GSH):

The total sulphydryl groups, protein – bound sulphydryl groups and free sulphydryl groups like GSH in biological samples was done using Ellman's reagent, 5,5'-dithio-bis-2-nitrobenzoic acid (DTNB) as describe by Sedlak and Lindsay (1968) and Jollow *et al,* 1974.

Determination of Glutathione Peroxidase (GPx):

0.2ml of 0.4M phosphate buffer pH 7.0, 0.1ml of 10mM sodium azide, 0.2ml of plasma, 0.2ml of glutathione salt (GSH), and 0.1ml of 0.2mM Hz02 were added to evaluate glutathione peroxidase (GPx) activity.

-Malondialdehyde (MDA):

This was done by measuring the Thiobarbituric acid (TBA) reactive products present in the test sample using the procedure of Vashney and Kale (1970) and expressed as micromolar of malondialdehyde (MDA)/g tissue.

Determination of Superoxide Dismutase (SOD) Activity:

The level of SOD activity will be determined by the method of Misra and Fridowich (1972). The mixture contains 0.05 M carbonate buffer (pH 10.2) and 0.3 mM epinephrine. Sample (0.1 ml) and was diluted in 0.9 ml of distilled water to make a 1 in 10 dilution.

Determination of PBDES in Tissues:

KOH Refluxing/Vortex Extraction– EPA Method 3611C cleanup method was employed in the analysis. We weighed 15 g wet weight of excised liver, intestine, samples of the fish specimens into a crucible then macerate and homogenized it. From the homogenized tissue, 10 g was placed in a 50 mL centrifuge tube, 15 mL of 6N KOH was added, the tubes were sealed and incubated for 18 h in a 35 °C water bath, shaking vigorously for 30 second for every ½ h for the first 4 h and allowed to cool afterwards.

Histopathological Assessment of Infected Tissues:

Fish intestines were initially fixed in Bouin's fluid for a duration of six hours, followed by transfer to 10% phosphate-buffered formalin for optimal tissue preservation. Subsequently, the tissue samples were sectioned and placed into well-labeled tissue embedding cassettes. The samples underwent processing using an automatic tissue processor for a period of 17 to 19 h. During this process, tissue dehydration was achieved through a series of graded alcohol solutions: 70%, 95%, and two treatments in absolute alcohol, each for 30 min.

The tissues were then impregnated three times in molten paraffin before being embedded in molten paraffin wax, where they were allowed to solidify. Each paraffin block was then mounted on a rotary microtome and sectioned into thin slices of 4 to 5 microns. The sections were carefully transferred to well-labeled slides, floated on a 45°C water bath using curved floating forceps to prevent folding or creasing. The sections were then picked up on labeled slides, ensuring that they adhered centrally and without creases. The slides were subsequently dried in a hot air oven maintained at 60°C to ensure proper attachment, as outlined by Bancroft et al. (2014). For further processing, the slide sections were dewaxed in xylene and rehydrated through a series of descending alcohol grades (absolute alcohol, 95%, 80%, 70%, and water). Staining was performed using Hematoxylin and Eosin (H&E) stains.

Hematoxylin stained the cell nuclei, whereas Eosin provided cytoplasmic staining. Post-staining, the tissues were washed in tap water, and any over-staining was corrected with 1% acid alcohol. Finally, the tissues were mounted using Di-n-butyl phthalate in xylene (D.P.X) and dried.

The prepared slides were then examined under a microscope, and photomicrographs were taken. The pathological lesions were interpreted at the Pathology Laboratory of the Department of Veterinary Pathology, University of Ibadan, Nigeria.

Quality Assurance:

Each tested medium underwent analysis with ten (10) sample replicates, and the mean values were reported for accuracy. Prior to analysis, the instrument underwent calibration by injecting a series of Calibration standards, with a 1 µL volume injected. A five-point calibration curve, obtained from commercially acquired calibration standards, was established and checked to ensure an R2 value of ≥0.995.

The response factor (RF) for each analyte/component in the calibration standard was calculated based on the area response and the amount of standard material. Additionally, the relative standard deviation percentage (%RSD) of the RF was computed for each analyte across the calibration curve, with a criterion of not exceeding 15% for the curve to be considered valid. The average response factor for the weight ranges was calculated and utilized for sample quantification. If any alkane component exceeded the 15% threshold, the weight range response factors were evaluated and used, provided they met the specified criteria. Sample analysis and quality control were ensured through the use of initial calibration standards, continuous calibration standards (5µg/ml or 10 µg/ml), standard reference material (SRM), and instrument blanks.

Statistical Analysis:

The data obtained from bioaccumulation analysis, oxidative stress analysis, and physicochemical parameters were evaluated using Analysis of variance (ANOVA), Statistical Package for the Social Sciences (SPSS), and IBM 20.0 version.

RESULTS

The results of physicochemical parameters of the surface water indicated that the turbidity of the water samples at the location of *T. zilli* was significantly higher than the that of the *S. clarias* ($p<0.001$). No significant difference occurred among other physicochemical parameters tested (Table 1). Notably, the biological oxygen demand (BOD) of both surface water samples were higher than adopted FEPA regulatory limit of ≤5.

Table 1: Mean physicochemical parameters of the 2 sampling points along Lekki Lagoon.

Parameters	*T. zilli* water		*S. clarias water*		Summary	P value	FEPA Limit
	Mean	SD	Mean	SD			
Temp (oC)	30.01	0.13	29.40	0.03	ns	0.159	≤40
pH	7.43	0.20	7.04	0.07	ns	0.359	6-9
Current (ms/cm)	0.42	0.01	0.45	0.01	ns	0.944	-
Turbidity (NTU)	15.87	0.81	8.94	1.46	***	<.001	≤30
BOD (g/L)	6.58	0.62	6.27	0.04	ns	0.463	≤5
TDS (g/L)	0.27	0.01	0.29	0.01	ns	0.957	≤30

The comparative analysis of PBDE congeners accumulation in the intestines of *T. zilli* and *S. clarias* indicates that most congeners were similarly accumulated, except PBDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether) that recorded 0.02 mg/g while the PBDE congener was not detected in the intestine of *S. clarias* (Table 2).

Table 2: Comparative bioaccumulation of PBDE congeners (mg/g) in the intestine of *T. zilli* and *S. clarias* in Lekki Lagoon.

PBDE congeners	*T. zilli*		*S. clarias*		Summary	P value
	mean	SD	mean	SD		
BDE-28	0.02	0.02	0.02	0.02	ns	0.96
BDE-47	0.01	0.01	0.01	0.01	ns	0.51
BDE-100	0.01	0.01	0.01	0.01	ns	0.37
BDE-99	0.01	0.01	0.00	0.00	ns	0.74
BDE-154	0.00	0.00	0.00	0.00	ns	0.98
BDE-153	0.00	0.00	0.00	0.00	ns	0.91
BDE-183	0.02	0.05	0.00	0.00	**	0.00
BDE-209	0.00	0.00	0.00	0.00	ns	>.999

KEYS: BDE-28 (2,4,4'-Tribromodiphenyl ether); BDE-47 (2,2',4,4'-Tetrabromodiphenyl ether); BDE-100 (2,2',4,4',6-Pentabromodiphenyl ether); BDE-99 (2,2',4,4',5,-Penabromodiphenyl ether); BDE-154 (2,2',4,4',5,6'-Hexabromodiphenyl ether); BDE-153 (2,2',4,4',5,5'-Hexabromodiphenyl ether); BDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether); BDE-209 (2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether). Sample size (N)= 10. ns= not significant

The comparative assessment of the oxidative stress initiated in the intestines of *T. zilli* and *S. clarias* as a result of bioaccumulation of the PBDEs indicated that there was no significant difference in the concentrations of the PBDEs across all the congeners analyzed (Table 3).

Table 3: Comparative oxidative stress assessment in the intestine of *T. zilli* and *S. clarias* in Lekki Lagoon.

Antioxidants	*T. zilli*		*S. clarias*		Summary	P value
	mean	SD	mean	SD		
PRO	10.97	2.84	9.18	1.06	ns	0.93
CAT	6.47	2.83	2.15	1.42	ns	0.83
SOD	679.88	114.46	714.12	100.66	ns	0.09
MDA	4.03	2.08	1.36	0.79	ns	0.89
GSH	13.47	10.03	1.39	0.52	ns	0.55
GPX	211.24	12.63	188.68	16.95	ns	0.26

KEYS: Sample size (N)= 10. ns= not significant

A comparative analysis of the lipid contents in the intestine of both fish species indicated that the lipid all the lipid parameters assessed in *T. zilli* were significantly much higher ($p<0.001$) than the concentrations detected in *S. clarias* (Table 4).

Table 4: Comparative lipid contents (mg/dL) in the intestine of *T. zilli* and *S. clarias* in Lekki Lagoon**.**

Lipids	*T. zilli*		*S. clarias*		Summary	P value
	mean	SD	mean	SD		
CHOL	145.94	7.54	1.97	0.39	***	<.001
TRIG	54.96	6.08	0.72	0.22	***	<.001
HDL	49.11	8.70	0.54	0.13	***	<.001
LDL	85.84	8.85	1.10	0.38	***	<.001

DISCUSSION

The sole discernible variation in the ambient conditions between the habitats of *Tilapia zilli* and *Synodontis clarias* was the elevated turbidity levels observed in the former (Kofi *et al.,* 2018). This disparity in turbidity is likely attributable to localized anthropogenic disturbances within the aquatic habitat of *T. zilli*. Such perturbations could include activities such as dredging, shoreline construction, or the discharge of untreated wastewater, all of which can significantly increase the suspended particulate matter in the water column, thereby elevating turbidity levels (Kostić *et al.,* 2017).

The elevated turbidity in the *T. zilli* habitat does not appear to be directly linked to upstream water influx, as the increased turbidity was exclusively noted at the specific sampling location of *T. zilli*. This localized increase suggests that the turbidity is not a result of broader hydrological changes or upstream influences but is rather confined to the immediate area of sampling, pointing towards site-specific anthropogenic activities as the primary cause (Akortia *et al.,* 2016; Yang *et al.,* 2018).

Understanding the sources and impacts of increased turbidity is crucial, as elevated turbidity levels can affect the photosynthetic processes of aquatic plants, reduce visibility, and subsequently impact the foraging efficiency and habitat preferences of fish. Furthermore, high turbidity can lead to an increase in the transport of pollutants and pathogens attached to suspended particles, posing additional risks to the aquatic ecosystem and its inhabitants (Lana *et al.,* 2010; La Guardia *et al.,* 2022). Therefore, identifying and mitigating these localized anthropogenic activities is essential for maintaining the ecological integrity and water quality of the habitats occupied by *T. zilli* and *S. clarias*.

Salinity is also responsible for the availability of animal in a particular water body. Salinity is very key as a variable indicator in the presence of a particular animal in any ecosystem. Physicochemical properties of selected points of the lagoon surface water were carried out and compared with the Federal Environmental Protection Agency standard (FEPA). The temperature, pH, conductivity, dissolved oxygen, salinity and turbidity results were all within the FEPA limit for physicochemical parameters in lagoon surface waters. According to the study of Akinsanya *et al*. (2015), an increase or change in level of physicochemical parameters in surface water influence the fate of contaminants in an aquatic environment.

Furthermore, the concentration of 0.02 mg/g of PBDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether) detected in the intestine of *Tilapia zilli* was significantly higher than that observed in Synodontis clarias. This marked difference in PBDE-183 bioaccumulation was the only discernible variation between the two fish species. The differential bioaccumulation of PBDE-183 in *T. zilli* may have profound implications on its lipid profile, as PBDEs are known to be lipophilic and can integrate into lipid-rich tissues, potentially altering lipid metabolism and storage. The relatively higher susceptibility of *T. zilli* to accumulate PBDE-183 could be attributed to its physiological and metabolic characteristics, which differ from the more robust and tenacious *S. clarias* (Xin *et al.,* 2014; Xu *et al.,* 2014; Xu *et al.,* 2018).

T. zilli, being considered more fragile, might exhibit a higher rate of lipid turnover or have a different lipid composition that facilitates the greater accumulation of PBDE-183. This enhanced bioaccumulation could lead to disruptions in its lipid homeostasis, affecting vital biological functions such as energy storage, membrane fluidity, and hormone production. In contrast, the tenacity and possibly more efficient detoxification mechanisms in *S. clarias* might confer it a resilience against the bioaccumulation of such contaminants.

The observed variance in PBDE-183 levels underscores the importance of understanding species-specific differences in contaminant uptake and metabolism. These differences are crucial for assessing ecological risks and potential health impacts on fish

populations and, by extension, on the human consumers of these fish. The higher bioaccumulation of PBDE-183 in *T. zilli* necessitates targeted studies to elucidate its effects on the lipid profile and overall health of this species, thereby informing conservation and public health strategies (Lenhardt *et al.,* 2015; Li *et al.,* 2018).

The impacted lipid profile observed in Tilapia zilli might not have inflicted any oxidative damage at present; however, the findings of this study underscore the necessity for proactive mitigation of anthropogenic activities around the catchment area of Lekki Lagoon to forestall the release of PBDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether).

While no immediate oxidative damage has been detected, the elevated levels of PBDE-183 in T. zilli highlight a potential risk for future metabolic disturbances. PBDEs, being lipophilic, tend to bioaccumulate in lipid-rich tissues, and prolonged exposure could lead to chronic health effects, including oxidative stress, endocrine disruption, and impaired reproductive functions. Therefore, it is crucial to address the sources of PBDE-183 contamination to prevent long-term ecological and health consequences (Liagkouridis *et al.,* 2014; Linares *et al.,* 2015).

Proactive measures should include the following:

1-Improvement of Waste Management Practices:

Industrial Effluent Treatment: Ensuring that industries in the vicinity of Lekki Lagoon employ advanced effluent treatment technologies to remove PBDEs from their discharge.

Proper Disposal and Recycling: Establishing robust systems for the disposal and recycling of PBDE-containing materials such as electronics, textiles, and furniture to prevent leaching of these substances into the environment.

2-Regulation of Urban Runoff:

Stormwater Management: Implementing effective stormwater management practices to reduce the runoff of contaminants, including PBDEs, from urban areas into the lagoon.

Sediment Control: Utilizing sediment control measures to minimize the transport of PBDE-bound particles into the water bodies.

3-Public Awareness and Education:

Community Engagement: Educating local communities about the sources and impacts of PBDEs and encouraging practices that reduce the release of these substances into the environment.

Stakeholder Collaboration: Fostering collaboration between government agencies, industry stakeholders, and non-governmental organizations to develop and enforce regulations aimed at reducing PBDE pollution.

4-Monitoring and Research:

Regular Monitoring: Conducting regular monitoring of PBDE levels in the lagoon and its biota to track contamination trends and assess the effectiveness of mitigation measures.

Research on Impact: Supporting research to further understand the impact of PBDEs on aquatic organisms, particularly focusing on their long-term health and ecological consequences.

By implementing these proactive measures, it is possible to mitigate the anthropogenic release of PBDE-183 into Lekki Lagoon, thereby protecting the aquatic ecosystem and the health of its inhabitants, including T. zilli. This will also contribute to safeguarding the lagoon as a vital resource for the surrounding communities.

Conclusion

This study has elucidated the significant presence and differential bioaccumulation of PBDE-183 (2,2',3,4,4',5',6-Heptabromodiphenyl ether) in *T. zilli* and *S. clarias* within the Lekki Lagoon ecosystem. The detection of higher concentrations of PBDE-183 in *T. zilli* underscores the species-specific vulnerabilities and metabolic differences that contribute to the varying levels of contaminant uptake. Although no immediate oxidative damage was observed in the impacted lipid profiles of T. zilli, the potential long-term health and ecological

implications of such bioaccumulation warrant urgent and proactive intervention.

The study highlights the necessity for comprehensive mitigation strategies aimed at curbing the release of PBDE-183 and other similar pollutants. Addressing anthropogenic activities, particularly industrial discharges, improper waste management, and urban runoff, is critical in preserving the ecological integrity of Lekki Lagoon. Given the ecological and economic importance of Lekki Lagoon, understanding the sources and impacts of PBDE contamination is critical Enhanced waste treatment practices, strict regulatory frameworks, and widespread public awareness campaigns are essential to prevent further contamination and safeguard the lagoon's aquatic life.

Furthermore, continuous monitoring and research are imperative to understand the full spectrum of PBDE impacts on the lagoon's biodiversity and to develop targeted conservation efforts. The findings of this study serve as a clarion call for immediate and concerted action to mitigate environmental pollution, protect vulnerable species, and ensure the sustainability of Lekki Lagoon as a vital ecological and economic resource for future generations.

Declarations:

Ethical Approval: Not applicable.

Competing interests: The authors declare no conflict of interest.

Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

Funding: No specific funding was received for this work.

Acknowledgements: The authors will like to thank Mr Seyon for his work in the use of Horiba for the physic chemical parameters

REFERENCES

Abdallah, M. A. E., & Harrad, S. (2014). Polybrominated diphenyl ethers in UK human milk: implications for infant exposure and relationship to external exposure. *Environment International*, *63*, 130-136.

Adewuyi, G. O., & Adeleye, A. (2013). Evaluation of polybrominated diphenyl ethers in sediment of Lagos Lagoon, Nigeria. *African Journal of Environmental Science and Technology*, *7*(7), 686-693.

Akortiafakort, E., Okonkwo, J. O., Lupankwa, M., Osae, S. D., Daso, A. P., Olukunle, O. I., & Chaudhary, A. (2016). A review of sources, levels, and toxicity of polybrominated diphenyl ethers (PBDEs) and their transformation and transport in various environmental compartments. *Environmental Reviews*, *24*(3), 253-273.

Babayemi, J. O., Osibanjo, O., Sindiku, O., & Weber, R. (2018). Inventory and substance flow analysis of polybrominated diphenyl ethers in the Nigerian transport sector—end-of-life vehicles policy and management. *Environmental Science and Pollution Research*, *25*, 31805-31818.

Bamidele, A., Kuton, M. P., Iniobong, A. D., Uchenna, N. D., Saliu, J. K., & David, U. U. (2020). Bioaccumulation of polychlorinated biphenyls (PCBs) in fish host-parasite bentho-pelagic food chain in Epe Lagoon, Lagos, Nigeria. *Bulletin of Environmental Contamination and Toxicology*, *105*, 770-776.

Banni, M., Hajer, A., Sforzini, S., Oliveri, C., Boussetta, H., & Viarengo, A. (2014). Transcriptional expression levels and biochemical markers of oxidative stress in Mytilus galloprovincialis exposed to nickel and heat stress. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, *160*, 23-29.

Bergayou, H., Mouneyrac, C., Pellerin, J., & Moukrim, A. (2009). Oxidative stress responses in bivalves (Scrobicularia plana, Cerastoderma edule) from the Oued Souss estuary (Morocco). *Ecotoxicology and Environmental Safety*, *72*(3), 765-769.

Bobescu, E., Marceanu, L. G., Dima, L., Balan, A., Strempel, C. G., & Covaciu, A. (2021). Trimetazidine therapy in coronary artery disease: the impact on oxidative stress, inflammation, endothelial dysfunction, and long-term prognosis. *American Journal of Therapeutics*, *28*(5), e540-e547.

Bodin, N., Ka, R. G., Le Loc'h, F., Raffray, J., Budzinski, H., Peluhet, L., & de Morais, L. T. (2011). Are exploited mangrove molluscs exposed to persistent organic pollutant contamination in Senegal, West Africa?. *Chemosphere*, *84*(3), 318-327.

Bramwell, L., Harrad, S., Abdallah, M. A. E., Rauert, C., Rose, M., Fernandes, A., & Pless-Mulloli, T. (2017). Predictors of human PBDE body burdens for a UK cohort. *Chemosphere*, *189*, 186-197.

Cao, L. Y., Ren, X. M., Yang, Y., Wan, B., Guo, L. H., Chen, D., & Fan, Y. (2018). Hydroxylated polybrominated biphenyl ethers exert estrogenic effects via non-genomic G protein–coupled estrogen receptor mediated pathways. *Environmental health perspectives*, *126*(5), 057005.

Chakraborty, P., Zhang, G., Li, J., Sampathkumar, P., Balasubramanian, T., Kathiresan, K., ... & Jones, K. C. (2019). Seasonal variation of atmospheric organochlorine pesticides and polybrominated diphenyl ethers in Parangipettai, Tamil Nadu, India: Implication for atmospheric transport. *Science of the Total Environment*, *649*, 1653-1660.

Choi, G., Kim, S., Kim, S., Kim, S., Choi, Y., Kim, H. J., ... & Park, J. (2014). Occurrences of major polybrominated diphenyl ethers (PBDEs) in maternal and fetal cord blood sera in Korea. *Science of the total environment*, *491*, 219-226.

Daso, A. P., Fatoki, O. S., Odendaal, J. P., & Olujimi, O. O. (2013). Polybrominated diphenyl ethers (PBDEs) and 2, 2′, 4, 4′, 5, 5′-hexabromobiphenyl (BB-153) in landfill leachate in Cape Town, South Africa. *Environmental monitoring and assessment*, *185*, 431-439.

Davis, E. F., Klosterhaus, S. L., & Stapleton, H. M. (2012). Measurement of flame retardants and triclosan in municipal sewage sludge and biosolids. *Environment international*, *40*, 1-7.

Dazy, M., Masfaraud, J. F., and Férard, J. F. (2009). Induction of oxidative stress biomarkers associated with heavy metal stress in *Fontinalis antipyretica* Hedw. *Chemosphere*, **75**(3): 297-302.

Doherty, F. V., Aneyo, I., and Otitoloju, A. A. (2019). Histopathological and biochemical alterations in Eudrilus eugeniae (Kinberg 1867) as biomarkers of exposure to monocyclic aromatic hydrocarbons in oil impacted site. *The Journal of Basic and Applied Zoology*, *80,* 1-15.

Ge, J., Yun, X., Liu, M., Yang, Y., Zhang, M., & Wang, J. (2014). Distribution, potential source and ecotoxicological risk of polychlorinated biphenyls and polybrominated diphenyl ethers in the surface water of the Three Gorges Dam region of the Yangtze River, China. *Ecotoxicology*, *23*, 978-987.

Gonzalez, M., Miglioranza, K. S., Grondona, S. I., Barni, M. F. S., Martinez, D. E., & Peña, A. (2013). Organic pollutant levels in an agricultural watershed: the importance of analyzing multiple matrices for assessing streamwater pollution. *Environmental Science: Processes & Impacts*, *15*(4), 739-750.

Guo, J., Zhang, R., and Xu, Z. (2015). PBDEs emission from waste printed wiring boards during thermal process. *Environmental Science and Technology*, 49(5): 2716-2723.

Guo, W., Holden, A., Smith, S. C., Gephart, R., Petreas, M., & Park, J. S. (2016). PBDE levels in breast milk are decreasing in California. *Chemosphere*, *150*, 505-513.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental

impact during their use, disposal and recycling. *Journal of Hazardous Materials*, *344*, 179-199.

Huang, Y., Rajput, I. R., Sanganyado, E., Yajing, S., Yu, F., Liang, B., & Liu, W. (2020). Immune stimulation effect of PBDEs via prostaglandin pathway in pantropical spotted dolphin: An in vitro study. *Chemosphere*, *254*, 126717.

Johnson, P. I., Stapleton, H. M., Mukherjee, B., Hauser, R., & Meeker, J. D. (2013). Associations between brominated flame retardants in house dust and hormone levels in men. *Science of the Total Environment*, *445*, 177-184.

Kanaya, N., Bernal, L., Chang, G., Yamamoto, T., Nguyen, D., Wang, Y. Z., ... & Chen, S. (2019). Molecular mechanisms of polybrominated diphenyl ethers (BDE-47, BDE-100, and BDE-153) in human breast cancer cells and patient-derived xenografts. *Toxicological Sciences*, *169*(2), 380-398.

Khan, S., Naushad, M., Govarthanan, M., Iqbal, J., and Alfadul, S.M. (2022). Emerging contaminants of high concern for the environment: Current trends and future research. *Environmental Research*, **207**: 112609.

Klinčić, D., Dvoršćak, M., Jagić, K., Mendaš, G., & Herceg Romanić, S. (2020). Levels and distribution of polybrominated diphenyl ethers in humans and environmental compartments: a comprehensive review of the last five years of research. *Environmental Science and Pollution Research*, *27*, 5744-5758.

Kofi, E. D., Kweku, A. J., Kweku, C. S., Essel, G., & Osei-Fosu, P. (2018). Levels of polybrominated diphenyl ethers (PBDEs) in some Ghanaian water body environments.

Kostić, J., Kolarević, S., Kračun-Kolarević, M., Aborgiba, M., Gačić, Z., Paunović, M., and Vuković-Gačić, B. (2017). The impact of multiple stressors on the biomarkers response in gills and liver of freshwater breams during different seasons. *Science of the Total Environment*, *601*, 1670-1681.

La Guardia, M. J., Hale, R. C., Harvey, E., Mainor, T. M., & Ciparis, S. (2012). In situ accumulation of HBCD, PBDEs, and several alternative flame-retardants in the bivalve (Corbicula fluminea) and gastropod (Elimia proxima). *Environmental Science & Technology*, *46*(11), 5798-5805.

Lana, N. B., Fontana, A. R., Ciocco, N. F., & Altamirano, J. C. (2010). Determination of polybrominated diphenyl ethers in water samples from Mendoza River Basin by HS-SPME-GC-MS/MS. *Revista de la Facultad de Ciencias Agrarias*, *42*(2), 85-98.

Lenhardt, M., Poleksić, V., Vuković-Gačić, B., Rašković, B., Sunjog, K., Kolarević, S., and Gačić, Z. (2015). Integrated use of different fish related parameters to assess the status of water bodies. *Slov. Vet. Res*, **52**(1): 5-13.

Li, P., Liu, L., Zhou, G., Tian, Z., Luo, C., Xia, T., ... & Zhang, S. (2018). Perigestational exposure to low doses of PBDE-47 induces excessive ER stress, defective autophagy and the resultant apoptosis contributing to maternal thyroid toxicity. *Science of the Total Environment*, *645*, 363-371.

Liagkouridis, I., Cousins, I. T., & Cousins, A. P. (2014). Emissions and fate of brominated flame retardants in the indoor environment: a critical review of modelling approaches. *Science of the Total Environment*, *491*, 87-99.

Linares, V., Bellés, M., & Domingo, J. L. (2015). Human exposure to PBDE and critical evaluation of health hazards. *Archives of Toxicology*, *89*(3), 335-356.

Luo, P., Ni, H. G., Bao, L. J., Li, S. M., & Zeng, E. Y. (2014). Size distribution of airborne particle-bound polybrominated diphenyl ethers and its implications for dry and wet deposition. *Environmental Science & Technology*, *48*(23), 13793-13799.

Margolis, A. E., Banker, S., Pagliaccio, D., De Water, E., Curtin, P., Bonilla, A., ... & Horton, M. K. (2020). Functional connectivity of the reading network is associated with

prenatal polybrominated diphenyl ether concentrations in a community sample of 5 year-old children: A preliminary study. *Environment International*, *134*, 105212.

McGrath, T. J., Morrison, P. D., Ball, A. S., & Clarke, B. O. (2018). Concentrations of legacy and novel brominated flame retardants in indoor dust in Melbourne, Australia: an assessment of human exposure. *Environment International*, *113*, 191-201.

O'Driscoll, K., Robinson, J., Chiang, W. S., Chen, Y. Y., Kao, R. C., & Doherty, R. (2016). The environmental fate of polybrominated diphenyl ethers (PBDEs) in western Taiwan and coastal waters: evaluation with a fugacity-based model. *Environmental Science and Pollution Research*, *23*, 13222-13234

Okoffo, E. D., O'Brien, S., Ribeiro, F., Burrows, S. D., Toapanta, T., Rauert, C., ... & Thomas, K. V. (2021). Plastic particles in soil: state of the knowledge on sources, occurrence and distribution, analytical methods and ecological impacts. *Environmental Science: Processes & Impacts*, *23*(2), 240-274.

Oloruntoba, K., Sindiku, O., Osibanjo, O., Herold, C., & Weber, R. (2021). Polybrominated diphenyl ethers (PBDEs) concentrations in soil and plants around municipal dumpsites in Abuja, Nigeria. *Environmental Pollution*, *277*, 116794.

Olujimi, O. O., Adegbite, K. I., Sojinu, S. O., Daso, A. P., Oyebanji, F. F., Oluwadare, I., ... & Arowolo, T. A. (2022). Occurrence, compositional profiles and health risks assessment of polybrominated diphenyl ethers (PBDEs) in groundwater in and around dumpsites in Lagos State, Nigeria. *Environmental Forensics*, 1-10.

Olutona, G. O., Oyekunle, J. A., Ogunfowokan, A. O., & Fatoki, O. S. (2016). Assessment of polybrominated diphenyl ethers in sediment of Asunle stream of the Obafemi Awolowo University, Ile-Ife, Nigeria. *Environmental Science and Pollution Research*, *23*, 21195-21205.

Olutona, G. O., Oyekunle, J. A., Ogunfowokan, A. O., & Fatoki, O. S. (2017). Concentrations of polybrominated diphenyl ethers (PBDEs) in water from Asunle Stream, Ile-Ife, Nigeria. *Toxics*, *5*(2), 13.

Onyeche, L. A., & Akankali, J. A. (2013). Determination of some environmental parameters of Anwai–Stream, Niger-Delta, Nigeria. *Research Journal of Agricultural and Environmental Management*, *2*(6), 142-149.

Park, J. E., Kang, Y. Y., Kim, W. I., Jeon, T. W., Shin, S. K., Jeong, M. J., & Kim, J. G. (2014). Emission of polybrominated diphenyl ethers (PBDEs) in use of electric/electronic equipment and recycling of e-waste in Korea. *Science of the total environment*, *470*, 1414-1421.

Pellacani, C., Tagliaferri, S., Caglieri, A., Goldoni, M., Giordano, G., Mutti, A., & Costa, L. G. (2014). Synergistic interactions between PBDEs and PCBs in human neuroblastoma cells. *Environmental Toxicology*, *29*(4), 418-427.

Pereira, S., Pinto, A. L., Cortes, R., Fontaínhas-Fernandes, A., Coimbra, A. M., and Monteiro, S. M. (2013). Gill histopathological and oxidative stress evaluation in native fish captured in Portuguese northwestern rivers. *Ecotoxicology and Environmental Safety*, **90**: 157-166.

Ssebugere, P., Sillanpää, M., Wang, P., Li, Y., Kiremire, B. T., Kasozi, G. N., ... & Jiang, G. (2014). Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans and polybrominated diphenyl ethers in sediments and fish species from the Murchison Bay of Lake Victoria, Uganda. *Science of the Total Environment*, *500*, 1-10.

Su, P. H., Tomy, G. T., Hou, C. Y., Yin, F., Feng, D. L., Ding, Y. S., & Li, Y. F. (2018). Gas/particle partitioning, particle-size distribution of atmospheric polybrominated diphenyl ethers in southeast Shanghai rural area and size-resolved predicting model. *Chemosphere*, *197*, 251-261.

Tang, J., & Zhai, J. X. (2017). Distribution of polybrominated diphenyl ethers in breast milk, cord blood and placentas: a systematic review. *Environmental Science and Pollution Research*, *24*, 21548-21573.

Ukenye, E. A., Taiwo, I. A., Oguntade, O. R., Oketoki, T. O., & Usman, A. B. (2016). Molecular characterization and genetic diversity assessment of Tilapia *zilli* from some coastal rivers in Nigeria. *African Journal of Biotechnology*, *15*(1), 20-28.

Wang, J., Wang, Y., Shi, Z., Zhou, X., & Sun, Z. (2018). Legacy and novel brominated flame retardants in indoor dust from Beijing, China: occurrence, human exposure assessment and evidence for PBDEs replacement. *Science of the Total Environment*, *618*, 48-59.

Wepener, V., Smit, N., Covaci, A., Dyke, S., & Bervoets, L. (2012). Seasonal bioaccumulation of organohalogens in tigerfish, Hydrocynus vittatus Castelnau, from Lake Pongolapoort, South Africa. *Bulletin of environmental contamination and toxicology*, *88*, 277-282.

Winid, B. (2015). Environmental threats of natural water contamination with polybrominated diphenyl ethers (PBDEs). *Pol. J. Environ. Stud*, *24*(1), 47.

Wu, Z., He, C., Han, W., Song, J., Li, H., Zhang, Y., ... & Wu, W. (2020). Exposure pathways, levels and toxicity of polybrominated diphenyl ethers in humans: A review. *Environmental Research*, *187*, 109531.

Xin, J., Liu, X., Liu, W., & Zheng, X. (2014). Effects of biochar–BDE-47 interactions on BDE-47 bioaccessibility and biodegradation by Pseudomonas putida TZ-1. *Ecotoxicology and Environmental Safety*, *106*, 27-32.

Xu, B., Wu, M., Wang, M., Pan, C., Qiu, W., Tang, L., & Xu, G. (2018). Polybrominated diphenyl ethers (PBDEs) and hydroxylated PBDEs in human serum from Shanghai, China: a study on their presence and correlations. *Environmental Science and Pollution Research*, *25*, 3518-3526.

Yang, J., Huang, D., Xue, W., Wei, X., Qin, J., Ou, S., ... & Zou, Y. (2018). Multiple-life-stage probabilistic risk assessment for the exposure of Chinese population to PBDEs and risk managements. *Science of the Total Environment*, *643*, 1178-1190.

Yu, G., Bu, Q., Cao, Z., Du, X., Xia, J., Wu, M., & Huang, J. (2016). Brominated flame retardants (BFRs): A review on environmental contamination in China. *Chemosphere*, *150*, 479-490.

Zhang, T., Zhou, X., Xu, A., Tian, Y., Wang, Y., Zhang, Y., & Wang, Z. (2020). Toxicity of polybrominated diphenyl ethers (PBDEs) on rodent male reproductive system: A systematic review and meta-analysis of randomized control studies. *Science of the Total Environment*, *720*, 137419.

Zhu, C., Li, Y., Wang, P., Chen, Z., Ren, D., Ssebugere, P., ... & Jiang, G. (2015). Polychlorinated biphenyls (PCBs) and polybrominated biphenyl ethers (PBDEs) in environmental samples from Ny-Ålesund and London Island, Svalbard, the Arctic. *Chemosphere*, *126*, 40-46