The relation of sediment texture to macro- and microplastic abundance in intertidal zone

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Abstract. The intertidal zone is a waters area directly affected by the contamination of plastic debris from land and sea. The aim of this research were to analyze the relation of sediment texture to macro- and micro plastic abundance and also to determine appropriate management strategy. This research was conducted in intertidal zone Jaring Halus Village Langkat Regency North Sumatera Province on February-April 2017. Plastic debris was collected using quadrat transect. Sediment was collected with correct, up to a depth of least 30 cm. Abundance of micro plastic in Station 1 were positively tolerated with clay (0.509), and silt (0.787) and negatively correlations with sand (0.709) Station 2 were positively correlations with sand (0.645) and negatively correlations with clay (0.575), and silt (0.626) Station 3 were positively correlations with clay (0.435), and silt (0.466) and negatively correlations with sand (0.599). The abundance of microplastic was positively correlations with the abundance of microplastic (0.765). Microplastic density is directly proportional to the content of clay and dust. The higher the clay and dust content the higher the micro plastic density.

1. Introduction

Marine debris is any human waste, which is solid (state of matter, with fixed volume and shape) or matter that enters the marine environment either directly or indirectly [1, 2, 3]. Sea waste covers any manufactured form or processed material then discarded or abandoned in the marine environment. Sea waste consists of goods, food/snacks used by humans and then put into the sea, either intentionally or unintentionally, such as marine transport, drainage, and sewage or waste disposal systems by the wind [2, 3, 4]. The size category is used to classify marine debris, ie mega debris (> 100 mm), macro debris (> 20-100 mm), meso debris (> 5-20 mm), and micro debris (0.3-5 mm) [1, 2, 5].

One example of marine debris is plastic. Plastics is the largest contributor of marine waste in the world. Experts estimate more than 50% of marine waste comprises plastic [1, 2, 4, 6]. Chemically the plastic effect tends to increase the size of plastic particles (micro plastic) decreases, whereas the physical effect increases with increasing plastic size [5, 6].

Macroplastic can cover the surface of sediments and disrupt the movement of aquatic organisms [7, 8, 9] and can prevent the growth of mangrove seeds [8]. Macroplastic can also be a host for the growth of invasive species especially those attached to the substrate [7, 10]. Meanwhile, micro plastic provides a more dangerous threat than with micro plastic. This is because it can enter into the digestion and accumulate in the body of aquatic organisms [7, 9, 10, 11].

Plastic degradation occurs in all environments and is controlled by several environmental factors. The degraded plastic is due to photo-oxidation by ultraviolet (UV) light and is accelerated by high temperatures [12]. Thus, the plastics in the marine environment will be more stable than the soil surface due to the damping of temperature and light (UV) by sea water [13]. Additionally, the development of biofilms on plastic waste will minimize ultraviolet exposure on plastic surfaces that have the potential to slow down the degradation process [14]. Plastic wastes are found on the surface of the water and water columns as well as marine sediments in various places all over the world [4, 15, 16, 17].

Jaring Halus Village is one of the coastal settlements that have problems in waste management. Along with the increasing population in the area, many activities that occur in this village, such as fishing, fishery, agriculture, plantation, and household activities will all generate waste. The aim of this research were to analyze the relation of sediment texture to macro- and micro plastic abundance and also to determine appropriate management strategy.

2. Materials and Methods
2.1. Study site
The research was conducted in JaringHalus Village, Langkat Regency, North Sumatra Province, Indonesia. Data were collected from February to April 2017. The tools used were Global Position System (GPS), meter, sample bottle, tool box, core, 1m × 1m board, filter, shovel, digital camera, and stationery.

2.2. Method of sediment sampling
Substrate sampling was taken using a core. This process is done at low tide waters along with macro and microplastic sampling. Substrate sampling is done by immersing core based on depth stratification; 0-10, 10-20, 20-30 cm.

Examples of basic substrate waters obtained were analyzed to determine the composition (%) of clay, dust, sand, in the laboratory. The following are the substrate texture determining steps:
1. Determine the composition of each substrate fraction. For example 45% sand fraction, 30% dust and 25% clay.
2. Draw a straight line on the percentage of sand point 45% parallel to the percentage side of dust, then drawn a straight line on the percentage of dust at 30% parallel to the percentage of clay, and drag a straight line on the percentage of clay 25% parallel to the percentage of sand .
3. The point of intersection of the three lines will determine the type of substrate analyzed, for example, this is clay. For substrate analysis using Triangle The United States Department of Agriculture (USDA)

2.3. Method of macro- and microplastic survey
The macro- and micro-plastic data used were taken from previous research [19].

2.4. Data analysis
Correlation analysis between macro and microplastic to sediment texture using Pearson Correlation and Kruskal-Wallis with SPSS.

3. Results and Discussions
3.1. Quality of sediment
The results of substrate texture analysis show that each station has a much different composition of the fraction of dust, clay, and sand. The highest sand fraction is in Depth 10 cm Plot 1 Station 2 of 93% and the lowest in Plot 2 Station 2 by 2%. Plot 2 Station 1 The depth of 10 cm has the highest dust fraction reaching 89% and the lowest at some observation point of 1%. The highest clay fraction composition was found in Plot 3 Station 3 The depth of 10 cm reached 50% and the lowest in Plot 2 Station 2 Depth 10 cm and Plot 3 Station 2 Depth 30 cm by 6%. The result of the measurement of the

sediment quality parameter is the percentage of sediment fraction obtained from the observation station is presented in table 1.

The result of Kruskal-Wallis test shows that the percentage of clay, sand, and dust at depth of 10 cm, 20 cm and 30 cm in the intertidal zone is not significantly different. The average percentage of clay, sand, and dust at depths of 10 cm, 20 cm, and 30 cm were 36.59 - 44.83, 39.91 - 42.24 and 39.00 - 43.87. This proves that the percentage of the sedimentary fraction does not differ with increasing depth in each observation plot. The result of Kruskal-Wallis test shows that the percentage of clay, sand, and dust at the upper, middle and lower limit in the intertidal zone is significantly different. At the upper limit of clay, sand and dust have average percentage of 30.63%, 58.37%, and 19.37%, respectively. At the center boundary of clay, sand and dust have an average percentage of 51.80%, 31.19%, and 44.43% respectively. At the lower boundary of clay, sand and dust have an average percentage of 40.57%, 33.44%, and 59.20%, respectively. The average percentage of highest clay in the center (plot 2), upper sand (plot 1) and dust at the bottom (plot 3).

The difference of the sedimentary fraction in the intertidal zone is thought to be influenced by the presence of sediment particles carried by ocean currents and rivers (estuaries). The process of sediment formation in coastal waters other than influenced by wave forces is also determined by artificial activities (humans) in the mainland [20]. The artificial influence around the coast affects the distribution of sedimentary fractions because this activity suppliers poorly sorted sediment. The sedimentary fraction is affected by relatively strong tidal waves and currents [21].

Table 1. Quality of sediment

Parameter	Station 1			Station 2			Station 3		
	1[*]	2[*]	3[*]	1[*]	2[*]	3[*]	1[*]	2[*]	3[*]
% Clay	21.31	8.87	20.82	7.28	24.33	15.12	35.44	24.91	32.28
% Sand	50.41	87.31	59.92	91.12	6.16	8.72	8.55	40.42	14.70
% Silt	28.50	3.87	19.26	1.57	69.36	76.09	57.46	36.05	53.24
C-Organic	1.57	2.13	1.88	1.56	2.79	1.88	3.12	2.99	2.71

*) Plot

3.2. Macro- and microplastic

The total number of macroplastic collected from 3 stations divided into 27 observation plots is 308 types with total weight is 3689.87 g. The highest macroplastic density found in Station 2 ranged between 18.33-190.33 species m^{-2} with weights ranging from 246.33 to 2103 gr. The lowest density found in Station 3 ranged from 3.33 to 11.67 species m^{-2} with weights ranging from 13.46 to 117.67 gr. Density and macro and microplastic weights can be seen in table 2 and table 3 [19].

The highest microplastic density is found in Plot 1 of all observation stations which is the highest tidal boundary.Microplastic film type is the highest type found in all observation plots. The film comes from fragmentation of plastic waste such as packets of food and soft drinks, plastic bags and plastic wrapping fish commonly used in fishing activities. The film also has the lowest density so it is easily distributed by the presence of currents and tides [19]

Table 2. Abundance and Macroplastic Weights

Station	Macroplastic Abundance (type m^{-2})			Total	Macroplastic Weight (gr)			Total
	Plot 1	Plot 2	Plot 3		Plot 1	Plot 2	Plot 3	
1	32.67	9.67	5	47	393	115.67	65.67	574
2	190.33	31.67	18.33	240	2203	508	246.33	2957
3	11.67	5.33	3.33	20	113.67	31.08	13.46	158
Total	234.67	46.67	26.67	308	2709.67	654.75	325.46	3689.87

Table 3. The Percentage of Density and Average Density of Microplastic

Station	Percentage of Microplastic Abundance				Abundance Average (type/kg)
	Film	Fiber	Fragmen	Pellet	
1	60.27	22.30	17.47	0	89
2	45.07	30.03	24.63	0.3	173.33
3	51.57	22.30	26.13	0	64
Total	52.30	24.88	22.74	0.1	326.33

3.3 The Relation of Sediment Fraction with Microplastic

The result of Pearson correlation test showed that the Stationplatz micro plastic density station 1 was positively correlated (0.509) with clay, negatively correlated (0.709) with sand and correlated positively (0.787) with dust. This suggests that microplastic density has a moderate relationship to clay and a strong relationship with dust. The higher percentage of clay and dust causes higher micro plastic density (table 4).

The microplastic density at Station 1 is strongly influenced by clay and dust proving that soft sediment is easier to become a micro plastic trap. In Station 2 the micro plastic density is negatively correlated (0.575) with clay, positively correlated (0.645) with sand and negatively correlated (0.625) with dust. The results of this test show differences with Station 1 where the micro plastic density has a negative correlation with sand. This happens because Station 2 is a community residential location where the highest plastic contamination pressure and micro plastic accumulate in the sediment layer.

In Station 3 the micro plastic density is positively correlated (0.435) with clay, negatively correlated (0.599) with sand and positively correlated (0.466) with dust. This suggests that microplastic density has a moderate relationship to clay and dust. The microplastic density of Stations 1 and 3 do not differ greatly in relation to clay, sand, and dust.

Microplastic density in the intertidal zone is influenced by two factors: The distance between the observation point and the percentage of the sedimentary fraction. The closer the distance to the main pollutant source causes higher micro plastic density. The higher percentage of clay and dust causes the sediment to soften and become a stronger trap against micro plastic. This is in accordance with the statement of [22] that soft sediments can more concurrently debris than rocky and gravel habitats [18, 23].

Table 4. Results of Pearson Correlation Test between Microplastic and Sediment Fraction

Microplastic	Sediment Fraction		
	Clay	Sand	Silt
1	0.509	-0.709	0.787
2	-0.575	0.645	-0.625
3	0.435	-0.599	0.466

4. Conclusions

The coastal area of Jaring Halus Village, especially in the intertidal zone to obtain environmental pressure (pollution) of plastic in the form of macro- and micro plastic. The highest macro- and micro plastic densities are found in Station 2 which is a community residential area as well as the main source of plastic pollution. Microplastic density is directly proportional to the content of clay and dust. The higher the clay and dust content the higher the micro plastic density.

References

[1]   United Nations Environment Programme 2011 UNEP Year Book Emerging Issues in Our Global Environment. UNEP. Nairobi.

[2]   National Oceanic and Atmospheric Administration 2013 Programmatic Environmental Assessment (PEA) for the NOAA Marine Debris Program (MDP). NOAA. Maryland

[3]   Engler 2012 The Complex Interaction between Marine Debris and Toxic Chemicals in Ocean. Office of Wetlands, Oceans, and Watersheds. U.S. Environmental Protection Agency. Pennsylvania Avenue. United States

[4]   Galgani F*et al* 2015 Global Distribution, Composition and Abundance of Marine Litter. M. Bergmann et al. (eds.), Marine Anthropogenic Litter, DOI 10.1007/978-3-319-16510-3_2

[5]   Hammer J et al 2012 Plastics in the Marine Environment: The Dark Side of a Modern Gift D.M. Whitacre (ed.), Reviews of Environmental Contamination and Toxicology. Springer Science + Business Media

[6]   Thevenon F*et al* 2014 Situation Analysis Report. Gland, Switzerland: IUCN. 52 pp.

[7]   Irwin Kimberly 2012 The Impacts of Marine Debris: A Review and Synthesis of Existing Research. Living Oceans Society December 2012

[8]   Smith SDA and Markic A 2013 *Plos One*. **8** (12).

[9]   National Oceanic and Atmospheric Administration Marine Debris Program 2016 Report on Marine Debris Impacts on Coastal and Benthic Habitats. Silver Spring, MD: NOAA

[10]   Ogunola OS and Palanisami T 2016 *J Pollut Eff Cont* **4**: 161

[11]   Eriksen M *et al* 2014 Plastic. *PLoS ONE*. **9** (12).

[12]   Valadez-Gonzalez A *et al* 1999 *Polymer Degradation And Stability*. **63** (2): 253-260.

[13]   Pegram JE and Andrady A L 1989 *Polymer Degradation and Stability*. **26** (1): 333–345.

[14]   Artham T*et al* 2009 *International Biodeterioration & Biodegradation*. **63** (1): 884-890.

[15]   Ryan PG*et al* 2009 *Philosophical Transactions of the Royal Society B*. **364** (1): 1999-2012.

[16]   Browne MA 2011 *Environ. Sci. Technol*. **45** (1): 9175-9179.

[17]   Claessens M et al 2011*Marine Pollution Bulletin*. **62** (1): 2199-2204.

[18]   Coppock RL *et al* 2017 *Environmental Pollution.* **230** (2017) 829-837

[19]   Bangun A P *et al* Impacts of Macro - and Microplastic on Macrozoobenthos Abundance in Intertidal Zone. International Confrence on Agriculture, Environtment,and Food security, Fakultas Pertanian USU 2017

[20]   Efriyeldi 1999 *Natur Indonesia.* **2** (1): 85-92

[21]   Rifardi 2008 Ekologi Sedimen Laut Modern UR-Press. Pekanbaru

[22]   Mulyadi H *et al* 2015 *Jurnal Dinamika Lingkungan Indonesia* **2** (1): 26-31

[23]   Watters DL *et al* 2010 *Marine Pollution Bulletin*. **60**: 131-138.