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Review

Sources, Occurrences, and Risks of Polycyclic Aromatic Hydro-Carbons (PAHs) in Bangladesh: A Review of Current Status

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Abstract: Polycyclic aromatic hydrocarbons (PAHs) pollution has emerged as a significant environmental issue in Bangladesh in the recent years, driven by both economic and population growth. This review aims to investigate the current trends in PAHs pollution research, covering sediments, water, aquatic organisms, air particles, and associated health risks in Bangladesh. A comparative analysis with PAHs research in other countries is conducted, and potential future research directions are explored. This review suggests that the research on PAHs pollution in Bangladesh is less well studied and has fewer research publications compared to other countries. Dominant sources of PAHs in Bangladesh are fossil fuel combustion, petroleum hydrocarbons, urban discharges, industrial emissions, shipbreaking, and shipping activities. The concentrations of PAHs in sediments, water, air particles, and aquatic organisms in Bangladesh were found to be higher than those in most of the other countries around the world. Therefore, coastal sediments showed higher PAHs pollution than urban areas. Health risk assessments reveal both carcinogenic and non-carcinogenic risks to residents in Bangladesh due to the consumption of aquatic organisms. According to this investigation, it can be concluded that there are considerably higher PAHs concentrations in different environmental compartments in Bangladesh, which have received less research attention compared with other countries of the world. Considering these circumstances, this review recommends that future PAHs pollution research directions should focus on aquatic ecosystems, shipbreaking areas, air particles, and direct exposure to human health risks. Therefore, this study recommends addressing the identification of PAH sources, bioaccumulation, biomagnification in the food web, and biomarker responses of benthic organisms in future PAHs pollution research.

Keywords: PAHs; sources; risks; shipbreaking; air particles; pollution status; Bangladesh

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1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are among the most widespread and persistent organic contaminants in the environment. PAHs are semi-volatile and have low water solubility in the environment [1,2]. Among the PAH compounds, 16 PAHs have been classified as hazardous pollutants by the "United States Environmental Protection Agency" [3]. Due to the extensive presence of PAHs in the environment, including in the air, surface water, soils, and biota [4,5], different countries have strict concerns about their toxic effects on ecosystems and human health [6,7]. Human exposure to PAHs can lead to various toxic effects such as carcinogenicity, endocrine-disrupting effects, genotoxicity, neurotoxicity, immunotoxicity, reproductive toxicity, etc. [8–10]. Adverse human health effects due to PAH exposure encompass cataracts, liver and kidney damage, pulmonary abnormalities, cancers, reduced immunity, respiratory problems, and symptoms resembling asthma [10]. Studies have shown elevated risks of lung cancer, which are sixteen times greater among charcoal furnace workers than in the general population. [11]. PAHs have also been linked tumor growth in mice, leading to cancer, and are linked to adverse effects on human pregnancy including abnormal head and weight circumference in newborns [12]. PAHs primarily sink into sediments from both natural and anthropogenic sources, subsequently leading to bioaccumulation in aquatic organisms [13]. The sources of PAHs in the environment are diverse and intricate, encompassing forest fires, volcanic eruptions, coal combustion, industrial and wastewater sewage, petroleum and oil leakage, mining, and transportation [14]. In an anoxic environment, PAHs are resistant to bacterial degradation [15,16]. However, under favorable or dissolved conditions, PAHs will be released into the aquatic environment and are bioavailable and bioaccumulated to aquatic organisms and the food web [17,18].

In the recent years, there has been significant interest in the bioaccumulation capacity of aquatic organisms and the biotoxicity of PAHs in freshwater, bay area, coastal, and marine ecosystems worldwide [19,20]. Research efforts have primarily focused on quantifying PAH concentrations in sediment, water, and aquatic organisms, with particular attention to source identification, risks, and human health implications [21–27]. Studies conducted in various countries have consistently found elevated PAH concentrations in aquatic ecosystems compared to global and national averages [13,28,29]. Reported concentrations range from 200 to 600 ng/g in sediment, 165.58 ng/g to 399.89 ng/g in water, and 18.4 to 398 ng/g (dry weight) in aquatic organisms [17,30,31]. In developing countries, PAH concentrations tend to be higher, ranging from 349.8 to 11,058.8 ng/g (dry weight) in sediment, 184.5 to 2806.6 ng/g (wet weight) in water, and 117.9 to 4216.8 ng/g in aquatic organisms [24,32]. Nonetheless, a variety of research on trophic transfer and PAHs biomagnification indicate that PAHs may biomagnify in the aquatic food web and may eventually have harmful impacts on human health [33]. Several other studies also suggest the carcinogenic and non-carcinogenic risks of PAHs in aquatic ecosystems, and the risk studies are the major concern of PAHs research [34–36]. Moreover, PAHs are also bound to atmospheric fine particles, causing serious health effects. In developing countries, the concentrations of $PM_{2.5}$-bound air particles PAHs were reported as 7.6–180 ng/m^3 for Myanmar [28] and 62.17–6606.53 ng/m^3 for China [35]. These particles, carrying PAHs, can accumulate in the human body, leading to direct adverse health effects.

Most scientists agree that global PAHs contamination will increase in the future due to an increasing human population and the industrial revolution [34–36]. This increase in PAHs pollution in different countries may have more regional-specific effects than global ones [34–36]. In these circumstances, we should emphasize more research, new technologies, control measures, and the prevention of PAHs in aquatic and terrestrial ecosystems.

However, the concern of PAHs pollution research, including distribution, sources, trophic transfer, biomagnification, and human health risks, has increased globally in recent times [34–36]. This increasing concern about PAHs pollution research in different countries is related to national policy and research capacity [37]. Developed countries are more concerned about any kind of pollution than developing countries [37]. This is due to a higher research capacity, institutes, and governments funding policies in developed countries than in developing countries [37]. Therefore, knowing the pollution status of certain pollutants would be crucial for policymakers to invest more research funding in certain topics. In recent times, several reviews of research have been published about PAHs pollution status, sources, distribution, bioaccumulation, risks, and future research directions in several environmental compartments and ecosystems in different countries [6,7,10,35–40]. Bangladesh is a developing and densely populated country in Southeast Asia [41]. Bangladesh is the 7th most populous country in the world with estimated population of about 160 million [41]. More than 1000 people are living per square kilometers throughout the country [42]. Due to development and industrialization, Bangladesh is intended to become an upper middle income country by 2031 [42]. Major economic activities are ready made garments (RMG), textiles, and manufacturing industries [43]. The major sources of PAHs are from the burning of biomass, industrial discharge, textile wastages, shipbreaking, coal power plants, and oil spills. But to our knowledge, there is no review study or status of PAHs pollution in Bangladesh [44,45].

Therefore, this review study on PAH pollution in Bangladesh is crucial for comprehending the current status of PAH pollution research across various environmental compartments, including sediments, water, air particles, and aquatic organisms. Given the global significance of PAH pollution and its adverse effects on both the environment and human health, understanding its dynamics and implications at the local level is crucial. By identifying current trends, research gaps, and future research directions, this review can enhance our understanding of PAH pollution. In line with global perspectives, it is essential to provide a comprehensive overview of PAH pollution and outline future research directions specific to Bangladesh.

2. Methodology

For this review, we conducted searches using various keywords in databases such as Web of Science, Google Scholar, and Scopus to gather relevant research articles [46,47]. Keywords like "PAHs pollution", "PAHs pollution in Bangladesh", and "PAHs pollution globally" were employed to retrieve peer-reviewed articles. Additionally, we used specific country names in combination with the term "PAHs pollution" to search for relevant publications, such as "PAHs pollution in China", "PAHs pollution in the USA", "PAHs pollution in India", "PAHs pollution in Pakistan", and "PAHs pollution in Bangladesh". The number of publications was tallied from 2004 to 2022 in the Web of Science database using the keyword "PAHs pollution globally". We followed the PRISMA method to select and include articles for review [46–48]. The selection process is outlined in Figure 1. For this review, we focused exclusively on peer-reviewed articles indexed in PubMed, Web of Science, and Scopus databases.

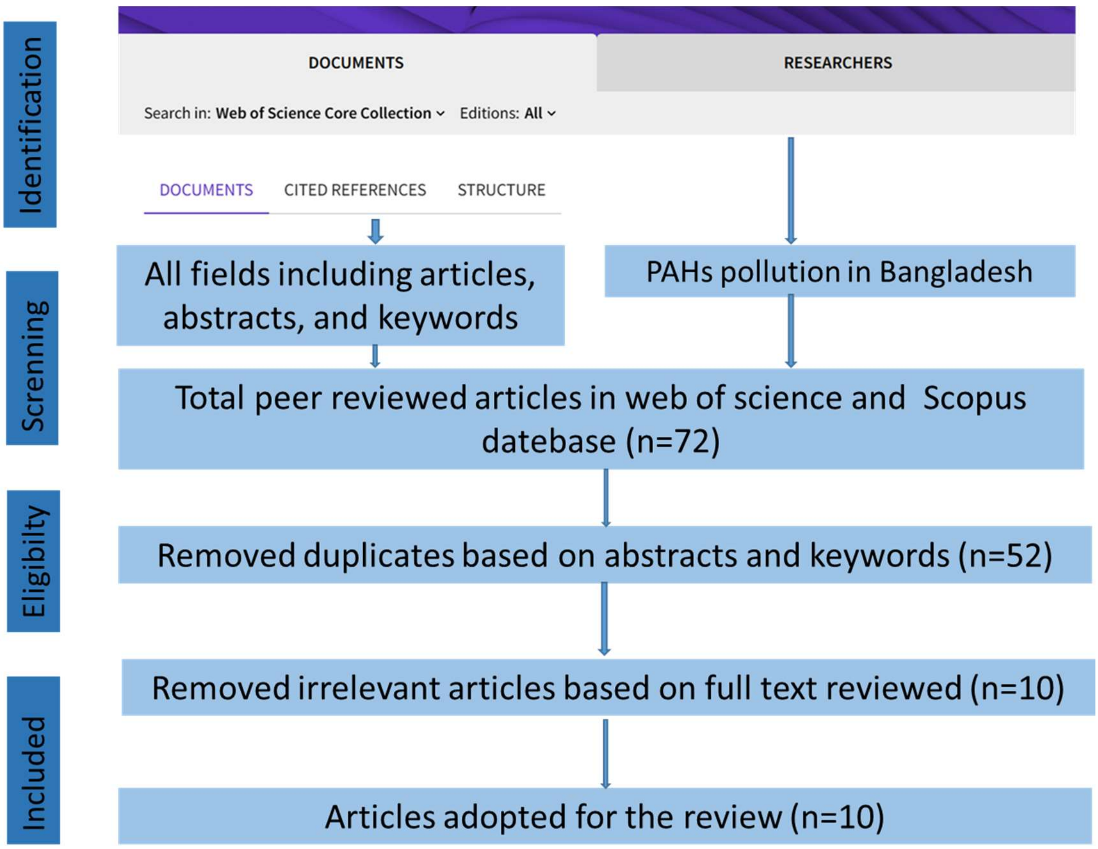

Figure 1. The selection process (PRISMA method) of research articles for the review of PAHs pollution research status in Bangladesh.

3. Comparable Progress of PAHs Research

Global polycyclic aromatic hydrocarbon pollution research has attracted considerable attention in recent times [35–40]. These higher attentions to PAHs research are mostly related to changes in global socioeconomic growth, anthropogenic activities, and energy transitions [34]. According to the Web of Science database, about 26,500 research articles have been published globally that are related to PAHs pollution from 2004 to 2022 [49]. The number of PAHs research publications has been increasing, and considerably more publications were started in 2012 (Figure 2).

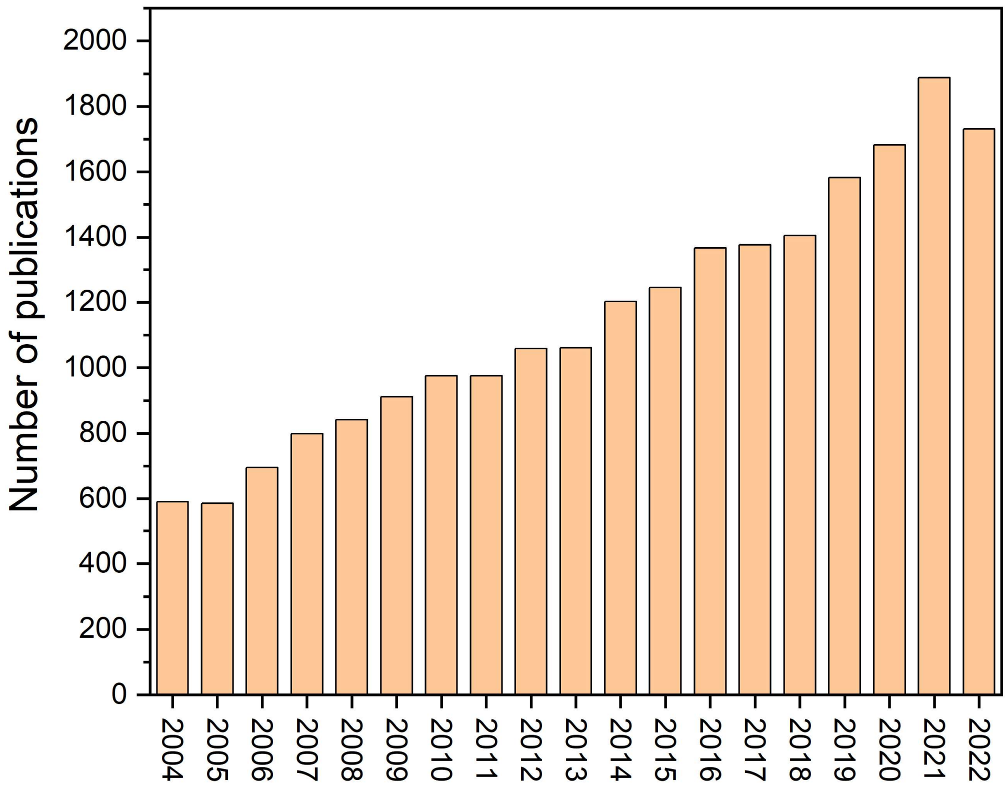

Figure 2. The number of PAHs pollution research publications in different years from all over the world (Data source: Web of Science) [49].

The number of PAHs pollution research publications is three times higher in present times than the number of publications in 2004 (Figure 3). These results suggest that the concern and research on PAHs pollution have considerably increased globally in recent times. According to the Web of Science, 10 research articles have been published that are related to PAHs pollution over the last 20 years in Bangladesh (Figure 3).

When comparing the number of research articles published by other countries, it appears that China has published the most articles related to PAH pollution (Figure 3). Therefore, surrounding countries like India and Pakistan also had a higher number of PAHs pollution-related research publications than Bangladesh (Figure 3). These results indicate that the research on PAHs pollution in Bangladesh is less well studied and has fewer research publications than in other countries.

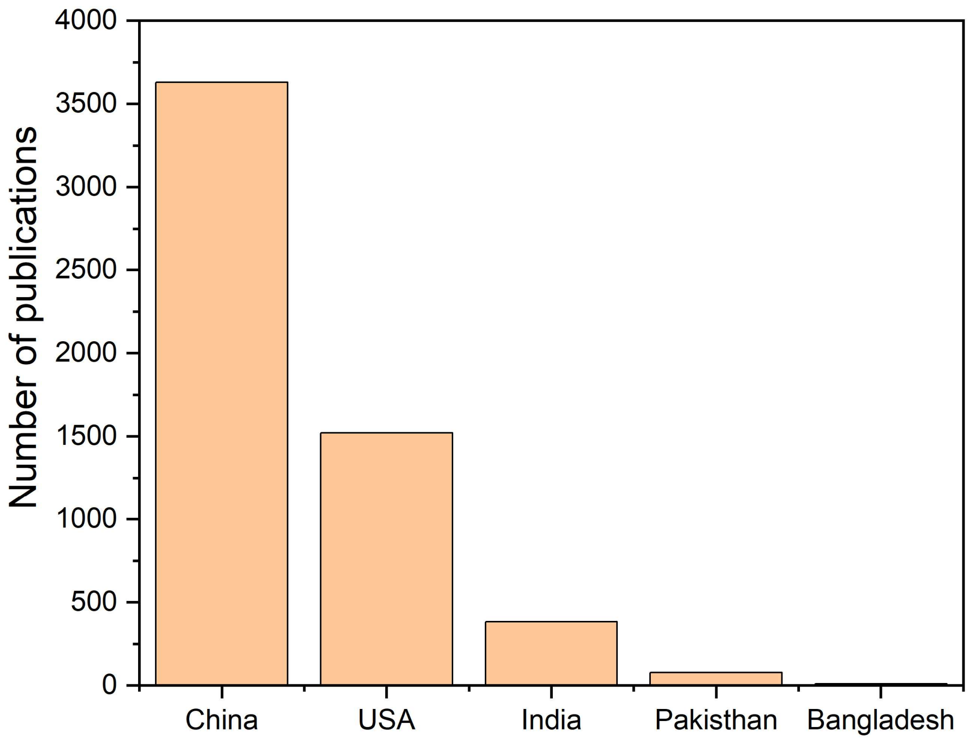

Figure 3. The number of PAHs pollution research publications in different countries around the world (Data source: Web of Science) [49].

4. Sources of PAHs

PAHs are typically introduced into aquatic and terrestrial ecosystems as a mixture of pollutants. From a global perspective, the sources of PAHs in the environment are mainly biological processes, industrial emissions, incomplete combustion of fossil fuels, forest fires, coal combustion, etc. [13]. The sources of PAHs are different in different countries, based on their economic conditions, development status, and implementation of pollution control strategies [13,24,37]. Bangladesh is a developing country with less economic status and research capacity than developed countries.

The primary sources of PAH pollution in Bangladesh are primarily from fossil fuel combustion and petroleum contamination [50,51] (Figure 4). In urban river areas, the major anthropogenic sources include urban runoff, industrial discharge, atmospheric deposition, and discharge from shipping activities [50,51] (Figure 4). However, in the coastal areas of Bangladesh, petroleum hydrocarbons are the primary source of PAH contamination [24]. Other anthropogenic and natural sources in these areas encompass oil spills, wood and coal combustion, boat and shipping activities, as well as land-based pollution discharge into the aquatic coastal ecosystems [24]. The sources of PAHs in airborne particles mainly originate from coal combustion, petroleum, and biomass resulting from waste disposal [52]. When comparing sources of PAH pollution in other countries, similar patterns were identified [53–58]. For instance, in the coastal areas of China, dominant sources of PAH pollution included coal, wood, and straw combustion. The second-highest major sources were engine combustion and oil spills [53]. In Nigeria, PAH sources comprised automobile repair industries, waste dumping, oil spills, and shipbreaking. Similarly, petroleum burning and transport in Iran, biomass burning in Thailand, oil refineries in Iraq, and petroleum combustion in India emerged as major sources of PAH pollution in sediments [54–58]. Overall, global sources of PAH pollution exhibited similarities across most countries, with petroleum contamination being the predominant source in Bangladesh.

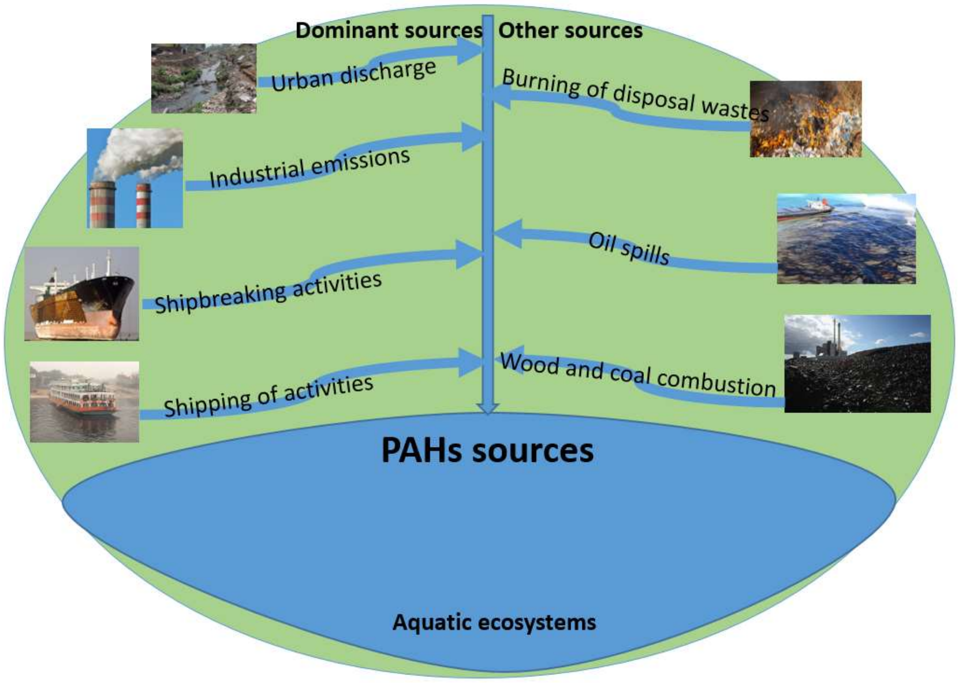

Figure 4. The major sources of PAHs pollution in Bangladesh.

5. PAHs in Sediment

Polycyclic aromatic hydrocarbons (PAHs) are common organic pollutants in sediments worldwide [54–58]. Due to their hydrophobic characteristics, these compounds are settled in the sediment of aquatic environments [53]. In aquatic ecosystems, particulate organic matter is controlled by the sorption of PAHs from the water column, resulting in sediment deposit [57,58]. The deposition of PAHs in sediment is a continuous process that can indicate environmental changes in pollutants in sediments over time [59]. In these circumstances, the research on PAHs in sediment can evaluate the PAHs cycles in sediments, historical trends, accumulation, and risks to aquatic ecosystems [50–60]. The studies of PAHs pollution in sediment in Bangladesh suggest that coastal sediment had the highest PAHs concentration compared to urban and river sediments (Table 1).

Table 1. PAHs concentration (ng/g) in the sediments of Bangladesh and different comparable countries in the world.

Country	Study Sites	PAHs Concentration (ng/g)		References
		Mean	Ranges and Maximum	
Bangladesh	Coastal sediment (summer)	5729	199.9–17,089.1	[24]
Bangladesh	Coastal sediment (winter)	4515	349.8–11,058.8	[24]
Bangladesh	Urban river sediment	432	45.8–1901	[51]
Bangladesh	Dhaka city natural soil	10.93	0.006–911.31	[61]
Bangladesh	Buriganga River	351.6	90.7–734.2	[62]
Bangladesh	Dhaleswari River	792.9	205.4–1880.3	[62]
China	Chinese Lakes	478	5279	[63]
China	Erahi Lake	1634.5	939.50–2538.97	[64]
China	Laizhou Bay	150.05	99.29–249.82	[65]
China	Nenjiang River	2069	76.5–9447	[66]
India	Industrial soils	5655.06	1662.90–10,879.20	[58]
India	Industrial soils	3256.74	1456.22–5403.45	[58]
India	Goa Coastline	-	1–875	[67]
Iraq	Tigris River	-	5619.2–12,793.0	[57]
Iran	Anzali Wetland	89.19	8.28–806.64	[68]
Iran	Musa Estuary	-	67.21–82.92	[69]
Egypt	Nile Delta	27.89	4.55–207.48	[70]
Thailand	Songkhla Lake	-	19.4–1218	[56]
Thailand	Nong Han Kumphawapi Lake	-	94.5–1112	[56]

The lowest PAHs concentration was found in urban natural soils in Bangladesh as indicated in Table 1. Across various studies on PAHs, sediment in Bangladesh demonstrated a wide concentration range, ranging from 0.006 to 17,089.1 ng/g (16 PAHs priority compounds by USEPA) (Table 1). When comparing PAH concentrations in Bangladeshi sediment with those in other countries, similar levels were observed in the industrial sediment of India and the river sediment of Iraq (Table 1) [24,51,56–58,61–70]. However, in most other countries, sediment PAHs concentrations were lower than those in Bangladesh, suggesting a higher accumulation or pollution of PAHs in Bangladeshi sediment (Table 1). However, the mean PAHs concentration of river sediment was lower than that of Chinese lake sediment and river sediment from Iraq (Table 1). Furthermore, PAH concentrations in urban areas were lower than those in most other countries. Overall, the PAHs pollution in the sediment of Bangladesh showed that coastal sediment has the highest PAHs concentration compared to river and urban sediments. Moreover, sediment PAHs concentrations are considerably higher than in most other countries [51,56–58,60–70]. The dominant compounds in coastal sediment are the 4-ring PAHs, constituting 52% to 81% of the total concentrations [24]. Consequently, the molecular ratios of PAHs in coastal sediments, specifically the 60% value, indicate a prevalence skewed toward the pyrolytic origin [24]. These results suggest higher accumulation and pollution of PAHs in Bangladesh's sediment.

6. PAHs in Water

The distribution of PAHs concentrations in the water column exists both in dissolved and particulate forms [71]. Consequently, the percentage of dissolved PAHs concentrations is higher than the particulate forms of PAHs in the water column [71]. The partitioning behavior of PAHs is primarily controlled by their hydrophobicity in the water column [71]. Specifically, dissolved forms of PAHs are predominantly composed of lower molecular weight of PAHs, while particulate PAHs are mostly associated with higher molecular weight PAHs [71]. In aquatic environments, PAHs are mainly introduced through various pathways, including atmospheric transport, rainfall, runoff, and industrial discharge [38]. The dissolved form of PAHs is toxic and readily bioavailable to aquatic organisms; consequently, it directly impacts aquatic ecosystems [71]. Globally, many countries express concerns about PAH pollution in aquatic environments, leading to a considerable volume of research publications on PAH pollution and associated risks in aquatic ecosystems [57,62,68,69,72–80]. However, research papers specifically addressing PAH concentrations or pollution in the water of Bangladesh are limited in the context of global research publications (Table 2).

Table 2. PAHs concentration (ng/L) in the water of Bangladesh and different comparable countries in the world.

Country	Study Sites	PAHs Concentration (ng/L)		References
		Mean	Ranges and Maximum	
Bangladesh	Buriganga River	9619.2	2794.2–26,086.8	[62]
Bangladesh	Dhaleswari River	1979.1	878.7–3836	[62]
Iraq	Tigris River	-	567.8–3750.7	[57]
Iran	Anzali wetland	78.31	5.14–253.37	[68]
Iran	Musa Estuary	0.36	0.14–0.66	[69]
China	East Liao River	436.99	396.42–624.06	[72]
China	Yangtze River	123.9	40.90–334.7	[73]
China	East Lake	36.95	22.87–73.65	[74]
China	Laizhou Bay	1178	277–4393	[75]
China	Hangzhou Bay	220	98.9–510	[76]
India	Hindon River	27.4	1.64–73.4	[77]
India	Yamuna River	22.1	1.98–93.0	[77]
Saudi Arabia	Jeddah Coast	360	151–748	[78]
Nigeria	Ikpoba River (wet period)	-	310,000–1,230,000	[79]
Nigeria	Ikpoba River (dry period)	-	420,000–1,960,000	[79]
Romania	Olt River dam	-	1.3–46.2	[80]

Only one research article addressing PAHs pollution in water columns has been published in Bangladesh, as outlined in Table 2. These research comparisons suggest that there is relatively less studied about PAHs pollution in the aquatic environment in Bangladesh compared to other countries worldwide (Table 2). According to the available research, the concentration of PAHs in river water in Bangladesh ranged from 878.7 to 26,086.8 ng/L (16 PAHs priority compounds by USEPA) [62]. The average concentrations of PAHs in water in Bangladesh were higher than those reported in most studies from other countries (Table 2). Specifically, the concentrations of PAHs in the water of the Anzali Wetland (Iran), Tigris River (Iraq), Musa Estuary (Iran), Yangtze River (China), East Lake (China), Hindon River (India), and other comparable study sites were considerably lower than those in Bangladesh (Table 2). Nigeria was the only country with a higher PAHs concentration level than Bangladesh (Table 2). These findings suggest that PAHs are contaminating the water in Bangladesh's aquatic ecosystems. In the Nigeria study area, possible sources of higher PAHs in the water included vehicular exhaust, automobile repair shops, and micro-plant industries, which are also comparable sources in Bangladesh, where higher concentrations of PAHs in water were detected. According to this comparative research and research concern, there is a higher level of PAHs pollution in the water in Bangladesh, with relatively less research attention dedicated to this issue compared to other countries.

7. PAHs in Air Particles

In the atmospheric environment, PAHs are generated from incomplete combustion, coal burning, biomass burning, vehicle emissions, and e-waste recycling [81]. Due to the variations in physiochemical properties, PAHs are distributed in both particulate and gaseous forms in the environment [81]. The particulate PAHs are bound with aerosolized particles, and these particles have an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) [81]. During inhalation, $PM_{2.5}$ particles with PAHs can be deposited in the lungs, which have higher aryl hydrocarbon receptor activities than coarse air particles [81]. So, the monitoring of $PM_{2.5}$-bound PAHs is very important for assessing human health risks. Bangladesh is one of the top countries in the world with the highest annual average of aerosolized particles ($PM_{2.5}$) in the air [82]. The air quality in Bangladesh is notably unhealthier than most of the other countries in the world [82]. However, the research focus on PAHs in air particles in Bangladesh is comparatively less studied than in other countries globally, as indicated in Table 3.

Table 3. PAHs concentration (ng/m^3) in the air particle of Bangladesh and different comparable countries in the world.

Country	Study Sites	PAHs Concentration (ng/m^3)		References
		Mean	Ranges and Maximum	
Bangladesh	Urban and rural area	-	3.6–22.4	[52]
Bangladesh	Urban and rural area (winter)	-	4.8–28.4	[52]
Bangladesh	Urban and rural area (monsoon)	-	2.7–30.5	[52]
Bangladesh	Bola Island (Bay of Bengal)	58.8	15.52–81.26	[83]
Bangladesh	Shipbreaking area, Chittagong	-	55–5778	[84]
Bangladesh	University of Dhaka (Urban area)	63.6	36.3–148	[81]
China	Three Gorges Reservoir	66.63	-	[85]
China	Hefei (urban area) (2019–2021)	-	0.01–9.56	[86]
China	Xian (urban area)	70	9.1–136.6	[87]
Nigeria	Benin (automobile repair area)	519.51	638.78	[88]
Nigeria	Cotonou (urban area)	2		[89]
Poland	Coastal area (urban region)	5.22	0.45–54.02	[90]
India	North-east side (air particles)	157.17	20.44–729.10	[91]
India	North-east side ($PM_{2.5}$)	87.68	29.36–220.49	[91]
India	Varanasi (urban area)	33.1	24.1–44.6	[92]
Russia	Southern Baikal region	20	31–50	[93]
Iran	Shiraz (urban area)	159.8	31.12–453.10	[94]
Iran	Shahryar city (industrial area)	23.25	3.94–41.30	[54]

Only four research articles have been published on PAHs in air particles in Bangladesh, focusing on their concentration, sources, and associated risks [52,81,83,84]. According to these research studies, rural and urban areas had lower PAHs concentrations than shipbreaking areas (Table 3). The islands of the Bay of Bengal showed a medium range of PAH concentrations in air particles but higher than urban and rural areas (Table 3). In Bangladesh, the concentration of PAHs in air particles ranges from 2.7 to 5578 ng/m^3 in urban, rural, and shipbreaking areas (Table 3). Comparing PAH concentrations in air particles with other countries, urban and rural areas in Bangladesh demonstrated similar levels to Hefei (China), Conotou (Nigeria), the coastal urban region (Poland), Varanasi (India), and Shahryar (Iran) (Table 3). However, in shipbreaking areas, PAH concentrations in air particles in Bangladesh were notably higher than in other countries [52,54,81,84–94]. This comparison suggests that shipbreaking areas could be among the most PAH-contaminated air particle zones in Bangladesh. In summary, the status of PAHs research in air particles indicates that Bangladesh has conducted fewer studies compared to other countries, yet it possesses the highest concentrations of PAHs in air particles.

8. PAHs in Aquatic Organisms

In aquatic ecosystems, PAHs can be accumulated by aquatic organisms due to their lipophilic and hydrophobic characteristics [53]. In addition, the log K_{OW} (partitioning coefficient) of PAHs also has a significant influence on PAHs accumulation in aquatic organisms [53]. PAHs with a lower log K_{OW} can easily be accumulated by aquatic organisms compared to PAHs with a higher log K_{OW} [95]. However, the bioaccumulation, trophic transfer, and biomagnification patterns of PAHs are related to the log K_{OW} of PAHs [53,95]. In aquatic ecosystems, PAHs with higher log K_{OW} can be easily transferred to higher trophic levels than PAHs with lower log K_{OW} [95]. This is because PAHs with higher log K_{OW} have lower biodegradability than other lower K_{OW} PAHs, resulting in higher biomagnification in the food web [95]. So, research about PAHs in aquatic organisms is very important to identify the possible toxic effects of PAHs on aquatic biota as well as human health risks due to the consumption of aquatic organisms [53,95]. In Bangladesh, the research regarding PAHs in aquatic biota and their risks to human health is very limited and does not have much concern for this topic [32,96]. Only two scientific research articles have been published about PAHs in aquatic organisms and human health risks in Bangladesh [32,96]. Globally, the PAHs in aquatic organisms' research publications are comparatively lower than in sediment research publications [49]. In addition, China has a higher number of publications that are related to PAHs in aquatic organisms and their risks to human health [49]. According to research in Bangladesh, PAHs concentrations in coastal aquatic organisms were in the range of 117.9 to 4216.8 ng/g (16 PAHs priority compounds by USEPA) [32]. A comparable finding was found at Laizhou Bay in China (Table 4).

Table 4. PAHs concentration (ng/g) in aquatic organisms of Bangladesh and different comparable countries in the world.

Country	Study Sites	PAHs Concentration (ng/g)		References
		Mean	Ranges and Maximum	
Bangladesh	Coastal areas (summer)	-	117.9–4216.8	[32]
Bangladesh	coastal areas (winter)	-	184.5–2806.6	[32]
China	Laizhou bay	1760	-	[53]
China	Laizhou bay	6599	-	[53]
China	Lake Chaohu	157	18.4–398	[17]
China	Nansi lake	-	67.3–533.9	[4]
China	Yellow river estuary	-	196.40–558.87	[95]
Nigeria	Okuli river	-	13.4–19.6	[97]
Nigeria	Okuli river	-	11.70–24.20	[97]
Nigeria	Ogun river	40.39	-	[98]
Nigeria	Eleyele river	72.84	-	[98]
Iraq	Derbendikhan reservoir	-	98–1271	[99]
Morrocco	Mediterranean coast	359.57	18.29–939.17	[100]
Morrocco	Atlantic coast	372.08	251–615.685	[100]
India	Sundarbans mangrove	-	43.3–541	[101]

When comparing PAH concentrations in aquatic organisms with those in other countries, the data strongly indicates a significantly higher accumulation or concentration of PAHs in aquatic organisms in Bangladesh (Table 4) [4,17,32,53,95,97–101]. This finding suggests a substantial anthropogenic input of PAHs into aquatic ecosystems in the country. Major sources of PAHs in these ecosystems include petroleum, petroleum combustion, industrial emissions, shipping and port activities, and urban discharges [32]. In summary, while PAH research on aquatic organisms in Bangladesh may be less extensive compared to other countries, the available data reveal a higher concentration of PAHs in aquatic biota. This highlights the need for increased attention to the sources and impact of PAHs on aquatic ecosystems in Bangladesh.

9. Risks to Human Health

The risks of PAHs are linked to human consumption through dietary fish, meats, and their byproducts [96]. Therefore, direct exposure to PAHs is another route of risk to human health [102]. It is well documented that the toxic effects of PAHs, including carcinogenicity, teratogenicity, and mutagenicity, are due to the consumption of aquatic organisms [53]. So, it is very important to monitor the human health risks of PAHs through the consumption of aquatic species. Globally, there has been a considerable increase in the human health risks of PAHs research in aquatic ecosystems. However, in Bangladesh, only two research articles have been published about the potential risks of PAHs due to the consumption of aquatic organisms [32,96]. The research related to PAH risks to humans in Bangladesh suggests very limited studies about PAHs risks [32,96]. Compared with other countries' research articles, it has been suggested that there is less research than other countries (Table 5).

Table 5. The possible health risks of PAHs in Bangladesh and other comparable countries of the world.

Country	Study Sites	Target Hazard Quotient		References
		Carcinogenic	Non-Carcinogenic	
Bangladesh	Coastal areas	Yes	Yes	[32]
Bangladesh	Urban areas	No	Yes	[96]
China	Laizhou Bay	Yes	Yes	[53]
China	Chaohu Lake	Yes	Yes	[17]
China	Nansi Lake	Yes	Yes	[4]
China	Yellow River Estuary	Yes	Yes	[4]
Nigeria	Okuli River	Yes	Yes	[97]
Nigeria	Ogbese River	Yes	Yes	[97]
Nigeria	Ogun River	Yes	Yes	[98]
Nigeria	Eleyele River	Yes	Yes	[98]
Morrocco	Mediterranean Coast	No	No	[100]
Mexico	Caleta Lagoon	No	Yes	[103]
Italy	Po River basin	No	Yes	[104]

This review suggests the potential for both carcinogenic and non-carcinogenic risks associated with PAHs in Bangladesh due to the consumption of aquatic species, as indicated by various risk criteria and indices (Table 5). These indices were potentiality of cancer risks, target hazard quotient and target cancer risks. This study evaluated the European Union recommended permissible maximum level of BaP and the USEPA recommended potency equivalent concentration (PEC) of total PAHs relative to BaP to understand the dietary exposure of PAHs through the consumption of aquatic organisms [32]. Similar comparable human health risks were found in different countries, especially in China and Nigeria (Table 5). In contrast, developed countries showed non-carcinogenic to no risk of PAHs to human health (Table 5). In summary, the assessment of human risks associated with PAHs indicates a relatively lower level of concern in Bangladesh compared to other countries. However, it is noteworthy that both carcinogenic and non-carcinogenic risks of PAHs to human health were observed in Bangladesh.

10. Future Research Directions and Recommendations

Globally, due to industrial development and increasing human populations, the anthropogenic input of PAHs is increasing in aquatic ecosystems [38]. Bangladesh is one of the world's most densely inhabited developing nations [105]. According to the report of the World Bank, industrial development is increasing in Bangladesh, and higher amounts of industrial pollutants are entering the terrestrial and aquatic ecosystems without proper treatment [105]. Due to industrial discharge, aquatic ecosystems such as rivers and coastal areas are the major hotspots of PAHs pollution in Bangladesh [60,62]. However, very limited research about PAHs pollution has been conducted on these ecosystems in Bangladesh compared to other countries (Tables 1 and 2). So, we recommend more research on PAHs pollution in rivers and coastal ecosystems in Bangladesh in different environmental compartments such as sediment, water, and aquatic organisms. Moreover, the prospective research directions for PAHs pollution in Bangladesh would be to quantify sources [70], distribution [70], spatial and temporal distribution [65], environmental fate [38], dissolved and particulate phases [106], toxicity [38], sediment core [63], and residue concentrations [107].

Bangladesh is one of the top countries to produce freshwater and marine fish [108]. Additionally, Bangladesh contributes approximately 2% to the global wild capture fisheries, encompassing both marine and freshwater environments [108]. Fish is the main food for about 160 million Bangladeshi people. However, there is very limited research about the risks of PAHs to human health due to the consumption of fish from rivers, lakes, and marine ecosystems (Tables 4 and 5). As a result, we recommend more research on PAHs pollution on freshwater and marine fish to evaluate the possible risks due to the consumption of these fish species. Researchers are mostly concentrated on carcinogenic and non-carcinogenic risks and concentrations of PAHs in aquatic tissues [38]. In Bangladesh, subsequent research is needed to reveal the specific toxic nature of PAHs to aquatic tissues and their food web [38]. These studies include bioaccumulation [53], biomagnification [17], biotransformation [109], trophic dynamics [53], endocrine disruption [110], and metabolomics responses [111].

The shipbreaking industry is an important sector to provide raw materials for steel industries in Bangladesh [112]. Bangladesh is one of the top destinations for recycling ships [113]. Ship recycling industries are mostly developed in the coastal areas of Bangladesh, especially in the Chittagong Division. In 2022, Bangladesh recycled 122 ships, which is the second-highest number among all the countries in the world (Figure 5).

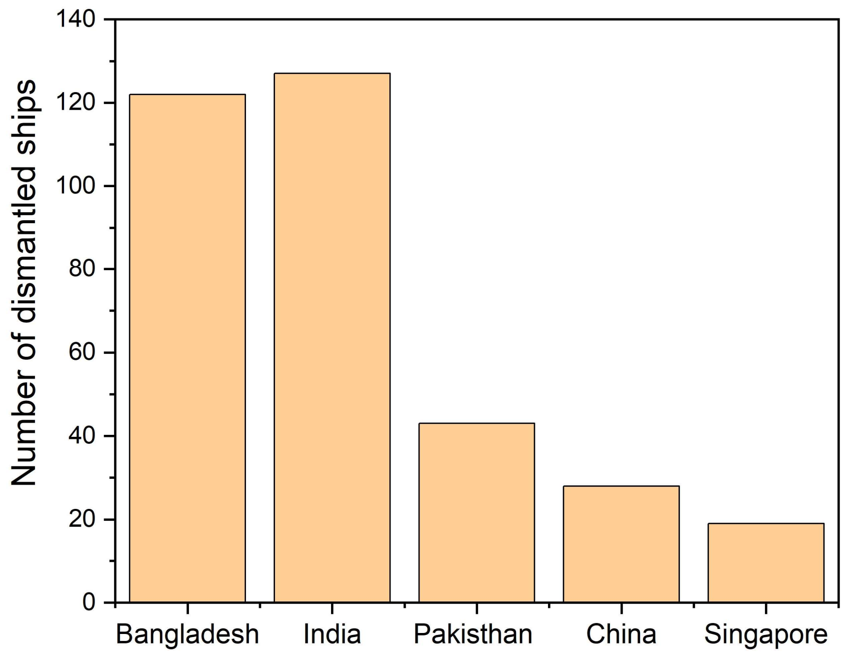

Figure 5. The number of dismantled ships in these countries in the year 2022 (Data source) [113].

In 2023, Bangladesh was anticipated to remain a prominent destination for ship recycling activities [113]. According to the shipbreaking platform, 582 ships were recycled globally, of which 197 (about 34%) were dismantled in Bangladeshi shipyards [113]. The data indicate increasing trends in ship scrapping in Bangladesh. During ship recycling, a large number of pollutants, such as oils, asbestos, metals, PAHs, and persistent organic pollutants, are released into the aquatic environment, which is a threat to aquatic biota as well as local residents [84]. But only one research article has been published from shipbreaking areas and it is showed higher amounts of PAHs in sediment than other coastal areas of Bangladesh [84]. Therefore, researchers are mostly prioritized to monitor the sediment and air pollution in shipbreaking areas in Bangladesh [84]. But more scientific research and monitoring are essential to quantifying the toxicity of PAHs, mostly the tissue-specific toxicity of PAHs in the benthic and sediment-dwelling organisms in shipbreaking areas [114,115]. These research directions include multi-tissue molecular responses, genomic effects, development effects, and physiological changes due to PAHs pollution in the shipbreaking areas [114,115]. Moreover, direct exposure to PAHs can also pose a serious risk to shipbreaking workers [116]. But there has been no research about the direct exposure risk to PAHs for shipbreaking workers. Several studies suggest that direct exposure to PAHs can lead to carcinogenicity, mutagenicity, developmental dysfunction, and sexual dysfunction in humans [106]. In these circumstances, we argue that subsequent research is needed to evaluate the health risks, including cancer [117], B-cell IgE production [118], DNA damage [119], and human hormonal dysfunction [120] of local residents as well as shipbreaking workers.

The distribution of PAHs in the environment is influenced by various physiochemical properties, leading to their presence in both particulate and gaseous forms [81]. Particulate PAHs typically adhere to aerosolized particles with aerodynamic diameters of less than 2.5 μm ($PM_{2.5}$). Bangladesh ranks among the countries with the poorest air quality globally, primarily due to elevated levels of $PM_{2.5}$ concentrations in the atmosphere [82]. From 2018 to 2021, Bangladesh consistently exhibited the highest $PM_{2.5}$ concentrations compared to other countries [82] (Figure 6). In 2022, the average $PM_{2.5}$ concentrations in Bangladesh were 13 times higher than the WHO global air quality guideline value (Figure 6). The presence of PAHs bound to air particles poses significant risks to human health through respiratory system deposition, with coal and biomass combustion representing the primary sources of particulate PAHs in the environment.

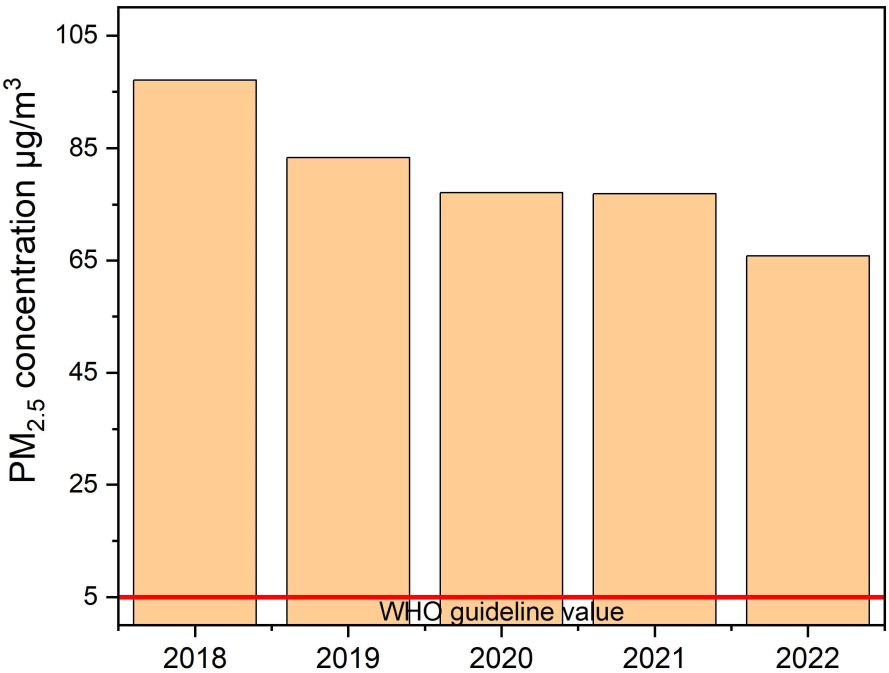

Figure 6. The annual average $PM_{2.5}$ concentrations of air in Bangladesh (Data source) [82].

In recent years, Bangladesh has witnessed the establishment of several coal power plants, leading to increased emissions of PAHs during electricity production [105]. Additionally, the rising trend of ship recycling is expected to contribute to higher levels of particulate PAHs in the air within shipbreaking areas [52]. But researchers in Bangladesh have predominately focused on identifying sources (molecular diagnostic ratios), distribution, and human health risks of PAHs in air particles [52,81,83,84]. In comparison to other countries, a very limited number of research articles have been published about PAHs in air particles in Bangladesh (Table 3). Given this scenario, we recommend more research about PAHs in air particles, including shipbreaking areas and urban areas, which could be the possible hotspot of particulate-bound PAHs in Bangladesh. Therefore, we recommend subsequent research is needed to identify the molecular distribution and gas-to-particle partition of PAHs in air particles through the technique of compound-specific stable carbon isotopes [87]. The human health risks of air particles, including lung cancer risks [121], lung cell toxicity [122], lung cell alternation, and genetic instability [123], should be focused in the future on Bangladesh. Overall, future research directions for addressing PAH pollution in Bangladesh should include investigations into aquatic ecosystems, with a focus on quantifying risks to fish, biomagnification within the food web, sediment pollution status in shipbreaking areas, responses of benthic organisms to PAH pollution, direct exposure risks of PAHs in urban areas, and air pollution status in urban and shipbreaking areas.

11. Conclusions

This review aims to explore the research trends of PAHs pollution in various environmental compartments in Bangladesh, including sediment, water, aquatic organisms, and air particles. A comparative analysis is conducted with PAHs research in other countries, and prospective future research directions for PAHs in Bangladesh are considered. The findings of this review indicate a scarcity of PAHs pollution research in Bangladesh compared to other countries. While only 10 research articles have been published on PAHs pollution in Bangladesh, the global count stands at approximately 26,500 research papers. The higher accumulation of PAHs in sediments, water, aquatic tissues, and air particles in Bangladesh suggests elevated anthropogenic inputs of PAHs in different environmental media. The major sources of PAHs pollution identified in the study include fossil fuel combustion, petroleum hydrocarbons, urban discharges, industrial emissions, shipbreaking, and shipping activities. Coastal sediments exhibited higher PAHs concentrations than urban sediments, emphasizing the need for increased attention to PAHs pollution in coastal areas in future research. Notably, aquatic organisms and air particles in Bangladesh contained higher PAHs concentrations compared to other comparable countries globally. There is also a potential higher carcinogenic risk associated with PAHs due to the consumption of aquatic species. Additionally, air particles in shipbreaking areas contained higher PAHs concentrations than in other areas of Bangladesh, suggesting that shipbreaking areas could be significant hotspots for PAHs pollution in the country. In conclusion, this review highlights the importance of future research focusing on the adverse effects of PAHs pollution in aquatic ecosystems, shipbreaking-related PAHs pollution, and air particle-associated PAHs pollution. Moreover, the direct exposure of PAHs to humans and their adverse effects on human health risks should be investigated in Bangladesh in the future.

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References

1. Dai, C.; Han, Y.; Duan, Y.; Lai, X.; Fu, R.; Liu, S.; Leong, K.H.; Tu, Y.; Zhou, L. Review on the Contamination and Remediation of Polycyclic Aromatic Hydrocarbons (PAHs) in Coastal Soil and Sediments. *Environ. Res.* **2022**, *205*, 112423. [CrossRef]
2. Li, J.; Shang, X.; Zhao, Z.; Tanguay, R.L.; Dong, Q.; Huang, C. Polycyclic Aromatic Hydrocarbons in Water, Sediment, Soil, and Plants of the Aojiang River Waterway in Wenzhou, China. *J. Hazard. Mater.* **2010**, *173*, 75–81. [CrossRef] [PubMed]
3. Pucknat, A.W. Health Impacts of Polynuclear Aromatic Hydrocarbons. Environmental Health Review No. 5. *Food Chem. Toxicol.* **1982**, *20*, 613.
4. Zhang, G.; Pan, Z.; Wang, X.; Mo, X.; Li, X. Distribution and Accumulation of Polycyclic Aromatic Hydrocarbons (PAHs) in the Food Web of Nansi Lake, China. *Environ. Monit. Assess.* **2015**, *187*, 1–12. [CrossRef]
5. Wei, Y.; Cui, H.; Hu, Q.; Bai, Y.; Qu, K.; Sun, J.; Cui, Z. Eutrophication Status Assessment in the Laizhou Bay, Bohai Sea: Further Evidence for the Ecosystem Degradation. *Mar. Pollut. Bull.* **2022**, *181*, 113867. [CrossRef]
6. Wang, J.-Z.; Zhu, C.-Z.; Chen, T.-H. PAHs in the Chinese Environment: Levels, Inventory Mass, Source and Toxic Potency Assessment. *Environ. Sci. Process. Impacts* **2013**, *15*, 1104. [CrossRef]
7. Han, J.; Liang, Y.; Zhao, B.; Wang, Y.; Xing, F.; Qin, L. Polycyclic Aromatic Hydrocarbon (PAHs) Geographical Distribution in China and Their Source, Risk Assessment Analysis. *Environ. Pollut.* **2019**, *251*, 312–327. [CrossRef] [PubMed]
8. Menzie, C.A.; Potocki, B.B.; Santodonato, J. Exposure to Carcinogenic PAHs in the Environment. *Environ. Sci. Technol.* **1992**, *26*, 1278–1284. [CrossRef]
9. Lowe, J.P.; Silverman, B.D. Predicting Carcinogenicity of Polycyclic Aromatic Hydrocarbons. *Acc. Chem. Res.* **1984**, *17*, 332–338. [CrossRef]
10. Sun, K.; Song, Y.; He, F.; Jing, M.; Tang, J.; Liu, R. A Review of Human and Animals Exposure to Polycyclic Aromatic Hydrocarbons: Health Risk and Adverse Effects, Photo-Induced Toxicity and Regulating Effect of Microplastics. *Sci. Total Environ.* **2021**, *773*, 145403. [CrossRef]
11. Soltani, N.; Keshavarzi, B.; Moore, F.; Tavakol, T.; Lahijanzadeh, A.R.; Jaafarzadeh, N.; Kermani, M. Ecological and Human Health Hazards of Heavy Metals and Polycyclic Aromatic Hydrocarbons (PAHs) in Road Dust of Isfahan Metropolis, Iran. *Sci. Total Environ.* **2015**, *505*, 712–723. [CrossRef] [PubMed]
12. Farombi, E.O.; Ajayi, B.O.; Adedara, I.A. 6-Gingerol Delays Tumorigenesis in Benzo[a]Pyrene and Dextran Sulphate Sodium-Induced Colorectal Cancer in Mice. *Food Chem. Toxicol.* **2020**, *142*, 111483. [CrossRef] [PubMed]
13. Du, J.; Jing, C. Anthropogenic PAHs in Lake Sediments: A Literature Review (2002–2018). *Environ. Sci. Process. Impacts* **2018**, *20*, 1649–1666. [CrossRef] [PubMed]
14. Chen, M.; Xu, P.; Zeng, G.; Yang, C.; Huang, D.; Zhang, J. Bioremediation of Soils Contaminated with Polycyclic Aromatic Hydrocarbons, Petroleum, Pesticides, Chlorophenols and Heavy Metals by Composting: Applications, Microbes and Future Research Needs. *Biotechnol. Adv.* **2015**, *33*, 745–755. [CrossRef]
15. Ito, K.; Uno, S.; Tanaka, H.; Miki, S.; Kokushi, E.; Yamamoto, M.; Koyama, J. Distribution of parent and alkylated PAHs in bivalves collected from Osaka Bay, Japan. *Jpn. J. Environ. Toxicol.* **2015**, *18*, 11–24.
16. Pozo, K.; Perra, G.; Menchi, V.; Urrutia, R.; Parra, O.; Rudolph, A.; Focardi, S. Levels and Spatial Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments from Lenga Estuary, Central Chile. *Mar. Pollut. Bull.* **2011**, *62*, 1572–1576. [CrossRef]
17. Qin, N.; He, W.; Liu, W.; Kong, X.; Xu, F.; Giesy, J.P. Tissue Distribution, Bioaccumulation, and Carcinogenic Risk of Polycyclic Aromatic Hydrocarbons in Aquatic Organisms from Lake Chaohu, China. *Sci. Total Environ.* **2020**, *749*, 141577. [CrossRef]
18. Takeuchi, I.; Miyoshi, N.; Mizukawa, K.; Takada, H.; Ikemoto, T.; Omori, K.; Tsuchiya, K. Biomagnification Profiles of Polycyclic Aromatic Hydrocarbons, Alkylphenols and Polychlorinated Biphenyls in Tokyo Bay Elucidated by δ13C and δ15N Isotope Ratios as Guides to Trophic Web Structure. *Mar. Pollut. Bull.* **2009**, *58*, 663–671. [CrossRef]
19. Honda, M.; Mukai, K.; Nagato, E.; Uno, S.; Oshima, Y. Correlation between Polycyclic Aromatic Hydrocarbons in Wharf Roach (*Ligia* Spp.) and Environmental Components of the Intertidal and Supralittoral Zone along the Japanese Coast. *Int. J. Environ. Res. Public Health* **2021**, *18*, 630. [CrossRef]
20. Honda, M.; Suzuki, N. Toxicities of Polycyclic Aromatic Hydrocarbons for Aquatic Animals. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1363. [CrossRef]
21. Han, M.; Li, H.; Kang, Y.; Liu, H.; Huang, X.; Zhang, R.; Yu, K. Bioaccumulation and Trophic Transfer of PAHs in Tropical Marine Food Webs from Coral Reef Ecosystems, the South China Sea: Compositional Pattern, Driving Factors, Ecological Aspects, and Risk Assessment. *Chemosphere* **2022**, *308*, 136295. [CrossRef]
22. Uno, S.; Koyama, J.; Kokushi, E.; Monteclaro, H.; Santander, S.; Cheikyula, J.O.; Miki, S.; Añasco, N.; Pahila, I.G.; Taberna, H.S.; et al. Monitoring of PAHs and Alkylated PAHs in Aquatic Organisms after 1 Month from the Solar I Oil Spill off the Coast of Guimaras Island, Philippines. *Environ. Monit. Assess.* **2009**, *165*, 501–515. [CrossRef]

23. Hahladakis, J.; Smaragdaki, E.; Vasilaki, G.; Gidarakos, E. Use of Sediment Quality Guidelines and Pollution Indicators for the Assessment of Heavy Metal and PAH Contamination in Greek Surficial Sea and Lake Sediments. *Environ. Monit. Assess.* **2012**, *185*, 2843–2853. [CrossRef]
24. Habibullah-Al-Mamun, M.; Kawser Ahmed, M.; Hossain, A.; Masunaga, S. Distribution, Source Apportionment, and Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in the Surficial Sediments from the Coastal Areas of Bangladesh. *Arch. Environ. Contam. Toxicol.* **2018**, *76*, 178–190. [CrossRef]
25. Xiang, N.; Jiang, C.; Yang, T.; Li, P.; Wang, H.; Xie, Y.; Li, S.; Zhou, H.; Diao, X. Occurrence and Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in Seawater, Sediments and Corals from Hainan Island, China. *Ecotoxicol. Environ. Saf.* **2018**, *152*, 8–15. [CrossRef]
26. Luo, X.-J.; Chen, S.-J.; Mai, B.-X.; Sheng, G.-Y.; Fu, J.-M.; Zeng, E.Y. Distribution, Source Apportionment, and Transport of PAHs in Sediments from the Pearl River Delta and the Northern South China Sea. *Arch. Environ. Contam. Toxicol.* **2008**, *55*, 11–20. [CrossRef]
27. Bixian, M.; Jiamo, F.; Gan, Z.; Zheng, L.; Yushun, M.; Guoying, S.; Xingmin, W. Polycyclic Aromatic Hydrocarbons in Sediments from the Pearl River and Estuary, China: Spatial and Temporal Distribution and Sources. *Appl. Geochem.* **2001**, *16*, 1429–1445. [CrossRef]
28. Zhang, N.; Maung, M.W.; Wang, S.; Aruffo, E.; Feng, J. Characterization and Health Risk Assessment of PM2.5-Bound Polycyclic Aromatic Hydrocarbons in Yangon and Mandalay of Myanmar. *Sci. Total Environ.* **2024**, *914*, 170034. [CrossRef] [PubMed]
29. Zheng, Z.-Y.; Ni, H.-G. Predicted No-Effect Concentration for Eight PAHs and Their Ecological Risks in Seven Major River Systems of China. *Sci. Total Environ.* **2024**, *906*, 167590. [CrossRef] [PubMed]
30. Qi, R.; Pan, L.; Liu, T.; Li, Z. Source Risk, Ecological Risk, and Bioeffect Assessment for Polycyclic Aromatic Hydrocarbons (PAHs) in Laizhou Bay and Jiaozhou Bay of Shandong Peninsula, China. *Environ. Sci. Pollut. Res.* **2022**, *29*, 56705–56726. [CrossRef] [PubMed]
31. Sun, J.; Pan, L.; Cao, Y.; Li, Z. Biomonitoring of Polycyclic Aromatic Hydrocarbons (PAHs) from Manila Clam Ruditapes Philippinarum in Laizhou, Rushan and Jiaozhou, Bays of China, and Investigation of Its Relationship with Human Carcinogenic Risk. *Mar. Pollut. Bull.* **2020**, *160*, 111556. [CrossRef]
32. Habibullah-Al-Mamun, M.; Ahmed, M.K.; Islam, M.S.; Tokumura, M.; Masunaga, S. Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in Commonly Consumed Seafood from Coastal Areas of Bangladesh and Associated Human Health Implications. *Environ. Geochem. Health* **2018**, *41*, 1105–1121. [CrossRef]
33. Qiao, M.; Wang, C.; Huang, S.; Wang, D.; Wang, Z. Composition, Sources, and Potential Toxicological Significance of PAHs in the Surface Sediments of the Meiliang Bay, Taihu Lake, China. *Environ. Int.* **2006**, *32*, 28–33. [CrossRef]
34. Cao, X.; Huo, S.; Zhang, H.; Zhao, X.; Guo, W.; He, Z.; Ma, C.; Zheng, J.; Song, S. Polycyclic Aromatic Hydrocarbons in China: Will Decoupling of Their Emissions and Socioeconomic Growth Emerge? *Earth's Future* **2022**, *10*, e2021EF002360. [CrossRef]
35. Li, C.; Li, Z.; Wang, H. Characterization and Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) Pollution in Particulate Matter in Rural Residential Environments in China-A Review. *Sustain. Cities Soc.* **2023**, *96*, 104690. [CrossRef]
36. Yan, D.; Wu, S.; Zhou, S.; Tong, G.; Li, F.; Wang, Y.; Li, B. Characteristics, Sources and Health Risk Assessment of Airborne Particulate PAHs in Chinese Cities: A Review. *Environ. Pollut.* **2019**, *248*, 804–814. [CrossRef] [PubMed]
37. Suvarapu, L.N.; Seo, Y.-K.; Lee, B.-S.; Baek, S.-O. A Review on the Atmospheric Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in Asia Since 2000—Part I: Data from Developed Countries. *Asian J. Atmos. Environ.* **2012**, *6*, 147–168. [CrossRef]
38. Vijayanand, M.; Ramakrishnan, A.; Subramanian, R.; Issac, P.K.; Nasr, M.; Khoo, K.S.; Rajagopal, R.; Greff, B.; Wan Azelee, N.I.; Jeon, B.-H.; et al. Polyaromatic Hydrocarbons (PAHs) in the Water Environment: A Review on Toxicity, Microbial Biodegradation, Systematic Biological Advancements, and Environmental Fate. *Environ. Res.* **2023**, *227*, 115716. [CrossRef] [PubMed]
39. Liu, J.; Jia, J.; Grathwohl, P. Dilution of Concentrations of PAHs from Atmospheric Particles, Bulk Deposition to Soil: A Review. *Environ. Geochem. Health* **2022**, *44*, 4219–4234. [CrossRef] [PubMed]
40. Yang, W.; Cao, Z.; Lang, Y. Pollution Status of Polycyclic Aromatic Hydrocarbons (PAHs) in Northeastern China: A Review and Meta-analysis. *Environ. Process.* **2021**, *8*, 429–454. [CrossRef]
41. Available online: https://www.worldbank.org/en/country/bangladesh/overview (accessed on 10 January 2024).
42. Available online: https://bangladesh.unfpa.org/en/node/24314 (accessed on 10 January 2024).
43. Available online: https://www.undp.org/bangladesh/blog/human-development-report-2021-22 (accessed on 10 January 2024).
44. Hasan, M.K.; Shahriar, A.; Jim, K.U. Water pollution in Bangladesh and its impact on public health. *Heliyon* **2019**, *5*, e02145. [CrossRef] [PubMed]
45. Salam, A.; Hossain, T.; Siddique, M.N.; Alam, A.S. Characteristics of atmospheric trace gases, particulate matter, and heavy metal pollution in Dhaka, Bangladesh. *Air Qual. Atmos. Health* **2008**, *1*, 101–109. [CrossRef]
46. Vasseghian, Y.; Sadeghi Rad, S.; Vilas–Boas, J.A.; Khataee, A. A Global Systematic Review, Meta-Analysis, and Risk Assessment of the Concentration of Vanadium in Drinking Water Resources. *Chemosphere* **2021**, *267*, 128904. [CrossRef] [PubMed]
47. Haque, M.K.; Uddin, M.; Kormoker, T.; Ahmed, T.; Zaman, M.R.U.; Rahman, M.S.; Rahman, M.A.; Hossain, M.Y.; Rana, M.M.; Tsang, Y.F. Occurrences, Sources, Fate and Impacts of Plastic on Aquatic Organisms and Human Health in Global Perspectives: What Bangladesh Can Do in Future? *Environ. Geochem. Health* **2023**, *45*, 5531–5556. [CrossRef]

48. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *J. Clin. Epidemiol.* **2009**, *62*, 1006–1012. [CrossRef]
49. Available online: https://clarivate.com/ (accessed on 20 November 2023).
50. Nawaz, M.S.; Ferdousi, F.K.; Rahman, M.A.; Alam, A.M.S. Reversed Phase SPE and GC-MS Study of Polycyclic Aromatic Hydrocarbons in Water Samples from the River Buriganga, Bangladesh. *Int. Sch. Res. Not.* **2014**, *2014*, 234092. [CrossRef]
51. Khan, R.; Islam, M.S.; Tareq, A.R.M.; Naher, K.; Islam, A.R.M.T.; Habib, M.A.; Siddique, M.A.B.; Islam, M.A.; Das, S.; Rashid, M.B.; et al. Distribution, Sources and Ecological Risk of Trace Elements and Polycyclic Aromatic Hydrocarbons in Sediments from a Polluted Urban River in Central Bangladesh. *Environ. Nanotechnol. Monit. Manag.* **2020**, *14*, 100318. [CrossRef]
52. Nargis, A.; Habib, A.; Zhao, S.; Nigar, R.; Liu, X.; Zhang, G.; Cai, M. Monitoring of Atmospheric Polycyclic Aromatic Hydrocarbons by Polyurethane Foam-Passive Air Samplers in Bangladesh: Source Apportionment and Health Risk Assessment. *Atmos. Environ.* **2022**, *289*, 119346. [CrossRef]
53. Liu, B.; Gao, L.; Ding, L.; Lv, L.; Yu, Y. Trophodynamics and Bioaccumulation of Polycyclic Aromatic Hydrocarbons (PAHs) in Marine Food Web from Laizhou Bay, China. *Mar. Pollut. Bull.* **2023**, *194*, 115307. [CrossRef] [PubMed]
54. Kermani, M.; Taghizadeh, F.; Jonidi Jafari, A.; Gholami, M.; Shahsavani, A.; Nakhjirgan, P. PAHs Pollution in the Outdoor Air of Areas with Various Land Uses in the Industrial City of Iran: Distribution, Source Apportionment, and Risk Assessment. *Heliyon* **2023**, *9*, e17357. [CrossRef] [PubMed]
55. Areguamen, O.I.; Calvin, N.N.; Gimba, C.E.; Okunola, O.J.; Elebo, A. Seasonal Assessment of the Distribution, Source Apportionment, and Risk of Water-Contaminated Polycyclic Aromatic Hydrocarbons (PAHs). *Environ. Geochem. Health* **2023**, *45*, 5415–5439. [CrossRef] [PubMed]
56. Pongpiachan, S.; Tipmanee, D.; Choochuay, C.; Deelaman, W.; Iadtem, N.; Wang, Q.; Xing, L.; Li, G.; Han, Y.; Hashmi, M.Z.; et al. Concentrations and Source Identification of Priority Polycyclic Aromatic Hydrocarbons in Sediment Cores from South and Northeast Thailand. *Heliyon* **2022**, *8*, e10953. [CrossRef]
57. Grmasha, R.A.; Stenger-Kovács, C.; Bedewy, B.A.H.; Al-sareji, O.J.; Al-Juboori, R.A.; Meiczinger, M.; Hashim, K.S. Ecological and Human Health Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAH) in Tigris River near the Oil Refineries in Iraq. *Environ. Res.* **2023**, *227*, 115791. [CrossRef]
58. Sankar, T.K.; Kumar, A.; Mahto, D.K.; Das, K.C.; Narayan, P.; Fukate, M.; Awachat, P.; Padghan, D.; Mohammad, F.; Al-Lohedan, H.A.; et al. The Health Risk and Source Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in the Soil of Industrial Cities in India. *Toxics* **2023**, *11*, 515. [CrossRef]
59. Zakir Hossain, H.M.; Sampei, Y.; Roser, B.P. Polycyclic Aromatic Hydrocarbons (PAHs) in Late Eocene to Early Pleistocene Mudstones of the Sylhet Succession, NE Bengal Basin, Bangladesh: Implications for Source and Paleoclimate Conditions during Himalayan Uplift. *Org. Geochem.* **2013**, *56*, 25–39. [CrossRef]
60. Raeisi, A.; Arfaeinia, H.; Seifi, M.; Shirzad-Siboni, M.; Keshtkar, M.; Dobaradaran, S. Polycyclic Aromatic Hydrocarbons (PAHs) in Coastal Sediments from Urban and Industrial Areas of Asaluyeh Harbor, Iran: Distribution, Potential Source and Ecological Risk Assessment. *Water Sci. Technol.* **2016**, *74*, 957–973. [CrossRef]
61. Akter, R.; Akbor, M.A.; Bakar Sidddique, M.A.; Shammi, M.; Rahman, M.M. Occurrence and Health Risks Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in Road Dust and Soil Samples at Dhaka City, Bangladesh. *Case Stud. Chem. Environ. Eng.* **2023**, *7*, 100304. [CrossRef]
62. Nahar, A.; Akbor, M.A.; Sarker, S.; Bakar Siddique, M.A.; Shaikh, M.A.A.; Chowdhury, N.J.; Ahmed, S.; Hasan, M.; Sultana, S. Dissemination and Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in Water and Sediment of Buriganga and Dhaleswari Rivers of Dhaka, Bangladesh. *Heliyon* **2023**, *9*, e18465. [CrossRef]
63. Xia, Y.; Zhang, Y.; Ji, Q.; Cheng, X.; Wang, X.; Sabel, C.E.; He, H. Sediment Core Records and Impact Factors of Polycyclic Aromatic Hydrocarbons in Chinese Lakes. *Environ. Res.* **2023**, *235*, 116690. [CrossRef]
64. Huang, T.; Zhou, J.; Luo, D.; Li, S.; Yang, H.; Huang, C.; Li, Y.; Zhang, Z. Sediment Record in Pollution, Toxicity Risk, and Source Assignment of Polycyclic Aromatic Hydrocarbons (PAHs) in Erhai Lake, Southwest China. *Mar. Pollut. Bull.* **2023**, *186*, 114424. [CrossRef]
65. Lu, Z.; Tian, W.; Zhang, S.; Chu, M.; Zhao, J.; Liu, B.; Yang, K.; Cao, H.; Chen, Z. Spatiotemporal Variability of PAHs and Their Derivatives in Sediments of the Laizhou Bay in the Eastern China: Occurrence, Source, and Ecological Risk Assessment. *J. Hazard. Mater.* **2023**, *460*, 132351. [CrossRef]
66. Yang, Y.; Zhao, Z.; Chang, Y.; Wang, H.; Wang, H.; Dong, W.; Yan, G. PAHs and PAEs in the Surface Sediments from Nenjiang River and the Second Songhua River, China: Distribution, Composition and Risk Assessment. *Process Saf. Environ. Prot.* **2023**, *178*, 765–775. [CrossRef]
67. Bhatawadekar, V.C.; Damare, S.R.; Garg, A. Risk Assessment of Polycyclic Aromatic Hydrocarbon Infested Sediments along the Coast of Goa, India. *Environ. Sci. Pollut. Res.* **2023**, *30*, 93114–93125. [CrossRef]
68. Cheshmvahm, H.; Keshavarzi, B.; Moore, F.; Zarei, M.; Esmaeili, H.R.; Hooda, P.S. Investigation of the Concentration, Origin and Health Effects of PAHs in the Anzali Wetland: The Most Important Coastal Freshwater Wetland of Iran. *Mar. Pollut. Bull.* **2023**, *193*, 115191. [CrossRef]
69. Zoveidadianpour, Z.; Doustshenas, B.; Alava, J.J.; Savari, A.; Karimi Organi, F. Environmental and Human Health Risk Assessment of Polycyclic Aromatic Hydrocarbons in the Musa Estuary (Northwest of Persian Gulf), Iran. *J. Sea Res.* **2023**, *191*, 102335. [CrossRef]

70. Hassaan, M.A.; El Nemr, A.; El Sikaily, A.; Ragab, S. N-Alkanes and PAHs Baseline Distributions and Sources in the Sediments of the Nile Delta Coast of the Southeastern Mediterranean. *Mar. Pollut. Bull.* **2023**, *194*, 115262. [CrossRef]
71. Chen, C.-F.; Ju, Y.-R.; Lim, Y.C.; Wang, M.-H.; Albarico, F.P.J.B.; Chen, C.-W.; Dong, C.-D. Occurrence and Ecological Risks of PAHs in the Dissolved and Particulate Phases of Coastal Surface Water of Taiwan. *Reg. Stud. Mar. Sci.* **2022**, *54*, 102503. [CrossRef]
72. Na, M.; Zhao, Y.; Rina, S.; Wang, R.; Liu, X.; Tong, Z.; Zhang, J. Residues, Potential Source and Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in Surface Water of the East Liao River, Jilin Province, China. *Sci. Total Environ.* **2023**, *886*, 163977. [CrossRef]
73. Shang, N.; Wang, C.; Kong, J.; Yu, H.; Li, J.; Hao, W.; Huang, T.; Yang, H.; He, H.; Huang, C. Dissolved Polycyclic Aromatic Hydrocarbons (PAHs-d) in Response to Hydrology Variation and Anthropogenic Activities in the Yangtze River, China. *J. Environ. Manag.* **2023**, *326*, 116673. [CrossRef]
74. Shi, M.; Zhu, J.; Hu, T.; Xu, A.; Mao, Y.; Liu, L.; Zhang, Y.; She, Z.; Li, P.; Qi, S.; et al. Occurrence, Distribution and Risk Assessment of Microplastics and Polycyclic Aromatic Hydrocarbons in East Lake, Hubei, China. *Chemosphere* **2023**, *316*, 137864. [CrossRef]
75. Wang, H.; Liu, Z.; Sun, L.; Wang, Y.; Luo, Q.; Wu, H.; Wang, X. Characterization and Risk Assessment of Polycyclic Aromatic Hydrocarbons in Surface Water from Liaohe River, Northeast China. *Polycycl. Aromat. Compd.* **2016**, *38*, 389–401. [CrossRef]
76. Wu, Y.; Zhang, Z.; Huang, W.; Liu, H.; Zhang, R.; Jiao, H.; Sun, A.; Chen, J.; Shi, X. Environmental Profile, Potential Sources, and Ecological Risk of Polycyclic Aromatic Hydrocarbons in a Typical Coastal Bay and Outer Bay Area. *Environ. Sci. Pollut. Res.* **2023**, *30*, 77757–77770. [CrossRef]
77. Kumar, B.; Verma, V.K.; Kumar, S.; Gargava, P. Polycyclic Aromatic Hydrocarbons in Surface Waters from India: Possible Sources and Risk Assessment. *Polycycl. Aromat. Compd.* **2023**, 1–17. [CrossRef]
78. El-Maradny, A.; Orif, M.; AlKobati, A.; Ghandourah, M.; Al-Farawati, R. Polycyclic Aromatic Hydrocarbons in the Water Column of Three Hot Spot Areas, Jeddah Coast, Eastern of Red Sea. *Reg. Stud. Mar. Sci.* **2023**, *64*, 103047. [CrossRef]
79. Areguamen, O.I.; Calvin, N.N.; Gimba, C.E.; Okunola, O.J.; Abdulkadir, A.T.; Elebo, A. Assessment of Seasonal Variation in Distribution, Source Identification, and Risk of Polycyclic Aromatic Hydrocarbon (PAH)–Contaminated Sediment of Ikpoba River, South-South Nigeria. *Environ. Monit. Assess.* **2023**, *195*, 302. [CrossRef]
80. Teodora CIUCURE, C.; GEANA, E.-I.; Lidia CHITESCU, C.; Laurentiu BADEA, S.; Elena IONETE, R. Distribution, Sources and Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Waters and Sediments from Olt River Dam Reservoirs in Romania. *Chemosphere* **2023**, *311*, 137024. [CrossRef]
81. Sei, K.; Wang, Q.; Tokumura, M.; Hossain, A.; Raknuzzaman, M.; Miyake, Y.; Amagai, T. Occurrence, Potential Source, and Cancer Risk of PM2.5-Bound Polycyclic Aromatic Hydrocarbons and Their Halogenated Derivatives in Shizuoka, Japan, and Dhaka, Bangladesh. *Environ. Res.* **2021**, *196*, 110909. [CrossRef]
82. Available online: https://www.iqair.com/world-most-polluted-countries (accessed on 26 November 2023).
83. Jeba, F.; Karim, T.T.; Khan, M.F.; Latif, M.T.; Quddus, K.F.; Salam, A. Receptor Modelling and Risk Factors of Polycyclic Aromatic Hydrocarbons (PAHs) in the Atmospheric Particulate Matter at an IGP Outflow Location (Island of the Bay of Bengal—Bhola, Bangladesh). *Air Qual. Atmos. Health* **2021**, *14*, 1417–1431. [CrossRef]
84. Nøst, T.H.; Halse, A.K.; Randall, S.; Borgen, A.R.; Schlabach, M.; Paul, A.; Rahman, A.; Breivik, K. High Concentrations of Organic Contaminants in Air from Ship Breaking Activities in Chittagong, Bangladesh. *Environ. Sci. Technol.* **2015**, *49*, 11372–11380. [CrossRef]
85. Wang, F.; Zhao, D.; Zhang, S.; Feng, T.; Wang, H.; Guo, Z.; Ma, L.; Rose, N.L. Gas-Particle Partitioning and Air-Water Exchange of Polycyclic Aromatic Hydrocarbons in the Three Gorges Reservoir, Southwest China. *Atmos. Environ.* **2023**, *299*, 119646. [CrossRef]
86. Chen, Y.; Ge, C.; Liu, Z.; Xu, H.; Zhang, X.; Shen, T. Characteristics, Sources and Health Risk Assessment of Trace Metals and Polycyclic Aromatic Hydrocarbons in PM2.5 from Hefei, China. *Environ. Geochem. Health* **2023**, *45*, 7651–7663. [CrossRef]
87. Li, J.; Wang, X.; Dai, W.; Qi, W.; Liu, H.; Shen, M.; Liu, Y.; Guo, X.; Zhang, Y.; Li, L.; et al. Molecular Compositions and Stable Carbon Isotopes (δ13C) of PAHs in Wintertime PM2.5 in Urban Xi'an, China: Implications for Source Distribution and Atmospheric Oxidation. *Atmos. Res.* **2023**, *292*, 106890. [CrossRef]
88. Onaiwu, G.E.; Eferavware, S.A. The Potential Health Risk Assessment of PM2.5-Bound Polycyclic Aromatic Hydrocarbons (PAHs) on the Human Respiratory System within the Ambient Air of Automobile Workshops in Benin City, Nigeria. *Air Qual. Atmos. Health* **2023**, *16*, 2431–2441. [CrossRef]
89. Cachon, F.B.; Cazier, F.; Verdin, A.; Dewaele, D.; Genevray, P.; Delbende, A.; Ayi-Fanou, L.; Aïssi, F.; Sanni, A.; Courcot, D. Physicochemical Characterization of Air Pollution Particulate Matter (PM2.5 and PM > 2.5) in an Urban Area of Cotonou, Benin. *Atmosphere* **2023**, *14*, 201. [CrossRef]
90. Siudek, P. Polycyclic Aromatic Hydrocarbons in Coarse Particles (PM10) over the Coastal Urban Region in Poland: Distribution, Source Analysis and Human Health Risk Implications. *Chemosphere* **2023**, *311*, 137130. [CrossRef]
91. Vishwakarma, P.; Rajeev, P.; Rabha, S.; Islam, N.; Saikia, B.K.; Gupta, T. Wintertime Trends of Particulate-Bound Polycyclic Aromatic Hydrocarbons (PAHs) at North-East Site of India: Chemical Characterization and Source Identification. *J. Atmos. Chem.* **2023**, *80*, 251–269. [CrossRef]
92. Singh, A.; Banerjee, T.; Latif, M.T.; Ramanathan, S.; Suradi, H.; Othman, M.; Murari, V. Molecular Distribution, Sources and Potential Health Risks of Fine Particulate-Bound Polycyclic Aromatic Hydrocarbons during High Pollution Episodes in a Subtropical Urban City. *Chemosphere* **2023**, *340*, 139943. [CrossRef]

93. Marinaite, I.I.; Khodzher, T.V.; Obolkin, V.A.; Potyomkin, V.L. Polycyclic Aromatic Hydrocarbons and PM10, PM2.5, PM1.0 Particles in the Atmosphere over the Southern Baikal Region. *Russ. Meteorol. Hydrol.* **2023**, *48*, 300–308. [CrossRef]
94. Mosallaei, S.; Hashemi, H.; Hoseini, M.; Dehghani, M.; Naz, A. Polycyclic Aromatic Hydrocarbons (PAHs) in Household Dust: The Association between PAHs, Cancer Risk and Sick Building Syndrome. *Build. Environ.* **2023**, *229*, 109966. [CrossRef]
95. Zhang, J.; Zhang, X.; Hu, T.; Xu, X.; Zhao, D.; Wang, X.; Li, L.; Yuan, X.; Song, C.; Zhao, S. Polycyclic Aromatic Hydrocarbons (PAHs) and Antibiotics in Oil-Contaminated Aquaculture Areas: Bioaccumulation, Influencing Factors, and Human Health Risks. *J. Hazard. Mater.* **2022**, *437*, 129365. [CrossRef]
96. Tareq, A.R.M.; Afrin, S.; Hossen, M.S.; Hashi, A.S.; Quraishi, S.B.; Nahar, Q.; Begum, R.; Ullah, A.K.M.A. Gas Chromatography–Mass Spectrometric (GC-MS) Determination of Polycyclic Aromatic Hydrocarbons in Smoked Meat and Fish Ingested by Bangladeshi People and Human Health Risk Assessment. *Polycycl. Aromat. Compd.* **2020**, *42*, 1570–1580. [CrossRef]
97. Aigberua, A.O.; Izah, S.C.; Aigberua, A.A. Occurrence, Source Delineation, and Health Hazard of Polycyclic Aromatic Hydrocarbons in Tissues of Sarotherodon Melanotheron and Chrysichthys Nigrodigitatus from Okulu River, Nigeria. *Environ. Monit. Assess.* **2023**, *195*, 364. [CrossRef]
98. Adewale, A.; Adegbola, P.I.; Owoade, A.O.; Aborisade, A.B. Fish as a Bioindicator of Polycyclic Aromatic Hydrocarbon Pollution in Aquatic Ecosystem of Ogun and Eleyele Rivers, Nigeria, and Risk Assessment for Consumer's Health. *J. Hazard. Mater. Adv.* **2022**, *7*, 100096. [CrossRef]
99. Rasheed, R.O. Seasonal Variations of Polycyclic Aromatic Hydrocarbons in the Muscle Tissue of Silurus Triostegus Heckel, 1843 from Derbendikhan Reservoir. *Polycycl. Aromat. Compd.* **2022**, *43*, 2144–2151. [CrossRef]
100. Bouzid, S.; Es Saouini, H.; Chiaar, A.; Lioubi, J.; Chakir, O.; Benomar, M.; Rhattas, C.; Chbani, I.; Er-Raioui, H. Preliminary Data on the Occurrence of PAH and *Anisakis* Spp. in Moroccan Anchovies: Environmental Parasitology and Human Health Risk. *Mar. Pollut. Bull.* **2023**, *194*, 115269. [CrossRef]
101. Zuloaga, O.; Prieto, A.; Usobiaga, A.; Sarkar, S.K.; Chatterjee, M.; Bhattacharya, B.D.; Bhattacharya, A.; Alam, M.A.; Satpathy, K.K. Polycyclic Aromatic Hydrocarbons in Intertidal Marine Bivalves of Sunderban Mangrove Wetland, India: An Approach to Bioindicator Species. *Water Air Soil Pollut.* **2009**, *201*, 305–318. [CrossRef]
102. Rahman, M.H.; Arslan, M.I.; Chen, Y.; Ali, S.; Parvin, T.; Wang, L.W.; Santella, R.M.; Ahsan, H. Polycyclic Aromatic Hydrocarbon-DNA Adducts among Rickshaw Drivers in Dhaka City, Bangladesh. *Int. Arch. Occup. Environ. Health* **2003**, *76*, 533–538. [CrossRef]
103. Canedo-Lopez, Y.; Ruiz-Marin, A.; Rocio Barreto-Castro, M. del Polycyclic Aromatic Hydrocarbons in Surface Sediments and Fish Tissues Collected from a Protected Lagoon Region. *Bull. Environ. Contam. Toxicol.* **2020**, *104*, 185–192. [CrossRef]
104. Squadrone, S.; Favaro, L.; Abete, M.C.; Vivaldi, B.; Prearo, M. Polycyclic Aromatic Hydrocarbon Levels in European Catfish from the Upper Po River Basin. *Environ. Monit. Assess.* **2013**, *186*, 2313–2320. [CrossRef]
105. Available online: https://data.worldbank.org (accessed on 10 November 2023).
106. Li, Z.; Qi, R.; Li, Y.; Miao, J.; Li, Y.; He, Z.; Zhang, N.; Pan, L. The Assessment of Bioavailability and Environmental Risk of Dissolved and Particulate Polycyclic Aromatic Hydrocarbons in the Seawater of Typical Bays. *Sci. Total Environ.* **2024**, *912*, 169124. [CrossRef]
107. Zheng, B.; Ma, Y.; Qin, Y.; Zhang, L.; Zhao, Y.; Cao, W.; Yang, C.; Han, C. Distribution, Sources, and Risk Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in Surface Water in Industrial Affected Areas of the Three Gorges Reservoir, China. *Environ. Sci. Pollut. Res.* **2016**, *23*, 23485–23495. [CrossRef]
108. Available online: https://www.fao.org (accessed on 5 November 2023).
109. Lyytikäinen, M.; Pehkonen, S.; Akkanen, J.; Leppänen, M.; Kukkonen, J.V.K. Bioaccumulation and Biotransformation of Polycyclic Aromatic Hydrocarbons during Sediment Tests with Oligochaetes (Lumbriculus Variegatus). *Environ. Toxicol. Chem.* **2007**, *26*, 2660–2666. [CrossRef]
110. Zhang, Y.; Dong, S.; Wang, H.; Tao, S.; Kiyama, R. Biological Impact of Environmental Polycyclic Aromatic Hydrocarbons (ePAHs) as Endocrine Disruptors. *Environ. Pollut.* **2016**, *213*, 809–824. [CrossRef]
111. Jones, O.A.H.; Spurgeon, D.J.; Svendsen, C.; Griffin, J.L. A Metabolomics Based Approach to Assessing the Toxicity of the Polyaromatic Hydrocarbon Pyrene to the Earthworm Lumbricus Rubellus. *Chemosphere* **2008**, *71*, 601–609. [CrossRef]
112. Hossain, M.S.; Fakhruddin, A.N.M.; Chowdhury, M.A.Z.; Gan, S.H. Impact of Ship-Breaking Activities on the Coastal Environment of Bangladesh and a Management System for Its Sustainability. *Environ. Sci. Policy* **2016**, *60*, 84–94. [CrossRef]
113. Available online: https://shipbreakingplatform.org/ (accessed on 2 November 2023).
114. Dubansky, B.; Whitehead, A.; Miller, J.T.; Rice, C.D.; Galvez, F. Multitissue Molecular, Genomic, and Developmental Effects of the Deepwater Horizon Oil Spill on Resident Gulf Killifish (*Fundulus grandis*). *Environ. Sci. Technol.* **2013**, *47*, 5074–5082. [CrossRef] [PubMed]
115. Whitehead, A.; Dubansky, B.; Bodinier, C.; Garcia, T.I.; Miles, S.; Pilley, C.; Raghunathan, V.; Roach, J.L.; Walker, N.; Walter, R.B.; et al. Genomic and Physiological Footprint of the Deepwater Horizon Oil Spill on Resident Marsh Fishes. *Proc. Natl. Acad. Sci. USA* **2011**, *109*, 20298–20302. [CrossRef]
116. Lauer, F.T.; Parvez, F.; Factor-Litvak, P.; Liu, X.; Santella, R.M.; Islam, T.; Eunus, M.; Alam, N.; Hasan, A.K.M.R.; Rahman, M.; et al. Changes in Human Peripheral Blood Mononuclear Cell (HPBMC) Populations and T-Cell Subsets Associated with Arsenic and Polycyclic Aromatic Hydrocarbon Exposures in a Bangladesh Cohort. *PLoS ONE* **2019**, *14*, e0220451. [CrossRef] [PubMed]

117. Mastrangelo, G.; Fadda, E.; Marzia, V. Polycyclic Aromatic Hydrocarbons and Cancer in Man. *Environ. Health Perspect.* **1996**, *104*, 1166–1170. [CrossRef]
118. Takenaka, H.; Zhang, K.; Diaz-Sanchez, D.; Tsien, A.; Saxon, A. Enhanced Human IgE Production Results from Exposure to the Aromatic Hydrocarbons from Diesel Exhaust: Direct Effects on B-Cell IgE Production. *J. Allergy Clin. Immunol.* **1995**, *95*, 103–115. [CrossRef]
119. Wei, Y.; Han, I.-K.; Hu, M.; Shao, M.; Zhang, J.; Tang, X. Personal Exposure to Particulate PAHs and Anthraquinone and Oxidative DNA Damages in Humans. *Chemosphere* **2010**, *81*, 1280–1285. [CrossRef]
120. Yin, S.; Tang, M.; Chen, F.; Li, T.; Liu, W. Environmental Exposure to Polycyclic Aromatic Hydrocarbons (PAHs): The Correlation with and Impact on Reproductive Hormones in Umbilical Cord Serum. *Environ. Pollut.* **2017**, *220*, 1429–1437. [CrossRef]
121. Xing, Y.F.; Xu, Y.H.; Shi, M.H.; Lian, Y.X. The impact of PM2.5 on the human respiratory system. *J. Thorac. Dis.* **2016**, *8*, E69.
122. Ferraz, E.R.A.; Rainho, C.R.; Fernandes, A.S.; Felzenszwalb, I. Differential Toxicity of an Organic PM2.5extract to Human Lung Cells Cultured in Three Dimensions (3D) and Monolayers. *J. Toxicol. Environ. Health Part A* **2016**, *79*, 221–231. [CrossRef]
123. Abbas, I.; Verdin, A.; Escande, F.; Saint-Georges, F.; Cazier, F.; Mulliez, P.; Courcot, D.; Shirali, P.; Gosset, P.; Garçon, G. In Vitro Short-Term Exposure to Air Pollution PM2.5-0.3 Induced Cell Cycle Alterations and Genetic Instability in a Human Lung Cell Coculture Model. *Environ. Res.* **2016**, *147*, 146–158. [CrossRef]