

Abundance of Meiofauna and Physical-Chemical Parameters as Water Quality Indicator

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Abstract

The zone of Losari Coast is an icon of Makassar city, however increase activity of surrounding communities causes a decrease in the water quality. Meiofauna is an effective benthic organism used as an indicator of water quality. This study assessed the meiofauna abundance and physical-chemical parameters as water quality indicator in the Losari Coast, Makassar. The sampling method in this study was purposive sampling. The results showed that total meiofauna abundance identified was 66791 indiv.m⁻², composed of 12 phylum and 91 species or genera. Stations at the estuary of the Jeneberang and Tallo River are two sites with high level of abundance, this condition allows presence of organic contaminants triggers the high growth of meiofauna in these locations. Dissolved Oxygen is below its supposed level in waters. Acidity, phosphate and nitrate content at some of research stations exceed the threshold of their allowed presence in waters set by Indonesia government. Ostracoda, oligochaeta, polychaeta, tunicata and ciliophora are phylums with a high level of abundance, because the phylum has high adaptability to pollutant. Good water quality is indicated by a variety of biota living in the waters, the range of diversity and uniformity indices shows that meiofauna species are categorized highly diverse and evenly distributed. The dominance index shows that there is no species was dominant, except stations around Losari reclamation project. Temperature, current velocity, depth, brightness, salinity, pH, DO, nitrate-seawater, and phosphate-seawater correlate with meiofauna abundance. The results as a consideration for the management or monitoring of coastal environments.

Keywords: abundance, water indicator, Losari coast, meiofauna, pollutant

Introduction

Coastal areas store an enormous amount of biodiversity and, therefore, require preservation, as a result of the integration of several interconnected, dynamic, and productive ecosystems. The aquatic resources are parts of the natural resources that are most widely used by the community. However, the exploitation remains to be neglectful of their sustainability, reducing their functions and qualities in the environment. The pollutants that directly or indirectly enter the coastal area endanger not only the lives of all biota but also the entire natural resources of coastal ecosystems, for instance, the threats of degradations of mangroves, seagrasses, coral reefs, and aquatic animals (Elyazar *et al.*, 2007; Dahuri *et al.*, 2008).

The coastal zone of Losari Beach is one of the coastal areas in South Sulawesi that have great potential coastal and marine resources. Increased human activity or development in its surroundings

deteriorates its condition to the threshold of alarming depletion of resource and ecosystem (Coremap, 2006). Some environmental parameters, e.g., physical and chemical characteristics, change slowly towards the negative category. Several studies show that the contents of dissolved heavy metals, namely lead (Pb), copper (Cu) and cadmium (Cd), have slowly exceeded the water quality standard and categorized the waters as polluted (Monoarfa, 2002; Werorilangi *et al.*, 2011; Jaya *et al.*, 2012; Setiawan, 2014).

A series of human activities upstream, such as house-scale and gold-crafting industries, densely populated housing, the constructions of hotels, restaurants, and cafes, tourist activities, hospitals, aquaculture, and agricultural practices, is the main cause of the entry of pollutants into the waters. It greatly affects water quality and threatens the existence of organisms that live on and under the water surface. Aquatic physical-chemical parameters are control factors that have direct or indirect

influence on the speed of metabolic rate and the aquatic organisms proliferation. Koropitan *et al.* (2009) stated that environmental physical factors has an important role in the speed of metabolic rate and respiration of aquatic biota so that need to dissolved oxygen gas is increasing. This shows that higher the influence of physical factors in the aquatic environment such as temperature, salinity, and the partial pressure of dissolved gases, therefore the dissolved oxygen value decreases in water. Likewise with aquatic chemical parameters that indirectly affect the process of aquatic organisms growth and development, such as in terms of the formation of energy and proteins in cell metabolic processes (Nicholson *et al.*, 2006).

In general, aquatic biota that can indicate water quality is benthic organisms, which are a community of microscopic to macroscopic invertebrates. This community lives and remains in seafloor environment for a long time. The use of benthic animals in water quality assessment is more effective and efficient, and it can function as a comparative data to the measurement of the physical and chemical characteristics of an aquatic environment (Arroyo *et al.*, 2004; Hariyati, 2007; Armenteros *et al.*, 2009; Giere, 2009; Riena *et al.*, 2012; Assy *et al.*, 2013; Pratomo *et al.*, 2013; Septiani *et al.*, 2013).

A benthic animal that can effectively indicate water pollution is meiofauna. Meiofauna defines a collection of organisms larger than microfauna but smaller than macrofauna. With a size range of 63-1,000 μm , these organisms can pass through a 1-mm mesh, but they are retained by a 45- μm mesh (Moodley *et al.*, 2000; Montagna *et al.*, 2002; Gwyther & Fairweather, 2002; Gwyther, 2003; Giere,

2009). Meiofauna is a biological component that can be used as an indicator of changes in water quality. There are some advantages of using it as a water quality bioindicator, namely: (1) this community of organisms has different sensitivity to various types of pollutants and provides a quick reaction to changes in waters; (2) due to its low mobility, it is easily influenced by the state of its surrounding environment; and (3) it is easy to capture and identify (Giere, 2009; Moreno *et al.*, 2011; Mirto *et al.*, 2012; Alves *et al.*, 2013). Therefore, this study aims to assess the abundance of meiofauna and environmental physical-chemical parameters as water quality indicator at Losari coast, Makassar.

Materials and Methods

The study was carried out in July-October 2017 at Losari coast, which stretches from the north to the south of Makassar City, South Sulawesi. This area represents the intensive human activity and development in the surrounding environment. Nine (9) sampling sites were located nearby tourist attraction areas, hotels, beach reclamation projects, aquaculture practices, agricultural land in the upper part of the river, hospitals, ports, industrial areas, house-scale industries, and densely populated housing. See Figure 1.

This study employed purposive sampling method, *i.e.*, the selection of samples based on specific objectives, on the aquatic substrate as the habitat of meiofauna. The study area was determined based on the previous research that described the Losari coast as an area contaminated by hazardous chemicals and metal contents.

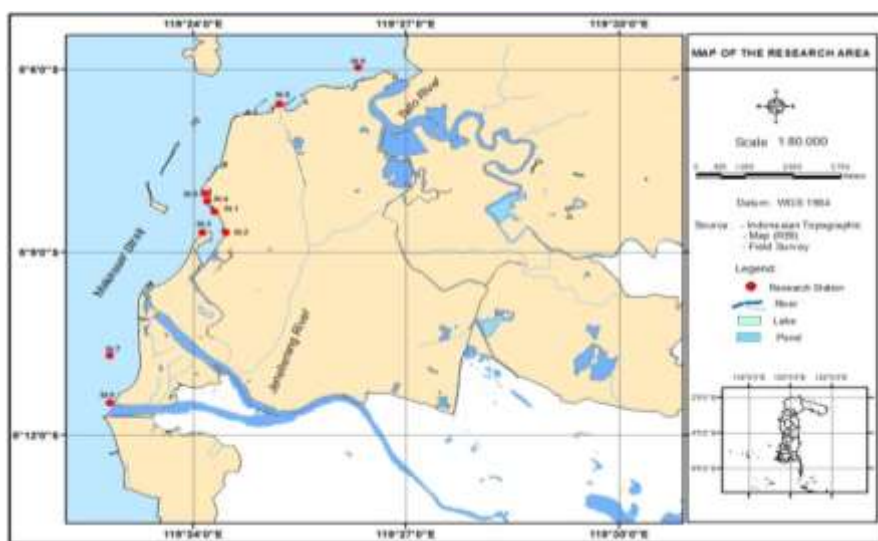


Figure 1. Map of sampling sites at Losari coast of Makassar City, South Sulawesi, Indonesia

The density of meiofauna on the Losari Coast was determined using formula by Krebs (1989). The diversity index in a community was calculated using the Shannon-Wiener's Index (Odum, 1994). Diversity Index can identify the extent of water pollution or determine the water quality of an area or region. Water quality classification based on the diversity index (Odum, 1994). The Dominance Index was measured with the formula of the Simpson's Index of Dominance (Krebs, 1989). Uniformity or evenness index was calculated using the formula of the Hill's Evenness Index (Krebs, 1989).

One-way ANOVA was applied which is aimed to examine the significant differences in the abundance of meiofauna at the research stations (Mirto *et al.*, 2012). Tukeys test was done following those that significantly different. Principal Component Analysis determined the abiotic variables (*i.e.* physical and chemical parameters) that affected the abundance of meiofauna.

Results and Discussion

Abundance and composition of meiofauna

Total meiofauna abundance discovered during the research was 66,791 indv.m^{-2} , consisting of 91 species or genera from 12 phyla (Figure 2 and Table 1.). Station I had a total meiofauna abundance of 3,209 indv.m^{-2} , while Station II, III, and IV had 3,185 indv.m^{-2} ; 4,746 indv.m^{-2} ; and 5,100 indv.m^{-2} , respectively. Station V had the lowest meiofauna abundance, *i.e.* 2,415 indv.m^{-2} , whereas Station VI had the highest one, *i.e.* 16,239 indv.m^{-2} . As for the remaining Station VII, VIII, and IX, the total meiofauna abundances were 10,909 indv.m^{-2} ; 10,118 indv.m^{-2} ; and 10,870 indv.m^{-2} , respectively. Based on the phylum, the total meiofauna abundance was as follows: Aelosomatidae (40 indv.m^{-2}), Ciliophora (1,902 indv.m^{-2}), Gastrotricha (555 indv.m^{-2}), Gnathostomulida (258 indv.m^{-2}), Nematoda (751 indv.m^{-2}), Nemertina (456 indv.m^{-2}), Oligochaeta (25,562 indv.m^{-2}), Ostracoda (31,945 indv.m^{-2}), Polychaeta (1,286 indv.m^{-2}), Sarcomastigophora (595 indv.m^{-2}), Tunicata (2,905 indv.m^{-2}), and Turbellaria (536 indv.m^{-2}). In numerical order, the composition of the density of meiofauna was as follows: Ostracoda (47.828%), Oligochaeta (38.272%), Tunicata (4.349%), Ciliophora (2.848%), Polychaeta (1.925%), Nematoda (1.124%), Sarcomastigophora (0.891%), Gastrotricha (0.831%), Turbellaria (0.8309%), Nemertina (0.683%), Gnathostomulida (0.386%), and Aelosomatidae (0.060%) (Figure 2. and 3.).

The highest abundance was found at Stations VI, VII, and IX, while the lowest one was identified at

Stations V and II. Compared with other phyla, Ostracoda, Oligochaeta, Ciliophora, and Tunicata had a high density, whereas Aelosomatidae had a low density. There was a significant difference in the average abundance of meiofauna in several research stations, as evident from $F= 7.584$ and $P= 0.00$. These results showed that the abundance of meiofauna phylum in every station was significantly different from each other or, in other words, without similarities. Tukey's test resulted in three groups of meiofauna inhabiting the Losari coast (Table 2. and 3.). The results of the one-way ANOVA affirmed the differences in the densities of meiofauna phylum at each station.

In general, Losari Beach is inhabited by true meiofauna, which is benthic organisms whose entire life cycle are in the form of meiofauna living at the bottom of the waters (permanent meiofauna). Ostracoda, Oligochaeta, and Ciliophora can adapt to habitats containing the accumulation of organic and inorganic contents from the nearby land and aquatic environment. These phyla can live in a variety of habitat conditions, such as muddy environments or surfaces covered with fine sand or coarse sand. Ciliophora has cilia covering some or all parts of its body as an organ that helps its movement to find food or adapt to an unfavorable environment. In a polluted environment, Oligochaeta is equipped with cysts on the walls of its body to anticipate anaerobic conditions (lack of oxygen) at the bottom of waters. Meanwhile, Ostracoda has adhesive threads to attach its body to benthic plants, sands, or other substrates (Giere and Pfannkuche, 1982; Hartmann, 1985; Rodriguez *et al.*, 2001).

Some of the meiofauna have slender bodies and adhesive glands. Oligochaeta can even adapt to oxygen-deficient habitats using its rigid body shape with a few but large setae. The reproduction rates of Ostracoda, Oligochaeta, and Ciliophora are also high even in unfavorable environmental conditions. They can anticipate such adversities because they are hermaphrodite, bisexual, and even parthenogenic, *i.e.*, asexual reproduction without the fertilization of two different sexes. Ciliophora can also regenerate by binary fission, *i.e.* direct division of the nucleic cells of the body to give rise to two cells without the fertilization of two entities with different sexes (Corliss, 1972; Fenchel, 1987; Higgins and Thiel, 1988). Tunicata can adapt to an unfavorable environment by simplifying its internal organs to a very small shape and hermaphroditic form (*i.e.*, having multiple sex cells for reproduction). The small gonadal sex is always carried on the lower side of the body until it becomes mature and develops into new individuals at any time (Higgins and Thiel, 1988; Mirto *et al.*, 2012).

Stations VI, VII, and IX represent the conditions in Jeneberang and Tallo Rivers estuaries that flow directly to the Losari coast. Stations VI and IX have a high abundance of meiofauna because organic pollutants, which trigger the high growth rate of meiofauna, are transported by both rivers and washed out by rainwater from the low-lying areas to the river mouth. The same case applies to Station VII, which illustrates the condition of Tanjung Merdeka Beach as the tourist attractions in Makassar City. This area is crowded with local tourists during the holidays and even on weekdays. The constructions of tourist-supporting facilities on and around the beach, such as villas, lodges with simple to luxurious amenities, semi-permanent buildings for recreation or rest, and cafes and food stalls, have started. The development at the tourism sites also plays a major role in the entry of organic wastes into the surrounding waters. These particles can cause a high abundance of meiofauna in this region.

Station V has a very low level of abundance. It illustrates the areas around Soekarno-Hatta Port, Makassar, which is the largest port in the eastern part of Indonesia. It is characterized by intensive development activities, busy maritime traffic, and port renovation to welcome the Indonesian government's Sea Toll Road Program. Station II also has a low abundance of meiofauna. It typifies the

conditions nearby the hotels, restaurants, cafes, hospitals, house-scale industries, and handicraft and gold-crafting industries. These anthropogenic activities introduce inorganic wastes, e.g., hazardous metals, to the surrounding waters and cause a fatal impact on the growth of aquatic organism (Monoarfa, 2002; Werorilangi et al., 2011; Jaya et al., 2012; Setiawan, 2014).

Dominance, diversity and evenness indices

The dominance index of meiofauna in all stations ranged from 0.0507 to 0.1178 with an average of 0.0746±0.0217. This range is close to 0, indicating the absence of dominant meiofauna species at each station. As for the diversity index, it ranged from 2.2653 to 3.0992 with an average of 2.8824±0.2009. These figures represent the high diversity of the community of meiofauna inhabiting the research stations (Odum, 1994). A high diversity means that the meiofauna can adapt to disturbed and polluted environments caused by the entry of contaminants from the surrounding land or environment (Coull et al., 1992; Albuquerque et al., 2007).

The evenness index varied between 0.7860 and 0.9459 with an average of 0.8673±0.0439. These index values are close to 1, which indicates that the meiofauna species are diverse and evenly

Table 1. The meiofauna abundance at Losari coast, Makassar City, South Sulawesi, Indonesia

Phyla	Density (indv. m ⁻²)									
	ST.I	ST.II	ST.III	ST.IV	ST.V	ST.VI	ST.VII	ST.VIII	ST.IX	Σ
Aelosomatidae	-	-	40	-	-	-	-	-	-	40
Ciliophora	238	297	159	20	99	119	120	692	158	1902
Gastrotricha	159	0	79	0	20	79	40	0	178	555
Gnathostomulida	0	20	119	0	0	0	0	40	79	258
Nematoda	20	0	79	158	178	0	0	0	316	751
Nemertina	20	20	99	0	0	40	79	0	198	456
Oligochaeta	218	1481	1402	1936	772	5747	4523	4583	4900	25562
Ostracoda	1960	1168	1307	1840	970	9977	6007	4585	4131	31945
Polychaeta	40	79	158	99	59	79	20	178	574	1286
Sarcomastigophora	356	20	40	0	0	40	80	0	59	595
Tunicata	0	20	1284	1047	158	79	40	0	277	2905
Turbellaria	198	40	20	0	159	79	0	40	0	536
Σ	3209	3185	4746	5100	2415	16239	10909	10118	10870	66791

Table 2. The Results of the One-way ANOVA of the meiofauna abundance along the Losari Coast

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	4.630E7	11	4209146.891	7.584	.000
Within Groups	5.328E7	96	555031.012		
Total	9.958E7	107			

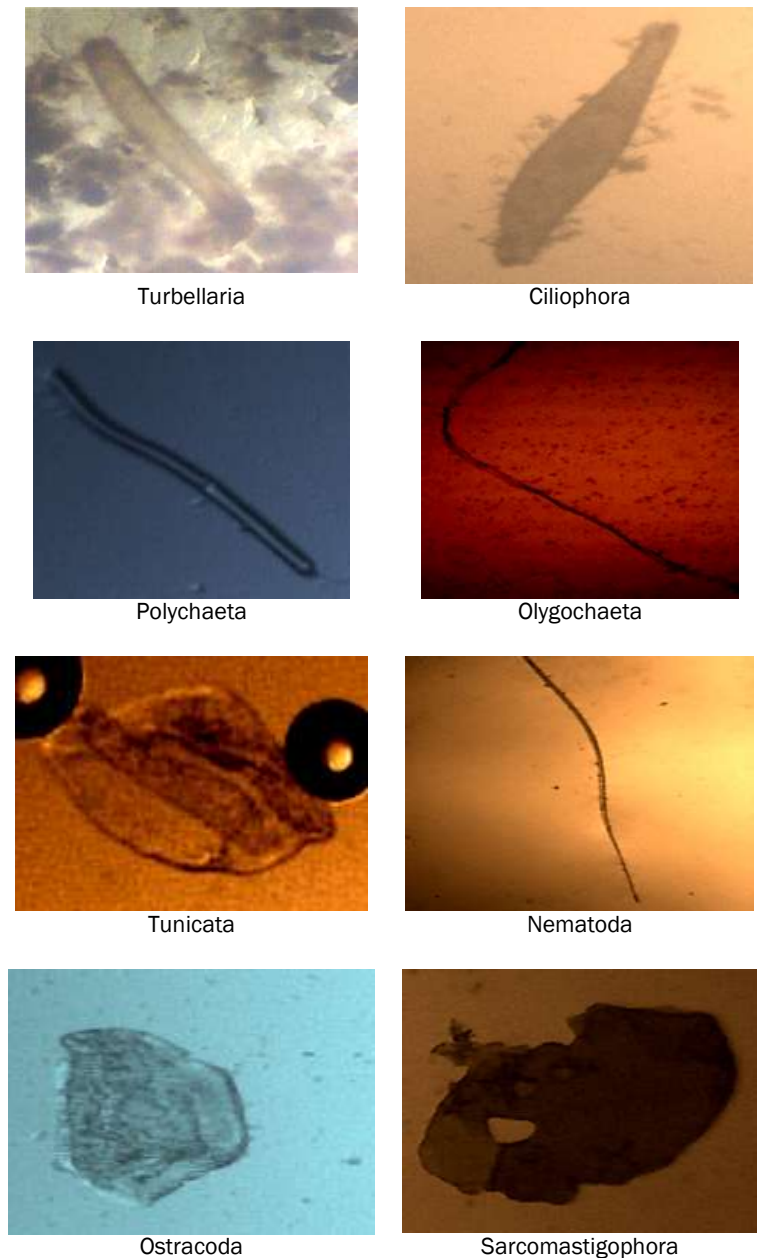


Figure 2. The meiofauna phyla which has high abundance in Losari Coast

distributed, or in other words, there are no dominant species at the research stations (Krebs, 1989). However, Station III is an exception. It has a low evenness index due to the presence of dominant meiofauna species. These station is dominated meiofauna are be able to adapt of disturbed environmental conditions caused by reclamation project activities.

Relationship between water quality and abundance of meiofauna

According to the Decree of the Indonesian Ministry of Environment No. 51/2004, some of the

physical-chemical parameters do not meet the standards for water quality. Dissolved oxygen was below its supposed level in waters. Meanwhile, pH as well as phosphate and nitrate content at some of the research stations exceed the threshold of their allowed presence in waters (Table 4.).

Figure 4 show a correlation between some of the physical-chemical environmental factors, such as temperature, current velocity, depth, brightness, salinity, pH, DO, nitrate in seawater, phosphate in seawater, and the abundance of meiofauna in the study area. The relationship between these variables are positive and negative, and the contributions of

the environmental factors to the abundance of meiofauna vary between 0.15% and 11.78% (Table 5). Seawater salinity, pH, and phosphate are positively correlated to the abundance of meiofauna at the bottom of the waters. In other words, the higher the range of these three parameters, the higher the abundance of organisms.

Acidity (pH) is influenced by the entry of contaminants into the waters, an acid aquatic environment (low pH) potentially lead to the death of aquatic organisms. In seawater, phosphate is an abiotic parameter that is necessary for the development of meiofauna in waters. Therefore, when the phosphate content decreases, the abundance of these organisms also drops (Clavero

et al., 1991; Morse, 1993). Water salinity is an environmental parameter that strongly affects the presence of meiofauna. Increased salinity interferes with the presence of meiofauna at the bottom of the waters. As well as, Aryawati et al. (2017) stated that temperature and pH are environmental parameters that support the growth of sea biota.

Temperature, current velocity, depth, brightness, DO, and nitrate-seawater are negatively correlated with the abundance of meiofauna in the study area. Accordingly, an increase in the range of these parameters is likely followed by a decrease in the abundance of meiofauna. Oxygen content is an important factor in the life of organisms like meiofauna. Dissolved oxygen is useful in the process

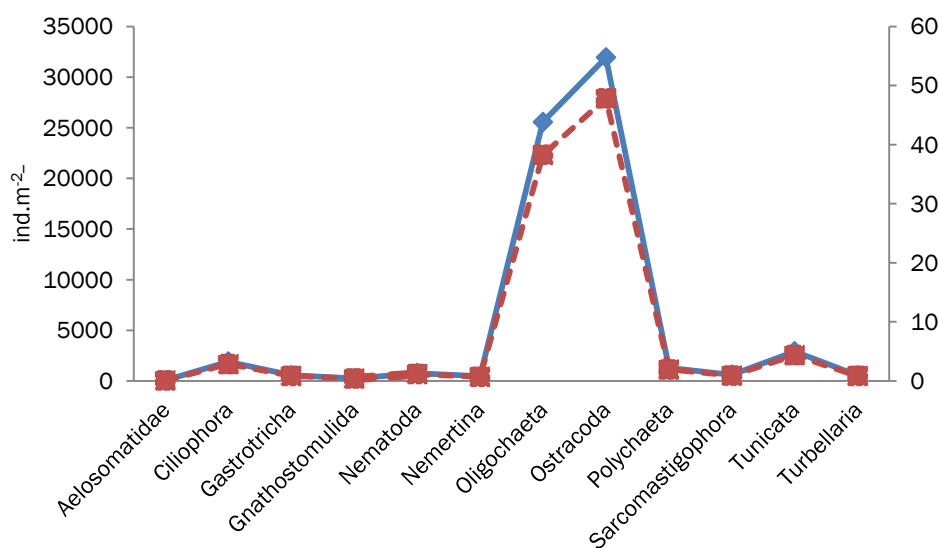


Figure 3. The composition of meiofauna phyla along the Losari Coast
 Note. —◆— = Abundance, - -■- = Composition

Table 3. Results of Tukey's test of meiofauna abundance along Losari coast, Makassar City, South Sulawesi, Indonesia

Phylum	N	Tukey HSD ^a Subset for alpha = 0.05		
		1	2	3
phylum Aelosomatidae	9	2.22		
phylum Gnathostomulida	9	11.00		
Phylum Nemertina	9	13.22		
phylum Turbellaria	9	15.56		
phylum Gastrotricha	9	19.89		
phylum Sarcomastigophora	9	226.22	226.22	
phylum Nematoda	9	266.33	266.33	
phylum Polychaeta	9	336.67	336.67	
phylum Ciliophora	9	393.56	393.56	
phylum Tunicata	9	700.89	700.89	
phylum Oligochaeta	9		1389.44	1389.44
phylum Ostracoda	9			2223.33
Sig.		.699	.056	.433

Table 4. Physical-chemical characteristics of waters at Losari coast, Makassar City, South Sulawesi, Indonesia

Parameters	Research Stations									Max. Limit*
	St. I	St. II	St. III	St. IV	St. V	St. VI	St. VII	St. VIII	St. IX	
Salinity	25	30	29	26	26	20	27	20	25	Natural
Ph	9.98	7.52	7.48	7.8	7.42	7.15	7.7	7.78	7.98	7-8.5
Temp. (°C)	30	28	31	28	32	33	30	32	33	Natural
Depth (m)	3.2	2.4	6	2	3	4	2.6	4	2	-
Current velocity (m.s ⁻¹)	0.032	0.08	0.4	0.1	0.59	0.68	0.35	0.42	0.67	-
Brightness (m)	2	2	3	1	1.5	3.5	2.5	3.4	1.5	-
DO	4	3.4	5	3.2	5	5	5	3	5	>5 mgL ⁻¹
Phosphate-seawater	0.03	0.12	0.0002	0.18	0.0003	0.005	0.0004	0.64	0.0024	0.015 mgL ⁻¹
Phosphate-sediment	0.02	0.025	0.019	0.015	0.018	0.017	0.013	0.023	0.023	-
Nitrate-seawater	0.0006	0.02	0.0003	0.51	0.00021	0.09	0.0002	0.78	0.00023	0.008 mgL ⁻¹
Nitrate-sediment	0.0014	0.001	0.0005	0.0006	0.0012	0.001	0.0006	0.0006	0.0006	-

Max. Limit*: Based on the Decree of the Indonesian Ministry of Environment No. 51/2004

Table 5. The Summary of the PCA: The contribution of the Physical-chemical variables (%) to the abundance of meiofauna

	F1	F2	F3	F4
Abundance	9.3351	0.3204	11.0283	0.5926
Dominance	15.5018	1.2818	0.2574	2.2129
Evenness	12.9428	2.4495	0.7741	6.7369
Diversity	10.8347	0.9757	6.8906	6.1825
Phosphate-seawater	0.1568	25.1152	1.6087	0.2906
Phosphate-sediment	0.0429	6.1403	1.7934	12.2964
Nitrate-seawater	1.4470	21.5619	0.0239	4.6404
Nitrate-sediment	0.0551	0.3321	0.0091	58.1719
Salinity	7.4806	3.8605	11.0559	2.1631
Ph	4.3253	6.5400	6.0891	0.5108
Temperature	11.7814	2.1903	6.5276	1.9727
Depth	8.2246	0.0313	25.6541	0.0261
Brightness	6.4216	0.0115	17.9144	2.8752
DO	0.5742	25.2823	0.1408	0.8765
Current Velocity	10.8760	3.9073	10.2326	0.4512

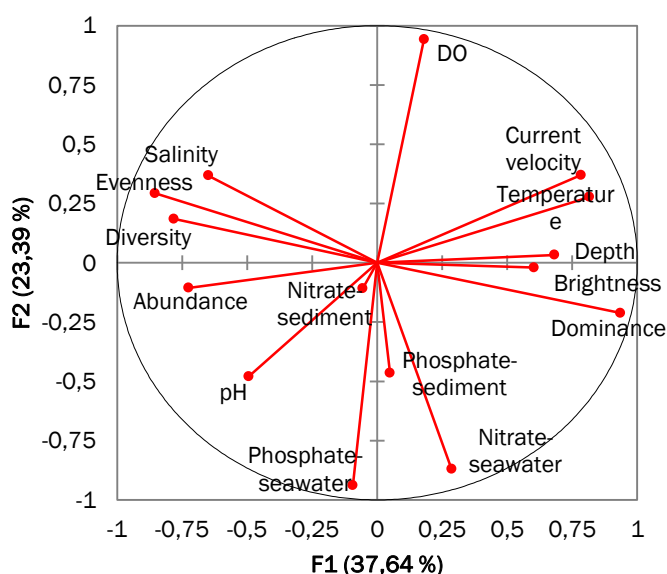


Figure 4. Output diagram of the Principal Component Analysis between the physical- chemical parameters and the abundance of meiofauna on the Losari coast, Makassar City, South Sulawesi, Indonesia

of breathing and metabolism of meiofauna that lives in the bottom of the waters. In general, high DO content can increase the abundance of meiofauna, but some meiofauna species can live well in anaerobic conditions (Silence *et al.*, 1993).

Nematoda, Ciliophora, Ostracoda, Gnathostomulida, Gastrotricha, and Oligochaeta are meiofauna that can live and reproduce in unfavorable environmental conditions, such as low DO content (Giere and Pfannkuche, 1982; Heip *et al.*, 1985; Coull, 1992; Morse, 1993). The same case applies to the other parameters, namely current velocity, temperature, depth, brightness, and nitrate-seawater, which shape the abundance of meiofauna in waters. However, some meiofauna species can survive even when some of these parameters are low in the environments (Giere, 2009).

Conclusion

Ostracoda, Oligochaeta, Tunicata, and Ciliophora have a high level of abundance on the Losari coast. The research stations located around Jeneberang and Tallo Rivers estuaries have a high abundance of meiofauna. Meanwhile, the research stations nearby the port, Paotere Harbor, hotels, hospitals, restaurants, cafes, and gold-crafting industries have a low abundance of meiofauna due to the direct physical disturbances to the habitat of meiofauna and the entry of hazardous metal contents generated by the diverse anthropogenic activities into the waters. The meiofauna species on the Losari coast are highly diverse, as evidenced by the diversity index (*i.e.*>2). The range of the evenness index of all stations is close to 1, indicating that the meiofauna species in the study area are very even.

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