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Water Quality Study Based on Meiofauna Abundance and Pollution Index in The Coastal Zone of Losari Beach, Makassar

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ABSTRACT

The coastal zone of Losari Beach is located in a strategic position and rich in potential coastal resources, but the high density of human activities has decreased the quality of the surrounding waters.This study aimed to examine water quality based on meiofauna abundance and pollution index in the coastal zone of Losari Beach, Makassar. It employed a quantitative descriptive approach with purposive sampling method. The identified total meiofauna abundance was117,176 individuals/m2consisting of 138 species from 13 phyla. Ostracoda, olygochaeta, sarcomastigophora, ciliophora, and polychaetawere phyla with the highest abundance because of their high adaptability to polluted aquatic conditions. Meanwhile, tardigrada and aelosomatidaewere found in very low abundance because both phyla only thrive in pollution-free environments and have a pattern of high migration flow from one habitat to another. As for aelosomatidae, the habitat of its speciesis limited to brackish or saline waters. A good-quality aquatic environment is a habitat for all benthic organisms and enables their even distribution. It explains the discovery of true and temporary meiofauna with uniform or even compositions in the bottom of the waters. The waters in the coastal zone of Losari Beach are heavily polluted. The stations located around the traditional Paotere harbor, hotels, restaurants, Losari Beach Platforms, the waste disposal outlets of Stella Maris Hospital, Fort Rotterdam canals, and Jeneberang River mouthhad very high pollution index. Some of these stations had low meiofauna abundance levels, and the poor water quality in their surroundings was caused by anthropogenic activity. Even though the area around TanjungMerdeka Beach had relatively low pollution index, it was categorized as severely contaminated because the index score was >10.

Keywords: Adaptation; anthropogenic activity; water quality; meiofauna; coast of Losari Beach, Makassar

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1. Introduction

The coastal area is the integration of several interconnected ecosystems that contain useful sources of biodiversity for community welfare. Situated adjacent to the mainland, it allows the creation of interactions between aquatic and terrestrial environments. The disposed water after rinsing or washing process transports pollutants generated by domestic activities, hotels, hospitals, industrial estates, and agricultural land are transported by the into drainage channels, canals, and then to the shore. Likewise, other pollutants on land are carried away by rainwater into the canals or rivers that eventually flow to the sea(Dahuri *et al.*, 2008).

The coast of Losari Beach is locatedin Makassar City and has high coastal resource potential, but the intensive human activity and development in the area result in resource depletion and water quality deterioration, which are characterized by the entry of many wastes into the waters. In general, the wastes produced by activities in hotels/restaurants, settlements, hospitals, aquaculture and agricultural sectors, and gold crafting industries are transported through many canals that empty into the beach. As a result, the improper waste disposal decreases water quality as it introduces heavy metals into the waters, namely iron (Fe), lead (Fb), mercury (Hg), and copper (Cu) (Werorilangi *et al.*, 2011; Jaya *et al.*, 2012; Setiawan, 2014).

Meiofauna is one of the benthic organisms that can be used as a bioindicator of polluted water quality. Meiofauna has a microscopic size with a range of 63 μm-1 mm and lives as an infauna and epifauna in the bottom sediment of the water (Gwyther & Fairweather, 2002; Zulkifli, 2008; Giere, 2009). Compared to other benthic organisms, meiofauna as a water quality indicator provides at least five advantages. First of all, it has a high sensitivity to anthropogenic inputs and pollutants that enter a body of water. Second, it has different levels of sensitivity to various types of contaminants and, third,reacts quickly to changes in waters. Fourth, it moves slowly and, therefore, it is very easily influenced by its surrounding circumstances. Also, the fifth advantage is its small size that allows easy capture and identification (Albuquerque *et al.*, 2007; Moreno *et al.*, 2008; Armenteros, 2009; Mirto *et al.*, 2012).

The physical and chemical parameters of waters are control factors that have a direct or indirect influence on the rate of metabolism and proliferation of aquatic organisms. Koropitan *et al.* (2009) state that physical environmental factors play an essential role in metabolic rate and respiration of aquatic biota, which increases the need for dissolved oxygen in waters. This condition shows that the higher the influence of physical factors in a marine environmenttemperature, salinity, and the partial pressure of dissolved gases, the lower the dissolved oxygen level in the water. The same correlation also applies to the chemical parameters that indirectly affect the process of growth and development of aquatic organisms, for instance, the formation of energy and proteins in the cellular metabolic process (Nicholson *et al.*, 2006).

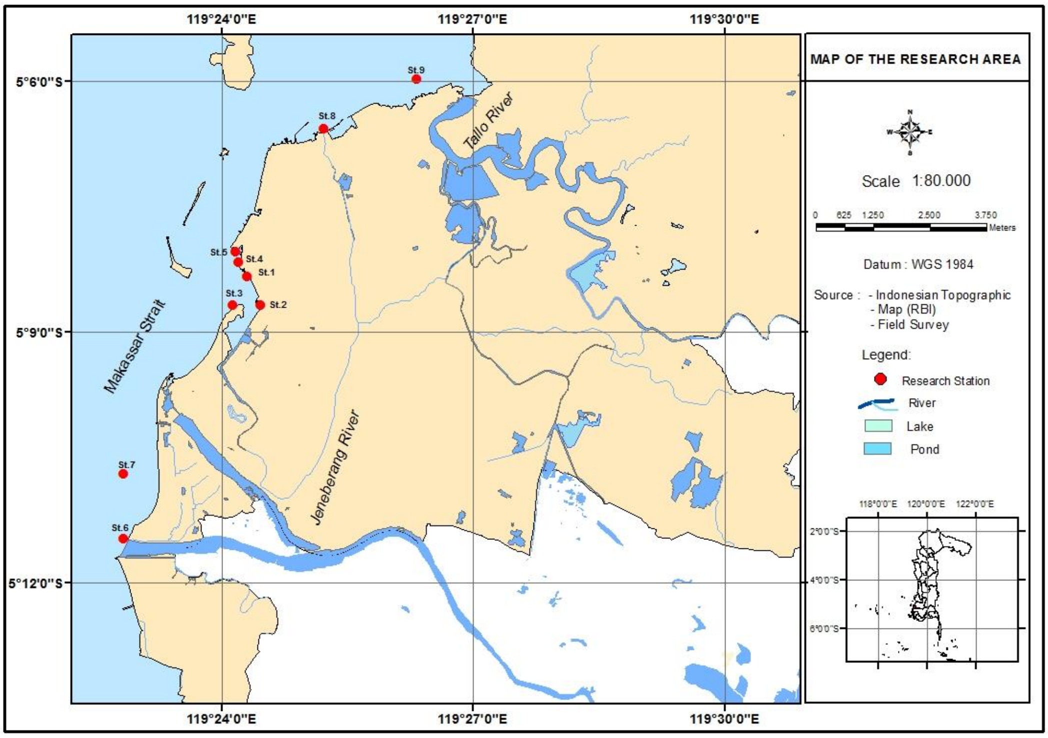

Figure 1. Map of the Research Area

Accordingly, this study aimed to assess water quality based on meiofauna abundance and pollution index in the coastal zone of Losari Beach, Makassar. The study results are expected to provide the local government with valuable information for the management of the coastal areas in Makassar City in an integrated and ecologically sustainable manner.

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2. Research Method

2.1 Research time and location

This research was conducted from November 2017 until January 2018 in the coastal zone of Losari Beach, Makassar (**Figure 1)**. It involved nine (9) observation stations, namely:

1. An observation station nearby a hotel building that was directly adjacent to Losari Beach (S 05°08’19.99”; E 119°24’18.57”)
2. An observation station around the waste disposal outlet of Stella Maris Hospital, settlements, and food stalls or cafes on Losari Beach (S 05°08’40.59”; E 119°24’28.40”)
3. An observation station near to the reclamation project of Losari Beach (S 05°08’40.59”; E 119°24’08.51”)
4. An observation station on the outlet of Fort Rotterdam canals, which function as water channel carrying various types of wastes from domestic activities and gold crafting industries along the road Jalan Somba Upu, Makassar (S 05°08’09.62”; E 119°24’12.32”)
5. An observation station close to Soekarno-Hatta Port (S 05°08’02.43”; E 119°24’10.34”)
6. An observation station on Jeneberang River mouth (S 05°11’28.67”; E 119°22’50.27”)

7. An observation station on TanjungMerdeka Beach (S 05º10'41.98"; E 119º22'50.27")
8. An observation station around Paotere Harbor (S 05º06'34.06"; E 119º25'13.71")
9. An observation station on Tallo River mouth (S 05º05'58.27"; E 119º26'19.84")

2.2 Sampling Method

The meiofauna samples, selected with purposive sampling method, were identified and grouped according to their respective taxa. The identification was performed under a binocular microscope using Higgins and Thiel's book (1988) as a reference. The physical-chemical parameters were measured both in- and ex-situ. The in-situ measurement was conducted at the time of sampling at each observation station, while the ex-situ measurement was carried out by collecting water samples and sediments in sample bottles or plastic seals and storing them in a cool box until further analysis in the laboratory, which employed the method developed by Greenan (1995) and Olsen (1954).

2.3 Statistical Analysis

The meiofauna abundance in the coastal zone of Losari Beach was analyzed using the below formula:

$$K=\frac{10000x\ a}{b} \quad \text{.........................} \quad (1)$$

K : Meiofauna density (individuals/m²; indv./m²)
a : The number of meiofauna(individuals)
b : The opening size of the Ekman Grab (22.5 cm x 22.5 cm)
10,000 : Conversion factor from cm²to m² (Krebs, 1989)

The status of water quality was decided by the Pollution Index, as regulated in the Decree of the Ministry of Environment No. 115 of 2003 on Guidelines for Determining the Status of Water Quality. The Pollution Index is a composite of several water quality parameters. The measure of pollution required the mean value of all C_i/L_{ij}. This value will be dismissed if one of the C_i/L_{ij}values is>1. Accordingly, this index must include the maximum scores of C_i/L_{ij}. If $(C_i/L_{ij})R$and $(C_i/L_{ij})M$ are greater than 1, then the waters for (J) utilization are contaminated. High values of both variables indicate severe water pollution. Therefore, the formula used to determine the level of pollution in the water was as follows,

$$P_{ij}=\sqrt{\frac{\left(C_{i}/L_{ij}\right)^2 M+\left(C_{i}/L_{ij}\right)^2 R}{2}} \quad \text{..............} \quad (2)$$

where:
Lij : The concentrations of the water quality parameters included in the standard for water utilization (J)
Ci : The concentrations of water quality parameters in the field
Pij : Pollution Index for water utilization (J)
(Ci/Lij)R : Mean value of Ci/Lij
(Ci/Lij)M : Maximum value of Ci/Lij

Table 1 presents the criteria of pollution based on the Decree of the Ministry of Environment in 2003.

Table 1. Pollution Criteria (KEP-MENLH./115/2003)

Pollution Index	Criteria
$0<P_{ij}<1.0$	Within the water quality standards
$1.0<P_{ij}<5.0$	Low pollution
$5.0<P_{ij}<10$	Moderate pollution
$P_{ij}>10$	High pollution

3. Results and Discussion

3.1 Meiofauna abundance in the coastal zone of Losari Beach, Makassar

The results showed that the total meiofauna abundance in the coastal zone of Losari Beach was 117,176 indv./m², comprising 138 genera and species from 13 phyla (**Table 2**). Ostracoda, olygochaeta, sarcomastigophora, ciliophora, and polychaeta were phyla with the highest abundance in the study area, whereas tardigrada and aelosomatidae had the lowest abundance.In ascending order, the abundance of interstitial meiofauna was ostracoda (51.955 indv./m²), olygochaeta (38.067 indv./m²), sarcomastigophora (6.903 indv./m²), ciliophora (4.932 indv./m²), polychaeta (4.828 indv./m²), turbelaria (2.933 indv./m²), tunicata (2.905 indv./m²), nematoda (2.787 indv./m²), gastroicha (734 indv./m²), nemertina (575 indv./m²), gnathostomulida (398 indv./m²), aelosomatidae (139 indv./m²), dan tardigrada (20 indv./m²) (**Figure 2** and **Table 2**).

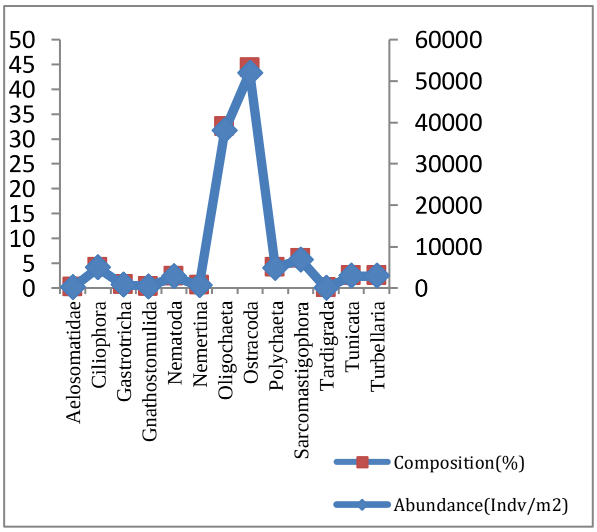

Figure 2. The graph of meiofauna abundance and composition in the coastal zone of Losari Beach, Makassar

In general, the type of meiofauna identified in the study area was classified as a true meiofauna. This species spends its entire life in the category of meiofauna size and lives in the bottom of waters (permanent meiofauna). The identified meiofauna were members of olygochaeta, ostracoda, sarcomastigophora, polychaeta, turbelaria, nematoda, gastroicha, gnathostomulida, tardigrada, andaelosomatidae. Meanwhile, the study also found temporary meiofauna belonging to two phyla, namely nemertina and tunicata. Temporary meiofauna spend only part of their life in meiofauna size. The benthic organisms are classified as meiofauna only during a stage of larvae or juvenile but as macrozoobenthos when they reach the stage of adults where they grow int o macro size (Arroyo *et al.*, 2004; Nybakken & Bertness, 2005). A stable, good water quality creates an aquatic habitat for all benthic organisms that are evenly distributed in the bottom of the water, i.e., the true and temporary meiofauna exist with a uniform or even composition in the bottom of the sea.

Table 2. Meiofauna abundance at the nine observation stations in the coastal zone of Losari Beach, Makassar

No	Phyla	Abundance (indv./m^2)									
		St. 1	St. 2	St. 3	St. 4	St.5	St.6	St. 7	St.8	St. 9	Total
1	Aelosomatidae	0	40	99	0	0	0	0	0	0	139
2	Ciliophora	613	653	278	693	278	337	377	752	951	4932
3	Gastrotricha	159	0	178	0	20	79	80	0	218	734
4	Gnathostomulida	0	20	119	0	0	20	0	80	159	398
5	Nematoda	909	0	850	376	178	0	0	0	474	2787
6	Nemertina	20	20	99	0	0	159	79	0	198	575
7	Oligochaeta	732	2154	4246	3280	1365	7307	5510	6321	7152	38067
8	Ostracoda	9229	4055	1347	3265	1783	10732	10336	5434	5774	51955
9	Polychaeta	554	79	1226	357	257	692	60	870	733	4828
10	Sarcomastigophora	1739	1404	1187	278	633	218	751	317	376	6903
11	Tardigrada	0	0	20	0	0	0	0	0	0	20
12	Tunicata	0	20	1284	1047	158	79	40	0	277	2905
13	Turbelaria	317	1502	60	40	219	159	178	378	80	2933
	Total	14272	9947	10993	9336	4891	19782	17411	14152	16392	117176

Ostracoda, olygochaeta, sarcomastigophora, ciliophora, and polychaeta were the most abundant phyla in the study area. It is caused by their high adaptability to aquatic environments that are contaminatedby organic and inorganic materials or particles in the bed sediments. This is confirmed by data on organic matter during by study does not meet the requirements based on government regulations (Decree of the Ministry of Environment No. 115 of 2003 on Guidelines for Determining the Status of Water Quality). Ostracoda can withstand extreme environmental conditions by sticking to benthic plants, sands, or other substrates using an attachment device called adhesive threads, while the in fauna species (habitats under aquatic sediments) usually take shelter under the substrate by making long burrows (Hartmann, 1985; Mirto *et al.*, 2012). As for olygochaeta, this phylum can adapt to polluted aquatic environments using its lean body and adhesive glands. It can also adjust to oxygen-deficient habitats because it develops rigid body shapes with a large number of small setae (Giere & Pfannkuche, 1982). The results of oxygen measurements during by study indicate these environmental parameters do not meet the requirements based on government regulations (Decree of the Ministry of Environment No. 115 of 2003 on Guidelines for Determining the Status of Water Quality).

The high adaptability is also owned by the phylum sarcomastigophora because it tends to thrive in soft substrate that contains high organic matter. The species in this phylum spend all of its entire life in the substrate at the bottom of waters as infauna or epifauna and, with the help of pseudopodia or some of their flagella, develop a high adaptive capacity to unfavorable environments (Giere 2009).

Ciliophora and polychaeta also had relatively high abundance although their composition was not as large as that of ostracoda, olygochaeta, and sarcomastigophora.

Ciliophora is a metazoan that has cilia on parts or all of its body, which function as organs that assist in the motility to search for food and adapt toharsh environments. This phylum is phagotrophic and holozoic, i.e., organisms that eat organic particles available at the bottom of the water to provide all their nutritional needs by involving vesicular internalization of solid or liquid particles. Also, it can adapt to contaminated areas by forming cysts on the walls of its body in anticipation of anaerobic conditions (lack of oxygen) in the aquatic environment (Corliss, 1972; Fenchel, 1987; Rossi *et al.*, 2001; Arroyo *et al.*, 2004).

Polychaeta has a high level of adaptation to muddy habitats that contain highly contaminated particles or materials. The species have a thin body with cilia covering all of its surfaces, and since their body has no segments, they can perfectly move in muddy habitats. Several highly adaptable phyla identified in the coastal zone of Losari Beach can proliferate despite the unfavorable environmental conditions because they regenerate through parthenogenesis, hermaphrodite, binner cleavage, fission, and budding systems (Giere, 2009; Zulkifli, 2008).

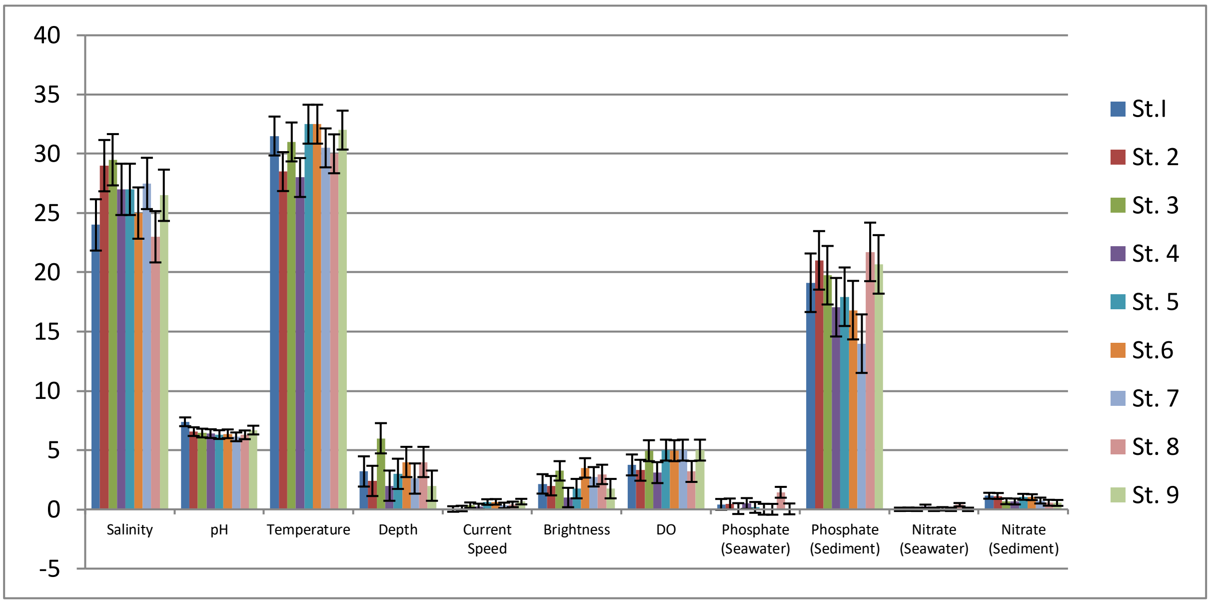

Figure 3. The standard deviation of physical and chemical parameters of meiofauna environments in the coastal zone of Losari Beach, Makassar

Tardigrada and aelosomatidae existed with low abundance in the study area. In general, tardigrada lives in clean and sandy habitats, on the surface of aquatic sediments (epibenthic) or interstitiallyi.e., live between the bed sediments. Tardigrada move actively in the bottom of the water and form high migration patterns from one habitat to another. Therefore, the very low abundance of this metazoan in the contaminated study area is natural. Although most species of meiofauna live in freshwater habitats, such as lakes, ponds, swamps, and rivers, aelosomatidae is found in limited number in brackish to saline waters (estuarine and coastal ecosystems)(Bunke, 1985; Moreno *et al.*, 2011).

The highest abundance was found at Stations 6, 7, and 9, which were located in Jeneberang River Mouth, Tanjung Merdeka Beach, and Tallo River mouth, respectively. Jeneberang and Tallo are two rivers that flank the coast of Makassar City to the south and north and flow directly into the coastal area of Losari Beach. The accumulation of organic or inorganic particles in the low-lying area transported by currents or rainwater into Jeneberang and Tallo that empty into the sea. These particles then provide a potential source of food for meiofauna at Stations 6 and 9. Contaminants entering the research station are wastes from industrial estates, tourism sites, traditional markets, settlements, slaughterhouses, agricultural and aquaculture area (e.g., pesticideand manure residues), and the use of detergents upstream. All of these can be converted into nutrients for meiofauna and, therefore, trigger an increase in growth and abundance at Stations 6 and 9. This finding is in line with Rossi *et al.* (2001), which state that meiofauna has great adaptability to water conditions that contain high organic particles.

Station 7 on Tanjung Merdeka Beach also represents one of the tourist attractions in Makassar City. Several supporting facilities for tourists have been developed in this site, e.g., villas, lodgings and accommodationwith simple to luxurious facilities, semi-permanent buildings for relaxing on the beach, and cafes or food stalls. The construction activities majorly contribute to the entry of organic wastes into the surrounding waters and are the cause of the high abundance of meiofauna in this region. According to Monoarfa (2002), the development around Losari can affect water quality and constrain the distribution and composition of organisms, allowing the dominance of a group of small organisms that can adapt to polluted environments.

Station 5 had very low abundance. It was located around the Soekarno-Hatta Port, Makassar, which is the largest port in the eastern part of Indonesia. This observation station was characterized by intensive human activities and busy port traffic. Meiofauna was found with low abundance in this region because the marine transportation involves ships and other vehicles equipped with turbines or propellers that destroy the habitat of meiofauna in the bottom of the water. Moreover, the expansion of the port areas dredges and damages the bottom sediments. Stations 2,4, and 8 were, respectively, located close to the waste disposal outlet of Stella Maris Hospital, the traditional Paotere Harbor, and the outlet of Fort Rotterdam canals functioning as water channel that transported various types of waste from domestic activities, house-scale industries, cafes or restaurants, and gold crafting industries along the road, i.e., Jalan Somba Upu, Makassar.

Meiofauna was also found at low level at these stations because their life cycle was disrupted by the presence of wastes containing hazardous metallic compoundsmercury (Hg), lead (Pb), copper (Cu), and cadmium (Cd) generated from gold crafting and other anthropogenic activities located along this road. The risk of further pollution may increase as this road now becomes the most prominent center for gold jewelry trade in the eastern part of Indonesia. Numerous studies suggest that the coastal area of Losari Beachis contaminated with hazardous metals, such as lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), mercury (Hg), and arsenic (As). The pattern shows that these dangerous components are spread from the south to the north of Makassar City, specifically starting from Jeneberang River mouth to Tallo River mouth (Werorilangi *et al.*, 2011; Jaya *et al.*, 2012; Setiawan, 2014).

3.2 Physical and chemical environmental parameters in the coastal zone of Losari Beach, Makassar

Table 3. The numerical values of the physical and chemical environmental parameters at each observation station.

Parameters	Stations									*max. Limit
	I	2	3	4	5	6	7	8	9	
Salinity	24	29	29.5	27	27	25	27.5	23	26.5	33-35 ‰
pH	7.39	6.56	6.44	6.39	6.31	6.375	6.12	6.29	6.69	7-8.5
Temperature	31.5	28.5	31	28	32.5	32.5	30.5	30	32	28-32 ^oC
Current Speed	0.03	0.074	0.35	0.25	0.62	0.635	0.335	0.42	0.655	0.1-0.9 m/s
Brightness	2.15	2	3.25	1	1.75	3.5	2.75	2.95	1.75	>3 m
DO	3.75	3.3	4.95	3.1	5	4.95	5	3.2	5	>5 mg/L
Phosphate (seawater)	0.42	0.46	0.066	0.495	0.1665	0.012	0.006	1.44	0.0412	0.015 mg/L
Phosphate (sediment)	19.12	21.01	19.755	17.055	17.94	16.81	13.98	21.725	20.67	0.015 mg/L
Nitrate (seawater)	0.0042	0.0116	0.0027	0.25755	0.0032	0.0461	0.0041	0.3905	0.00235	0.008 mg/L

The measurement results showed that some of the physical and chemical parameters were not meet requirements the threshold defined by the Government of the Republic of Indonesia in the Decree of the Ministry of Environment No. 115 of 2003 (**Table 3**). The graph and the range of standard deviation of the parameter scores in each station are presented in **Figure 3.**

Table 3 and **Figure 3** show that some parameters such as salinity, pH, brightness, and DO are not meet requirements the predetermined thresholds, likewise the phosphate and nitrate contents are not meet requirements their allowed presence in seawater and sediments. The range of the standard deviation for all parameters at the nine research stations was 0.142-2.469salinity (2.165), pH (0.368), temperature (1.641), depth (1.275), current s peed (0.233), brightness (0.818), DO (0.883), phosphate-seawater (0.456), phosphate-sediment (0.469), nitrate-seawater (0.142), and nitrate-sediment (0.248).

The salinity was low because some of the research sites were located near to river mouths and canals, i.e., waste disposal outlets, connecting the mainland with the coastal area of Losari Beach. This finding supports Hamuna *et al.* (2018), which claim that low salinity is caused by the supply of fresh water carried by a river that empties into the beach or sea. The low range of pH is potentially caused by the influence of biotic and abiotic parameters in waters like the photosynthetic activity of marine biota and water temperature and salinity. Alkaline and acidic waters are hazardous for aquatic biota because these conditions interfere with their physiological function, i.e., disturbances in cellular metabolism and respiration (Silalahi *et al.*, 2017). The pollutants also made the DO in this study lower than the good quality standard. According to Kadim *et al.* (2018), DO is related to the level of pollution and the types of organic and inorganic wastes that have entered the waters.

Contrary to the salinity, pH, brightness, and DO, the phosphate and nitrate contents in seawater were mostly far above the threshold. This situation is extremely dangerousfor the life of biota inhabiting the waters because it can trigger the enrichment of aquatic nutrients (eutrophication), which then stimulates the rapid growth of algae and other aquatic plants. This condition is exacerbated by the decreasing DO content of the marine environment (Effendi, 2003).

Various human activities around Losari Beach are the leading cause of phosphate and nitrate in seawaters exceeding the maximum threshold. The activities in the mainland produce domestic, industrial, and agricultural wastes, which are untreated and then enter terrestrial waterschannels, canals, and riversbefore eventually flow into the sea. This condition is in line with Hamuna *et al.* (2018), which correlate high phosphate concentrations with intensive human activities that introduce domestic, industrial, and agricultural (farm, animal husbandry, and plantation) wastes into the water.

3.4 The pollution index of the physical and chemical parameters of the aquatic environment in the coastal area of Losari Beach, Makassar

The calculation of the Pollution Index refers to the physical and chemical parameters of the aquatic environment represented by some of the observation stations. The parameters are salinity, temperature, pH, current speed, brightness, DO, phosphate-seawater, phosphate-sediment, nitrate-seawater, and nitrate-sediment. The range of the pollution indices is presented in **Table 4** and **Figure 4.**

Based on **Table 4** and **Figure 4**, the pollution index scores range between 11.518 and 12.556. Because this range is (Pij)>10, it indicates that the waters represented by all observation station s in the coastal zone of Losari Beach, Makassar are heavily polluted (Decree of the Ministry of Environment No. 51 of 2004). This finding agrees with Maricar *et al.* (2015), which found that the seawater in Losari Beach fell into the category 'polluted' and that the lead metal content (PB) was above the legal threshold and the salinity was below it.

Station 8 had the highest pollution index, while Station 7 was categorically the lowest. Station 8 was close to Paotere Harbor, and the activities within and around it were very likely to disturb the water quality. Aside from the many fishing boats that were moored to the pier, this harbor was also the house of busy fish auction centers, traditional markets, slums, densely populated housing, and the outlets of Paotere and Panampu Canal that accommodated the disposal of wastes from gold crafting and other industries in the north of Makassar City. All anthropogenic activities are the main causes of poor water quality, i.e., high pollution index and low abundance of benthic (meiofauna) organisms.

Table 4. The Pollution Index (NIP) scores of the physical and chemical environmental parameters in the coastal zone of Losari Beach

Stations	Pollution Index Scores (Pij)	Criteria
1	12,232	High Pollution
2	12,311	High Pollution
3	12,088	High Pollution
4	12,126	High Pollution
5	12,110	High Pollution
6	12,009	High Pollution
7	11,518	High Pollution
8	12,556	High Pollution
9	12,129	High Pollution

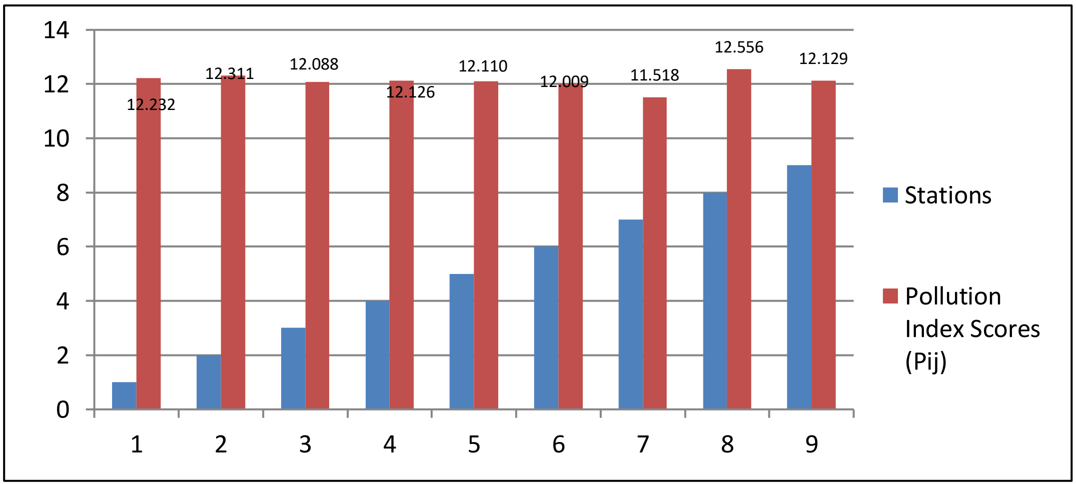

Figure 4. The graph of the pollution index of the physical and chemical environmental parameter coastal zone of Losari Beach

Stations 1, 2, 4, and 9 also had high pollution index values. These stations represented areas occupied by hotel buildings, restaurants, food stalls, tourist attractions, Losari Beach

Platform, the waste disposal outlet of Stella Maris Hospital, the Fort Rotterdam Canalthe outlets for wastes disposed of different types of industrial and domestic activities in Makassar City and Jeneberang River m outh. These human activities are the cause of the high pollution index in the coastal zone of Losari Beach, Makassar.

In comparison with the other observation stations, Station 7 had the lowest pollution index. It represented the surroundings of Tanjung Merdeka Beach, one of the beach resorts in Makassar City. Despite its relatively low pollution index, this area was categorized as heavily polluted because the pollution index was above 10 (i.e., 11.518). The beach is surrounded with many lodgings, hotels, food stalls, and restaurants.

4. Conclusions and Recommendations

Ostracoda, olygochaeta, sarcomastigophora, ciliophora, and polychaeta were the meiofauna phyla that had the highest abundance. Some of them have high adaptability to aquatic environments that are contaminated with organic and inorganic particlesor materials accumulating in the bed sediments of the waters.

Tardigrada and aelosomatidae were found with very low abundance. These phyla tend to inhabit pollutant-free sandy substrates as they live interstitially at the bottom of the waters. Also, tardigrada can move in sediments actively, creating a pattern of high migration from one habitat to another. Although most species of meiofauna live in freshwater, aelosomatidaeis found in limited number in brackish to saline water.

A good-quality aquatic environment provides a habitat for all benthic organisms with even distribution, i.e., the true and temporary meiofauna can be found in a uniform or even composition at the bottom of the water. Therefore, an integrated and sustainable coastal area management in Losari Beach, Makassar becomes necessary.

The condition of the waters in the coastal zone of Losari Beach is heavily polluted, as evident in the mean value of pollution index, (Pij)> 10. Station 8 represents areas with very high pollution index due to the activities in the traditional Paotere Harbor where many fishing boats are moored, and busy fish auction centers and traditional markets take place. Its surroundings are also used for slums and densely populated housing, as well as the outlets of Paotere and Panampu Canals that accommodate the disposal of domestic and industrial wastes in the north of Makassar City. The poor water quality at Station 8 was also marked by a rather low abundance of meiofauna.

The research location around Tanjung Merdeka Beach (Station 7) had the lowest pollution index. However, since the index was higher than 10, the represented water body was also categorized as heavily polluted. Tanjung Merdeka Beach is one of the beach resorts in Makassar City that is crowded with local tourists.

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