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Identification and Distribution of Polycyclic Aromatic Hydrocarbon Pollutants in Coastal Ecosystem the Marine Tourism Area, South Sulawesi

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Abstract. Today's marine tourism is experiencing rapid growth to meet the global needs of the world's population. Exploitation of marine biological wealth is no less important because it involves human life. The marine ecosystem must be of high quality and free from exposure to toxic pollutants, such as PAHs. The marine ecosystem must be of high quality and free from exposure to toxic pollutants, such as PAHs, microplastics. This research aims to provide data and information about the types and abundance of aromatic hydrocarbon compounds in sediments, sea water and marine biota around KKI waters. The analytical method to meet these objectives uses GS/MS. The status of marine tourism areas, especially around KKI waters, is declared polluted by PAHs. The types of PAHs identified in each sample at the three sampling stations were dominated by naphthalene (NL), phenanthrene (PT), pyrene (PR) and azulene (AZ). The average total abundance of PAHs in sponge samples (±70.51%), sediments (±67.30%), followed by seawater samples (±64.85%), starfish samples (±41.80%) and fish (±26.74%). The NL type PAHs were found in all types of samples and at all stations, where the PAHs were thought to originate from industrial, hospital, and household activities. The status of marine tourism, especially around the KKI waters, for tourists needs to be careful and alert, because the KKI area is not completely free from harmful and toxic pollutants, so it is a risk to health. Makassar City TMA managers are encouraged to make efforts to reduce the rate of increase in the concentration of regional PAHs, such as providing periodic data and information about harmful pollutants, education for every tourist to care about waste and planting coastal plants such as mangroves which have a biofilter function against toxic pollutants.

Introduction

Makassar City Marine Tourism is an activity whose activities are carried out in marine areas or tourism in coastal areas and surrounding islands, including the surface (Marzuki et al., 2020). The Marine Tourism Area (MTA) of Makassar City consists of several islands, namely Kodingareng Keke Island, Barrang Lompo, Barrang Caddi, Samalona and Langkay Island. This area is a source of regional budget revenue for Makassar City, so regulations and models for managing the marine tourism area are needed in order to remain friendly to every visitor (Marzuki et al., 2021). The MTA architectural arrangement is important to pamper visitors, but it is also very important to provide guarantees to every visitor related to the security, safety and health aspects of the attraction (Bergmann et al., 2015). Therefore, the local government needs to protect the tourist area so that it remains safe and worth visiting by many people, while providing protection for the marine life in it. In this area there are various types of marine biota that need to be maintained in quality or not exposed to global trend pollutants (microplastics, pesticide residues, PAHs, heavy metals and medical waste) (Brodie et al., 2019).

The coastal ecosystem of the marine tourism area of Samalona Island is one of the islands visited by many domestic and foreign tourists. Tourist activity on the island is quite dense and occurs almost every day, so the interaction between visitors and the coastal ecosystem,

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especially sea water as a means of bathing is very intense. (Marzuki et al., 2021a). In this area, there are also many fish and other marine biota, such as sponges, starfish, seagrass (Souza et al., 2017). If the coastal ecosystem is exposed to one of the global trend categories of pollutants, for example hydrocarbon components, especially polycyclic aromatic hydrocarbons, of course, the ecosystem has a direct or indirect adverse effect on the ecology of the coastal environment, tourists, and even the wider human population (Obire et al., 2020).

Polycyclic aromatic hydrocarbons (PAHs) are one of the toxic and carcinogenic pollutants. Marine waters are very vulnerable to contamination by PAHs, including the ecosystems in it. The presence of PAHs components and their descent in large volume water media, such as in the oceans are generally not visible to the naked eye (Bendouz et al., 2017; Gran et a., 2022). Exposure to PAHs in marine areas comes from several sources, both natural sources through geochemical cycles, industrial and human activities, such as petroleum processing, manufacturing, ship transportation, marine tourism activities and household waste. (Baburam Feto, 2021; Mao & Guan 2016). These PAHs components eventually empties into the sea due to the influence of gravity and natural cycles in a certain period of time. Ocean areas sometimes become giant containers and contain many types of pollutants from various types of waste. This condition has a negative impact on the sustainability of marine ecosystems and threatens the lives of various types of biota in it, as well as can reduce the quality of the sea as a friendly area for fish, marine biota and even have an impact on human health problems (Pita et al., 2018).

PAHs and their derivative components are susceptible to being found in the environment, especially in coastal ecosystems with various types, but the concern for analysis in this study are 16 types, ranging from simple components and moderate toxic properties with 2 and 3 ring structures, to complex structural components and high toxicity with 4 and 5 rings., as recommended by ASTM and National Academic of Science (Agrawal et al., 2018). The 16 types of PAHs that need to be watched out for, as recommended by ASTM, are based on the findings of these PAHs components in the petroleum processing industry which are estimated to have the potential to exist in the free environment, either naturally occurring or due to exploration and exploitation activities (Akoto et al., 2016; Jańczuk et al., 2021).

Pollutants formed by the elements carbon and hydrogen, not just PAHs. Microplastic is also a type of pollutant, which in the last two decades has become a trending topic by many countries in the world, because it causes problems both for the environment and for food. Sources of microplastic pollutants generally come from human activities in meeting their daily needs (Avana et al., 2022; Burhan et al., 2021). Microplastics are the result of decomposition or slurry of plastic materials that undergo destruction and degradation due to the interaction process with various other components through physical, chemical, and biological processes resulting in the destruction of plastic polymers that occur naturally in the environment (Ambumani & Kakkar 2018). In terms of toxicological aspects, microplastics are classified as dangerous pollutants for humans and food sources and include pollutant materials for the environment (Castelluccio et al., 2022).

PAH type pollutants in the environment, especially in the marine environment, may come from many sources, for example natural sources due to seepage of geological activities, ship transportation activities, offshore oil production, washing of tankers in the form of ballast, leakage of underwater oil distribution pipelines, oil spills due to shipwrecks, petroleum exploration and exploitation and industrial activities, coal-fired power generation waste, including industrial waste, household waste and atmospheric origin (Chaerul et al., 2021; Igiri et al., 2018; Gao et al., 2006). All of these sources, because the dynamics of life in anthropogenic processes can lead to marine waters as pollutants that have toxic, carcinogenic, and even mutagenic properties (Rusli et al., 2021; Liu et al., 2019).

Exposure to PAHs in marine ecosystems has the potential to cause chain effects, not only on marine life but can target living things which in the end in the ecotoxicological process cause health effects on humans (Marzuki et al., 2021b). The volume and types of PAHs that are estimated to enter the marine environment tend to get bigger over time, the dynamics and human needs are very varied (Mustafa et al., 2022). This condition is certainly a serious concern for various groups because of concerns about ecological hazards to living things and the environment (Garba et al., 2022).

The development of human life in the last three decades, with the need for tourism, has led to a trend of growth and development of natural and marine tourism. The need for marine tourism of the global community today is answered by the Makassar City Government by offering marine tourism destinations which include five small islands that are included in the administration of the Makassar City Tourism Office, namely Langkay Island, Barrang Caddi, Barrang Lompo, Samalona, and Kodingareng Keke (Marzuki et al., 2015). This Makassar City marine tourism destination is close to Soekarno-Hatta Harbor, fish landing port, and directly adjacent to Losari Beach with typical culinary activities. Along Losari Beach, several industries such as dairy factories, hotels and hospitals operate (Marzuki et al., 2021c). This situation is considered that the Makassar City Marine Tourism destination is vulnerable to harmful pollutants, such as PAHs, microplastics, medical waste residues and even pesticide residues from household activities (Marzuki et al., 2020a; Essumang et al., 2009).

The selection of Kodingareng Keke Island as the sampling location was based on the consideration that the island was visited by both domestic and foreign tourists, especially on weekends. The types of samples of fish, sponges, starfish, sediments and seawater around the island are objects that are in direct contact with tourists, so it is feared if these samples are contaminated with hydrocarbon pollutants, especially PAHs, it is considered to have direct or indirect health effects direct.

Types of pollutants that may be exposed to the waters around Kodingareng Keke Island, not only PAHs, but also other pollutants, such as microplastics, pesticide residues, medical waste and others, however PAHs were chosen as the object of research, because of their carcinogenic and mutagenic properties. The toxic nature of these PAHs is important to investigate, because they have an impact on the health of marine ecosystems as well as on humans, so that data and information are needed for the sake of vigilance and prevention of every visitor who does marine tourism on the island.

Models and methods that can be used to prevent and minimize the volume and ecological impact of potential PAH contaminants in the Marine Tourism Area (MTA) of Makassar City, include: (1) the manager of the tourist destination is expected to provide education to the surrounding community and tourists to care about waste properly. do not throw garbage, especially types of plastic waste directly in the MTA area (Marzuki et al., 2017). (2) The MTA area should provide biota-based tourism and a natural atmosphere by planting mangroves at certain points, because mangroves have a dual function apart from being a biofilter of various pollutants, as well as housing that can invite various types of biota and coastal communities to make the mangrove population as a habitat. habitats and shelters that provide a lot of nutrients, even mangroves can bring out a natural view of the MTA area (Fitri et al., 2021; Marzuki et al., 2020b). (3) Availability of data and information about the quality and feasibility of the Makassar City MTA ecosystem, in particular whether it is free from exposure to PAH pollutants and other types of pollutants (Marzuki et al., 2017). This third point is the study material and the purpose of the research.

Experimental

Materials

The materials used are sediment samples, sea water, sponges, fish, Starfish. Each type of sample consists of three kinds obtained at three different stations. Other materials, physiological 0.9% NaCl, N-hexane for GC, Standard PAH 16 mix ASTM (Supelco), Na_2SO_4 pa, NaOH pa, sterile seawater and ethanol.

Equipment

Equipment used, including: Gas Chromatography/Mass Spectrometry (GC/MS) Agilent Technologies 7890A, Set Portable Water Quality AZ 8361, a set of glassware (pyrex), stainless steel mesh filter 5 mm, full box, vacuum pump, pestle and mortar , separating funnel, reflux apparatus set, indicator paper, 200 mesh sieve (Marzuki et al., 2015a). and other equipment which is supporting equipment.

Characterization and Sampling

There were fifteen kinds of samples, all of which were obtained around the waters of Kodingareng Keke Island (KKI), one of the islands included in the MTA. This sample was obtained at three sampling stations around KKI waters with station codes ST 1, ST 2 and ST 3 . respectively.

Seawater conditions at the sampling point (station) and physical characteristics observed at each station, such as sampling coordinates, pH, salinity, TDS, HDL, and others (Table 1 and 2).

Table 1. Sampling point seawater conditions

Sampling station	Coordinate	Salinity (‰)	Depth MSL (m)
ST 1	5°6’38.12376’’ S 119°17’7.76544’’ E	28.3	3.6
ST 2	5°6’11.62476’’ S 119°17’6.06228” E	28.1	4.3
ST 3	5°6’23.55372” 190°20’27.62376” E	27.3	5.1

For fish, starfish and sponge samples, morphological analysis was carried out to determine the type or species of each sample. Sampling was carried out following standard operating sampling procedures (Kamaruddin et al., 2021; Marzuki et al., 2016). Each sample obtained was put in dark plastic, labeled and put in a full box. The average value of seawater salinity at the three sampling stations (27.9), is relatively not much different from one another (Table 1). When compared with the salinity value of other marine waters, it does not show a striking difference (Shimoda et al., 2006). Salinity of sea water is one of the factors in assessing sea water quality, which in general can be said that the quality of sea water around KKI status is good or there is no indication that the waters are contaminated with hazardous materials, such as the main hydrocarbon components of the type of PAHs (Tereza et al., 2018).

Table 2. Physical characteristics of sampling station

Sampling station	Temperature (^{0}C)	pH	HDL (ds/m)	TDS (mg/L)
ST 1	29.4	7.47	14.46	7.41
ST 2	30.9	7.69	14.20	7.21
ST 3	30.3	7.70	12.67	7.50

Physical characteristics of seawater at the sampling station (Table 2), respectively, with the average values of temperature (30.2 ^{0}C), pH (7.62), electrical conductivity (13.78 ds/m), and total dissolved solids (7.37 mg/L).). The value of the seawater physics parameter indicates that the waters around the KKI are in quality status. This means that physically the waters are not indicated to be exposed to harmful pollutants, however, that several types of pollutants in the category of hazardous and toxic materials (PAHs, microplastics, heavy metals, pesticide residues and medical waste) are pollutants that cannot be seen by direct observation (Ye et al., 2022; Baalkhuyur et al., 2018).

The role of KKI Island as one of the marine tourism destinations of Makassar City which is visited by many tourists, so it is necessary to have data on the quality of marine tourism that must be free from contaminants that can interfere with public health (Bayan et al., 2016). The KKI water quality data is needed because of concerns about being polluted by dangerous and toxic pollutants, where the position of KKI is close to pollutant sources such as ports, hospitals, hotels and industries operating along Makassar's Losari beach which is not too far from KKI.

Preparation and Measurement

Sample preparation of sediment, fish, sponges and starfish samples for analysis of the abundance and type of PAH was carried out by reflux extraction method using ethanol to extract all chemical components in the sample. Each sample was cleaned, mashed, and dried in free air until the moisture content was below 7%. Ethanol extraction was then extracted using N-hexane as solvent to separate non-polar components (PAH) (Gemiero et al., 2021; Marzuki et al., 2021d). Running sample of N-hexane extract using GC/MS. The visible chromatograms were analyzed based on retention time, peak number, peak height, abundance and components that were assessed if the percentage of similarity was 90% according to the instrument library. Preparation of seawater samples for analysis of the abundance and types of PAHs was carried out by filtering the seawater samples first, then extracted using ethanol in a 250 mL separating funnel, the ratio of sample to solvent = 1: 2 (Kappler et al., 2018). The ethanol extract was further extracted in a 250 mL separatory funnel using N-hexane as solvent. Extract N-hexane who is running using GC/MS. Note: the addition of sufficient Na_2SO_4 can be done before running using GC/MS, if the sample is said to be contaminated with water components (Hermabessiere et al., 2018).

Result and Discussion

The marine tourism destination of Makassar City presents the diversity of marine life, the beauty of the island, and the culinary menu of various types of fish. This condition is very important to provide information about the quality of sea water and marine biota in the tourist destination area. Morphological identification of marine biota, such as fish and various other types of marine biota, including the quality of sea water itself, needs to be done, because these objects interact a lot with the general public.

Table 3. Morphology marine biota (fish, sponge and starfish) samples based on sampling stations

Sampling station	Fishes	Sponges	Starfish
ST 1	*Pomacentrus Moluccensis*	*Clathria Reinwardtii*	*Holothuria* sp
ST 2	*Chrysiptera Unimaculata*	*Clathria* Sp	*Tridagna* sp
ST 3	*Chromis viridis*	*Plakortis nigra*	*Linckia Laevigata*

The morphology and types of fish, sponge and starfish samples obtained at each station were different (Table 3). This difference occurs because the sampling is done randomly, where the sample acquisition is carried out according to what was found at the time of sampling. The different types of sponge fish and starfish at each sampling station indicate that the area is rich in marine biota populations (Marzuki et al., 2021). It is this diversity of marine life that needs to be maintained and preserved, so that it can be exploited by the community in the long term. One way to preserve the diversity and population of marine biota is to prevent pollution of harmful pollutants such as PAHs, microplastics, medical waste and exposure to heavy metals (Akinde & Iwuozor, 2016).

The types of chemical components identified in the sediment samples at three different stations. The number of hydrocarbon components corresponds to the number of peaks seen at each station, namely ST 1 = 11 components, ST 2 = 12 compounds and ST 3 = 11 hydrocarbon compounds.

Table 4. Types and distribution of PAHs in sediment samples based on sampling stations

Sampling station	Peak number	Retention time (S)	Quality (%)	Abundance (%)	Compound name
ST 1	3	9.168	91	64.312	NL
	5	13.205	96	1.153	PT
	7	15.549	90	2.456	AZ
	9	19.023	91	1.021	PR
ST 2	3	9.167	91	66.021	NL
	6	13.206	97	0.789	PT
	8	16.283	92	0.568	FR
	10	19.024	91	0.324	PR
ST 3	2	9.168	91	63.124	NL
	4	13.205	96	1.345	PT
	7	14.234	92	1.231	AR
	9	19.023	96	1.235	PR

Note: NL = Naphthlene; PT = Phenanthrene; AZ = Azulene
FR = Fluoranthene; AR = Anthracene; PR = Pyrene

A number of these hydrocarbon components identified in the sediment samples at each station consisted of 4 components of the PAH group, according to their respective peak numbers, while the peak numbers that were not listed were non-PAHs hydrocarbon components (Table 4). These data illustrate that these components are non-aromatic hydrocarbon compounds, so they are not listed in the table sequentially (Fang et al., 2020). The types of PAHs identified in the sediment samples, including NL, PT and PR were identified at each station. The AZ component was identified only at ST 1, FR was found at ST 2 and AR was only seen at ST 3 (Table 4). The abundance of FR and AR is also very small, 0.568% for FR and 1.231% for AR respectively (Marzuki et al., 2021a).

Table 5. Types and distribution of PAHs in seawaters samples based on sampling stations

Sampling station	Peak number	Retention time (S)	Quality (%)	Abundance (%)	Compound name
ST 1	2	9.167	91	64.221	NL
	4	11.124	96	1.186	AC
	6	13.206	92	1.643	PT
ST 2	2	9.165	93	63.046	NL
	4	11.125	97	0.978	AC
	5	13.203	86	0.696	PT
ST 3	2	9.167	94	63.237	NL
	4	13.203	91	1.217	PT
	6	14.236	92	0.845	AR

Note: AC = Acenaphthene

The number of hydrocarbon components identified in seawater samples obtained around KKI waters was 7 species, marked by 7 peaks that were visible at each station, however, only three types of hydrocarbon components were included in the PAHs group. Naphthalene (NL) and Phenanthrene (PT) were found at all stations, while Acenaphthene (AC) was identified at ST 1 and 2, while anthracene (AR) was only found at ST 3 (Table 5). Relatively the same data is also shown in Table 6

The type and number of PAHs components that were identified in seawater were less than those identified in sediment samples. This indicates that the properties of aromatic hydrocarbons can accumulate and are difficult to decompose (Table 5). The presence of PAHs in mud is more difficult to degrade than PAHs in seawater (Coban et al., 2000).

Table 6. Types and distribution of PAHs in sponges samples based on sampling stations

Sampling station	Peak number	Retention time (S)	Quality (%)	Abundance (%)	Compound name
ST 1	3	9.168	95	64.872	NL
	5	13.204	93	1.762	PT
	7	15.547	90	2.341	AZ
	10	19.024	91	0.872	PR
ST 2	3	9.169	92	64.897	NL
	6	13.205	93	0.659	PT
	8	14.235	92	1.125	AR
	9	19.205	90	0.987	PR
ST 3	2	9.168	91	63.945	NL
	4	13.205	96	1.204	PT
	6	15.545	96	10.165	AZ
	8	16.283	91	0.698	FR
	10	19.204	91	1.216	PR

The types and abundances of PAHs that were identified in sponge samples were more varied than those in seawater. The number and types of PAHs components in sponges were relatively the same as those in sediments, namely NL PT, and PR types found at all stations, followed by AZ identified at ST 1 and ST 3, while AR and FR PAHs were identified at ST 2, respectively and ST 3 (Table 6). This can occur with the assumption that the habitat and interactions of sponges are more in the sediment, as well as the nutritional pattern of sponges that suck mud (filter feeder) to capture and filter food as nutrients (Bell et al., 2013).

This assumption is reinforced by the ability of sponges to convert carbon into energy, so it is very possible for sponges to have dynamics with sediment as a form of adaptation in maintaining life so that they continue to grow and develop in mud habitats (Orani et al., 2018).

The peaks that appeared in the fish samples were identical to the hydrocarbon components in detail, 5 peaks at ST 1 and 6 peaks at ST 2 and 3. From these peaks, 2 types of PAHs were identified at ST 1, namely NL and AC, at ST. 2 identified 3 types of PAHs, namely NL, AC and PT, while at ST 3 there were NL and PT (Table 7). Based on the types of PAHs that were identified in fish samples at each station, it showed that there were similarities with the PAHs contaminants identified in seawater samples (Table 5.

Table 7. Types and distribution of PAHs in fishes samples based on sampling stations.

Sampling station	Peak number	Retention time (S)	Quality (%)	Abundance (%)	Compound name
ST 1	1	9.167	94	24.221	NL
	3	13.204	92	2.186	AC
ST 2	2	9.168	93	26.046	NL
	4	11.124	91	1.261	AC
	5	13.203	90	0.731	PT
ST 3	2	9.167	93	23.623	NL
	3	13.204	91	2.862	PT

Based on these data, it can be assumed that there is a relationship between fish and seawater. The interaction of fish with seawater is an absolute habitat, because seawater is a place for fish to grow and develop. If the type of pollutant identified in fish has similarities with the type of pollutant in seawater, it should be so and in accordance with theory (Iyer et al., 2013; Okoro, 20110).

Analysis of the abundance and types of PAHs in starfish samples, showed 7 peaks on ST 1, 9 peaks on ST 2 and 8 peaks on ST 3, Further analysis identified only 3 types of PAHs components on ST 1 and 2, while on ST 3 only 2 type. (Table 8). The type of PAHs identified in the starfish samples at each station, namely NL was found at all stations, AC type was identified at ST 1 and 3, PT type was found at ST 1 and 2 and AR was only found at ST 2.

The types and concentrations of PAHs in each sample are detailed sediments, sponges, fish and in seawater in Table 8 and Figure 1.

Table 8. Types and distribution of PAHs in starfish samples based on sampling stations.

Sampling station	Peak number	Retention time (S)	Quality (%)	Abundance (%)	Compound name
ST 1	2	9.167	94	34.325	NL
	4	11.123	92	3.109	AC
	6	13.204	93	5.731	PT
ST 2	2	9.168	92	36.164	NL
	5	13.206	90	3.125	PT
	6	14.235	92	4.896	AR
ST 3	2	9.167	94	33.146	NL
	4	11.125	92	4.892	AC

The findings of the types of PAHs in the 5 types of samples showed that there were similarities between the identified aromatic hydrocarbon pollutants between the types of samples, but it did not necessarily assume that the samples were contaminated with PAHs from the same source (Roy et al., 2018; Nikel et al., 2014). The types of samples of sponges, fish and starfish are different at each sampling station (Table 3), as an indication that the three have different lifestyles and the level of tolerance to PAHs is also relatively different (Liu et al., 2019). Another assumption is that the samples were not entirely exposed to the same type of PAHs as well as the abundance of aromatic compounds found to be different, this indicates that PAHs in the waters around KKI (Freeman et al., 2021).

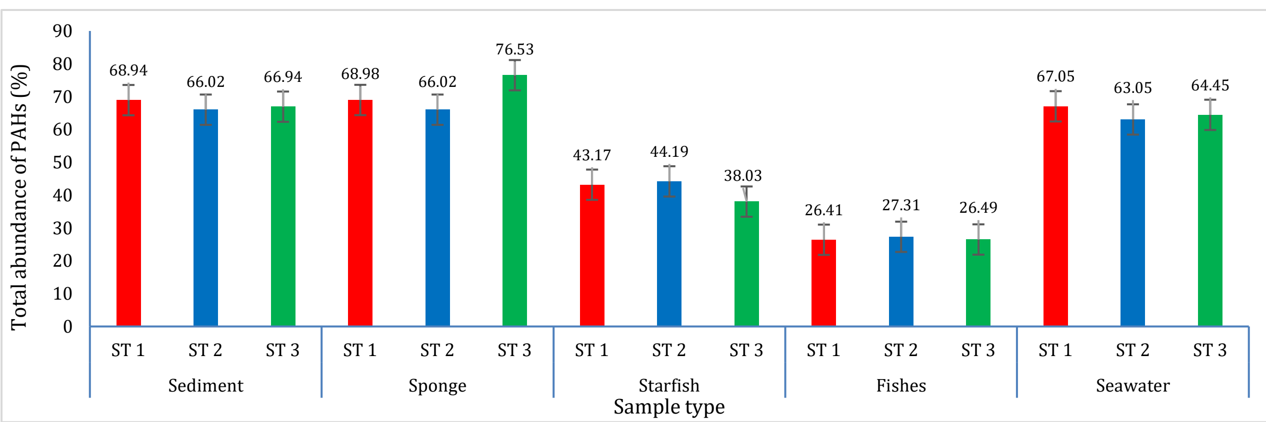

Figure 1. Total abundance of PAHs in each sample type by sampling station

Analysis of the total abundance of PAHs in each sample, showed that the sponge sample at ST 3 was highest and the lowest was in the fish sample at TS 3 (Fig. 1). The highest average percentage of total abundance of PAHs for each sample is sponge sample (70.51%), then sediment (67.30%), followed by seawater sample (64.85%), then starfish sample (41.80 %) and fish samples (26.74%). The highest total abundance of PAHs in sponge samples, both by category per station and based on the total of all sponge samples at all stations.

This result can be interpreted that the lifestyle of sponges with feeder filters allows sponges in the waters around KKI to be exposed to higher levels than other types of samples, although this does not mean that sponges are the biota most affected by PAHs (Marzuki et al., 2021b; Imachi et al., 2011). This is based on the ability of sponges to convert carbon components into energy for use in activities. This also shows that exposure to PAHs in fish, starfish, seawater and other marine biota is a life catastrophe, but for sponges it is a condition in which sponges can survive (Sabota & Swi

2021). Several previous studies have shown that sponges are often used as a reference to determine that a marine area is exposed to PAHs, because sponges can be used as bio-monitoring and bio-indicators of exposure to PAHs (Armus et al., 2021; Bell et al., 2013).

Based on the total abundance identified, it can be said that the naphthalene (NL) component was found in all types of samples at the three stations, followed by pyrene (PR) and Phenanthrene (PT), then azulene (AZ) (Marzuki et al., 2020a). Analysis of the type of PAHs in each sample associated with the source of the aromatic hydrocarbon compounds suggested that for AZ type PAHs it may be from oil spills or petroleum products due to ship transportation, or from tanker washing, where it is known that azulene is a characteristic that is almost always present. on every petroleum and its processed products (Arroyo et al., 2021; Smulek et al., 2020).

Other types of PAHs, such as NL, PR, PT, most likely originate from industrial activities, agricultural activities and household waste. The type of NL is widely used in the production of insect poisons such as camphor, while other types, such as AC, FR and AR are thought to originate from medical activities or medical waste, pesticides, or from various types of waste that decompose in marine waters or may originate from waste burning. or organic material (Del-Mondo et al., 2021).

In terms of the toxic properties of aromatic hydrocarbons, NL PAHs are classified as hazardous and low-toxic, while PT, AC, AR and FR are in the moderately toxic category and PR types are high-toxic PAHs. The finding of several types of PAHs around KKI waters, in the qualitative aspect it is said to be polluted, but in a quantitative review further research is needed to determine whether the area is feasible and safe to visit or not, with reference to the Decree of the Minister of Environment of the Republic of Indonesia No. 51 of 2004, regarding sea water quality standards for PAH, a maximum of 0.003 mg/L (Gusty et al., 2021).

Conclusion

Based on PAHs data on five types of samples obtained at three different stations around the waters of Kodingareng Keke Island, it is concluded in several statements, (1) Sediment, seawater and marine biota (sponges, starfish) are declared polluted by PAHs. (2) The types of PAHs that were identified in each sample in ST 1-3 were dominated by naphthalene (NL), Phenanthrene (PT), pyrene (PR) and azulene (AZ). (3) The order of total abundance of PAHs in each sample is sponge sediment seawater starfish fish. (4) PAHs of the NL type were found in all types of samples and at all stations, where the PAHs were thought to originate from industrial, hospital, and household activities. (5) Further research is needed to determine the concentration of each type of PAHs that have been identified by referring to the Decree of the Minister of Environment RI, No. 51, Year 2004. (6) The status of marine tourism, especially around Kodingareng Keke Island, for tourists, needs to be careful and alert, because the KKI area is not completely free from harmful and toxic pollutants, so it is a health risk.

Conflict of Interest

The authors declare that there is no conflict of interest.

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