Spatial Distribution of Microplastic Contamination in Blood Clams (Anadara granosa) on the Jeneponto Coast, South Sulawesi

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Abstract

Plastic waste in oceans will threaten of marine biota. There is a very high degree of plastic pollution in Indonesia, however the distribution of microplastic contamination in seafood, particularly that ingested by the general populace as a daily meal from seas, is quite low. The purpose of this investigation is to map the distribution of microplastic contamination in blood clams (Anadara granosa) throughout the South Sulawesi coast. Observational study employing a spatial analysis exploratory design. Blood clams (Anadara granosa) and information on wind, currents, and tides are used to map the distribution of microplastic pollution. The Kriging model was used for their geographical analysis. Purposive sampling was used to collect a total of 25 samples of blood clams (Anadara granosa) from offshore locations, residential waterways, mangrove ecosystems, rivers, and river estuaries. The results showed that the highest distribution of microplastic contamination was found in mangrove ecosystem areas and residential waters, while the lowest was found in river areas. Blood clams (Anadara granosa) have high levels of microplastic contamination because of sources of plastic pollution that come from waste disposal activities. It became stuck in the fisheries and mangrove ecosystems along the coast. Oceanography has an impact on how currents and winds migrate from the northeast (where mangrove habitats are) to the north (where residential waters are), carrying microplastic particles. Provision of waste management facilities by the local government and using the depuration method to eliminate microplastics in blood clams (Anadara granosa) consumed by the community needs to be done to reduce the impact on ecology and health.

Keywords: Microplastic Contamination, Spatial Analysis, Blood Clams (Anadara granosa), Coastal Coast

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Introduction

Today, plastic production to meet needs has increased in the past century, and global plastic production reached 359 million tons in 2018 (Plastic Europe, 2018); (Shen et al., 2019). The amount of plastic waste in Indonesia's oceans will threaten its marine biota. Data on the presence of microplastics in seafood from Indonesian waters is minimal, even though, on the other hand, the level of plastic pollution in Indonesia is high (Cauwenberghe et al., 2013).

Microplastics are plastic particles smaller than 5 mm (Hartmann et al., 2019). Microplastics are produced within these dimensions or result from the fragmentation of the larger plastic structure. Microplastics are a concern because they can increasingly pollute the aquatic environment (Hurley R & Rothwell, 2018), terrestrial (de Souza Machado et al., 2018) and air (Prata, 2018). In addition, there have been several reports on microplastics in food (Barboza et al., 2018), especially seafood (Cho et al., 2019); Daud, 2020), sea salt (Karami et al., 2017; Yang et al., 2015; Kosuth et al., 2018), and drinking water (Kosuth et al., 2018); Mason et al., 2018; Schymanski et al., 2018).

Field research data indicate that microplastics are detected mainly in the digestive tract of marine animals (de Sá et al., 2018). In experimental trials, cellular uptake and tissue accumulation of microplastics and, more importantly, nano plastics have been demonstrated (Deng et al., 2017 ; Avio et al., 2015). Plastic particles are seen as foreign bodies in tissues and can trigger local immune reactions (Schwabl et al., 2019).

There have been many studies on microplastics in the sea, which threaten the food chain (Yudhantari et al., 2019). Microplastics contaminate the blood cockles (Tuhumury C & Ritonga, 2020; Delya et al., 2021). In its development, no one has researched the spatial distribution of microplastic and nano plastic exposure to shellfish, while the consumption of blood clams is still massive. This case became public health problem in Indonesia and even globally since the dangers of plastic, macroplastic, mesoplastic, microplastic, and nanoplastic were published in an article (Daud, 2019; 2020).

People in Jeneponto Regency consume a lot of seafood, such as fish, shrimp, squid, and shellfish. The average expenditure per capita for fish, shrimp, squid, and shellfish consumption in 2019 was Rp. 44,343 or 11.82%, and in 2020 it increases to Rp. 49,563 or 1.84% (Central Bureau of Statistics for Jeneponto Regency, 2021). Tarowang District is a bay area where the tendency of current patterns will carry microplastics. The sea's particle distribution strongly depends on wind, currents, and tides, which can move particles, especially microplastics which cause distribution.

Spatial analysis was carried out to see the distribution of the presence of microplastics (B. S. Hadi, 2013) which contaminate blood clams (*Anadara granosa*) so that potential hazards to the health of people who consume shellfish can be identified and analyzed sources of microplastic pollution. Spatial analysis was carried out in Makassar City Waters to see the spatial distribution of heavy metal contamination that enters and contaminates water areas (Werorilangi et al., 2019). Spatial analysis was carried out in this study to see the distribution of microplastics (B. S. Hadi, 2013) that contaminate blood clams (*Anadara granosa*). So the potential health hazards to the people who consume shellfish can be identified, and to analyze the sources of microplastic pollution. Spatial analysis was conducted in Makassar City Waters to see the spatial distribution of heavy metal contamination that enters and contaminates water areas (Werorilangi et al., 2019). The distribution and seasonal variations of microplastics in the Tallo River, Makassar, also show the distribution of microplastic contamination (Wicaksono et al., 2021). Spatial microplastic analysis has also been done on Lusi Island, Jabon District, Sidoarjo (Maulana, 2021), and the Citanduy River, West Java (Widigdo et al., 2021).

Mapping the microplastic contamination in blood clams (*Anadara granosa*) aim to see the microplastic distribution. The spatial map can be adopted to develop an early warning system for people who frequently consume them (Jaya et al., 2017). Information on the spatial distribution of microplastics on Jeneponto, South Sulawesi's coast, is still being determined. It is crucial to carry out spatial mapping so that practitioners and interested parties can make initial predictions of locations with high microplastic abundance. People who often consume blood clams contaminated with microplastics as food ingredients or daily side dishes can be at high risk for health (Barboza et al., 2018; CIEL, 2019; Smith et al., 2018). This study aimed to analyze the distribution of microplastic contamination in blood clams (*Anadara granosa*) on the coast of Jeneponto, South Sulawesi.

Based on this background, researchers are interested in examining the spatial analysis of microplastic contamination in blood clams (*Anadara granosa*) on the coast of Jeneponto, South Sulawesi, which lives around the coast, regarding microplastics in marine biota, especially in shellfish (Daud & Mahmuda Dullah, 2013).

Materials and Research Methods

This research is an observational study with an exploratory design using a spatial analysis approach on microplastic contamination in blood clams (Anadara granosa) in Jeneponto Coast, South Sulawesi Province (Sugiyono, 2011), Blood clams (Anadara granosa) sampling in areas where blood clams (Anadara granosa) take for public consumption. The microplastic abundance test on blood clams (Anadara granosa) check at the Marine and Fisheries Science Ecotoxicology Laboratory, Hasanuddin University. This research was carried out on the Jeneponto Coast starting in September-December 2022. A preliminary survey takes to identify areas where people collect blood clams for consumption as daily side dishes and sources of plastic waste contamination that enters the coast in Jeneponto Regency, South Sulawesi Province.

Sampling used a purposive sampling technique based on inclusion criteria: samples took at 5 sampling points in each area where blood clams (Anadara granosa) collect for public consumption. There are five areas in 5 areas consisting of offshore areas (area 1), residential waters (area 2), mangrove ecosystems (area 3), rivers (area 4), and river estuaries (area 5). Blood clam (Anadara granosa) samples were taken as much as 1 fruit/individual blood clam (Anadara granosa) at 5 sampling points in each area. The distance between sampling points is 50-100 m. Each sampling point took 1 individual with a sample weight ranging from 1.58 - 13.56 grams of wet-weight of blood clams (Anadara granosa).

Primary data was obtained directly by taking blood clams (*Anadara granosa*) samples for testing in the laboratory. The test was analyzed by taking samples of blood clams (*Anadara granosa*), weighing and storing them in sample containers, and adding 10% KOH three times the sample weight. Next, homogenized the sample. Stored it at room temperature for 24 hours, and the microplastics identifying using a stereo microscope, including shape and amount.

According to Digka et al., (2018)this microplastic abundance calculation can be calculated using the equation:

$$K = \frac{n}{g}$$

Equation :

K = Microplastic abundance (particles/g wet weight);

n = Number of microplastics;

g = Sample wet weight

Secondary data in the wind and current uses data were available at Marine Copernicus with a weather forecast system. Tidal data uses predictive data on tides.big.go.id for the month according to the time of the study, which will be processed into tabulations and analyzed. The analysis uses the kriging interpolation method through the ArcGis 10.8 application to become a data model for microplastic distribution patterns in the study area. Among the popular interpolation methods are Trend, Spline, Inverse Distance Weighted (IDW) and Krigging (B. S. Hadi, 2013). Each method has different characteristics, so different interpolation results will result if applied to the same area. This study used the Kriging interpolation method to combine the linear weights to estimate the values between the data samples. This model assumes that the distance and orientation between data samples show a spatial correlation (ESRI, 2008). After analysis, the data showed frequency distribution tables and patterns with ArcGIS 10.8. A narration will accompany each presentation, making the data easy to understand.

RESULTS

This research took place in Pao Village, Tarowang District, Jeneponto Regency, South Sulawesi Province, in 2022. The village is on the coast of Jeneponto Regency. A lowland area with a distance of ± 1 km above sea level. This area is for developing fishery, aquaculture, seaweed cultivation, yellow corn farming, and rice fields. The people of Pao Village's economic activities in meeting their families' needs are diverse, ranging from civil servants, traders, farmers, masons/carpenters, motorcycle taxi drivers, and farm workers (Central Bureau of Statistics for Jeneponto Regency, 2021).

The data obtained were processed using Microsoft Excel and ArcGIS 10.8 computer programs and then in the form of frequency tables and spatial data in the form of maps of the distribution of microplastic contamination. The results of this study are:

1. Presence and Form of Microplastics in Blood Clams (*Anadara granosa*)

The number and form of microplastics in Blood Clams (*Anadara granosa*) by area can show in the following table:

Table 1
Number of Microplastics in Blood Clams (*Anadara granosa*) Based on Area

Area	Number of MP
Offshore	13
Residential Waters	21
Mangrove Ecosystem	19
River	5
Estuary	10
Total	68

Source: Primary Data 2022

The amount of microplastic in blood clam (*Anadara granosa*) based on location show is quite varied. The amount of microplastic in blood clam (*Anadara granosa*) is most abundant in residential waters area, with as many as 21 particles. In comparison, the lowest amount of microplastic is found in river area, as many as 5 particles.

Figure 1. Blood Clams (Anadara granosa) samples

Form of Microplastics in Blood Clams (*Anadara granosa*) based on area can show in the following table:

Table 2
Form of Microplastics in Blood Clams (*Anadara granosa*)
Based on Area

Area	Type of MP	
	Line	Fragment
Offshore	13	0
Residential Waters	21	0
Mangrove Ecosystem	15	4
River	5	0
Estuary	6	4
Total	60	8

Based on table 2, the form of microplastics found in blood clams (*Anadara granosa*) show that there are two types of microplastics: line and fragment. The most common type of microplastic is the line type, with as many as 60 particles.

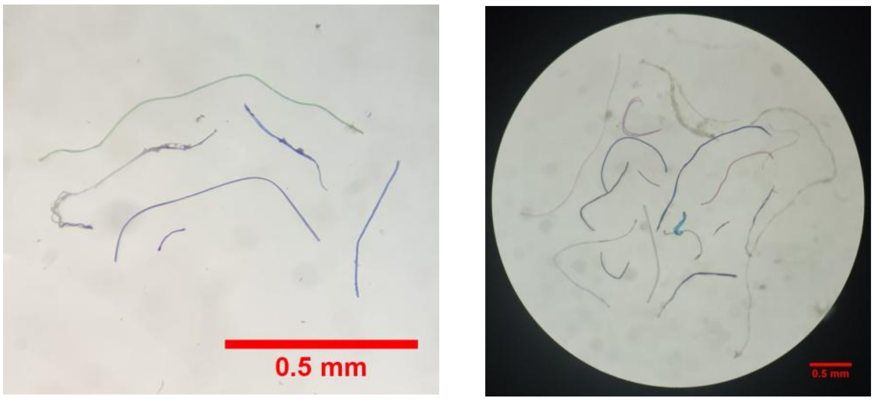

Figure 2. Line-shaped microplastics

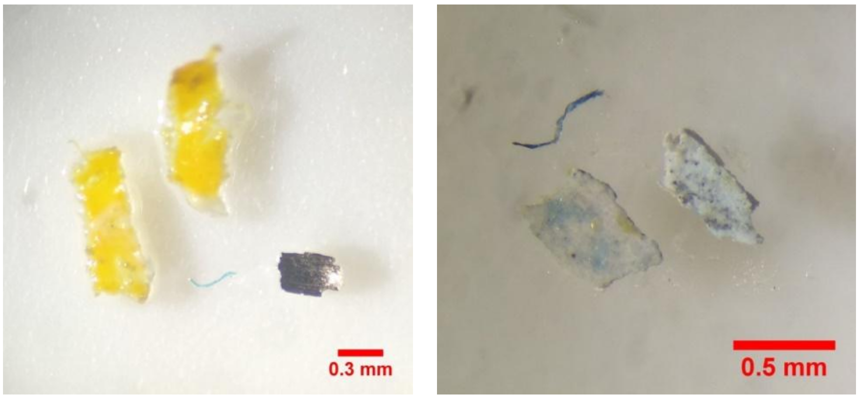

Figure 3. Microplastic in the form of fragments

2. Total Abundance and Types of Microplastics in Blood Clams (*Anadara granosa*)

   Microplastics found in blood clams (*Anadara granosa*) at each area have varying abundance values at each sampling point, as shown in Figure 3 below:

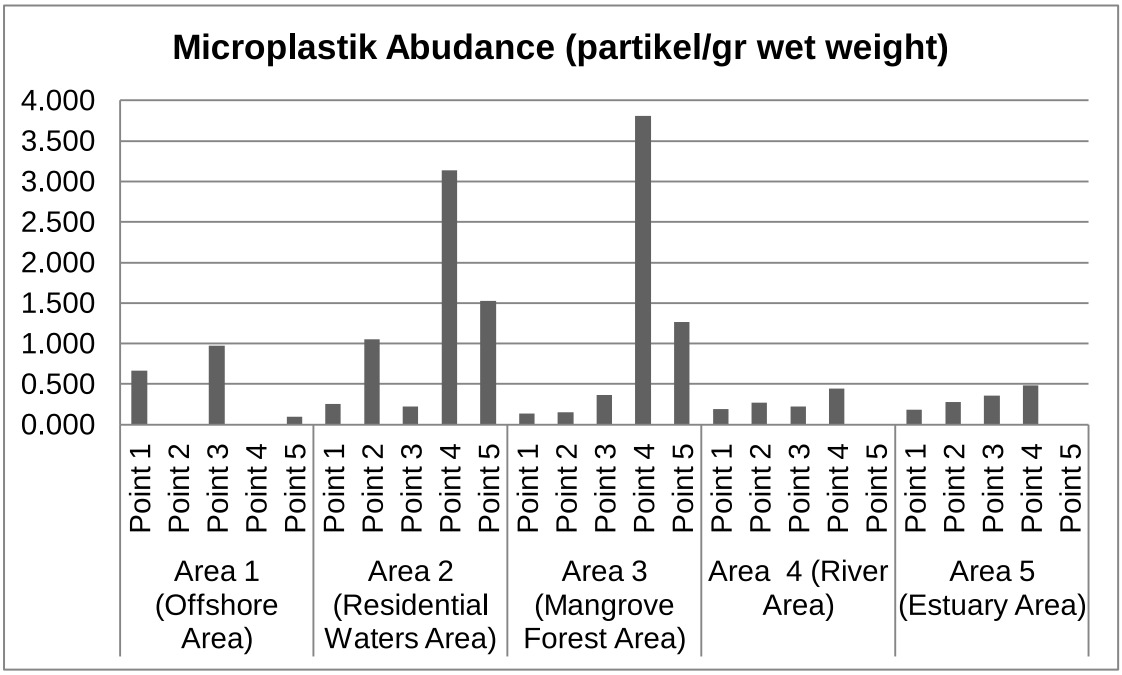

Figure 4.
Microplastic Abundance Results in
Blood Clams (*Anadara granosa*) (n=25)

The research results have found microplastic contamination of blood clams (*Anadara granosa*) in each area where blood clams (*Anadara granosa*) are collected for consumption by the public. After analysis, the highest microplastic abundance in blood clams (*Anadara granosa*) at point 4 at the mangrove ecosystem location of 3.806 particles/gram wet weight. However, there was also high plastic contamination at points 2, 4, and 5 in residential waters areas. In contrast, the lowest contamination was found at points 2 and 4 at offshore locations and point 5 at river and estuary areas where no microplastic contamination.

3. Spatial Distribution of Total Abundance of Microplastics in Blood Clams (*Anadara granosa*)

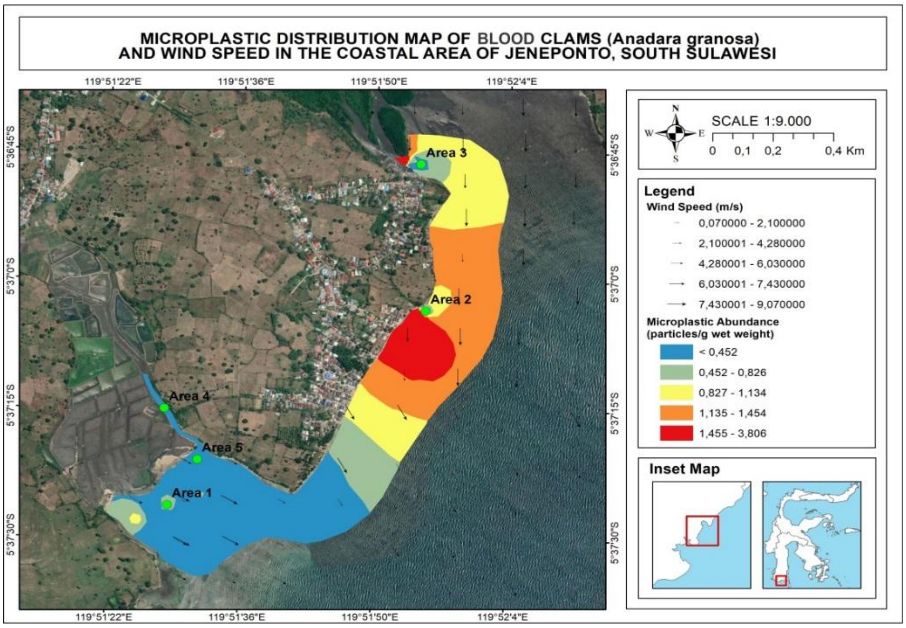

Figure 4
Microplastic Distribution Map of Blood Clams (*Anadara granosa*) and Wind Speed in The Coastal Area of Jeneponto, South Sulawesi

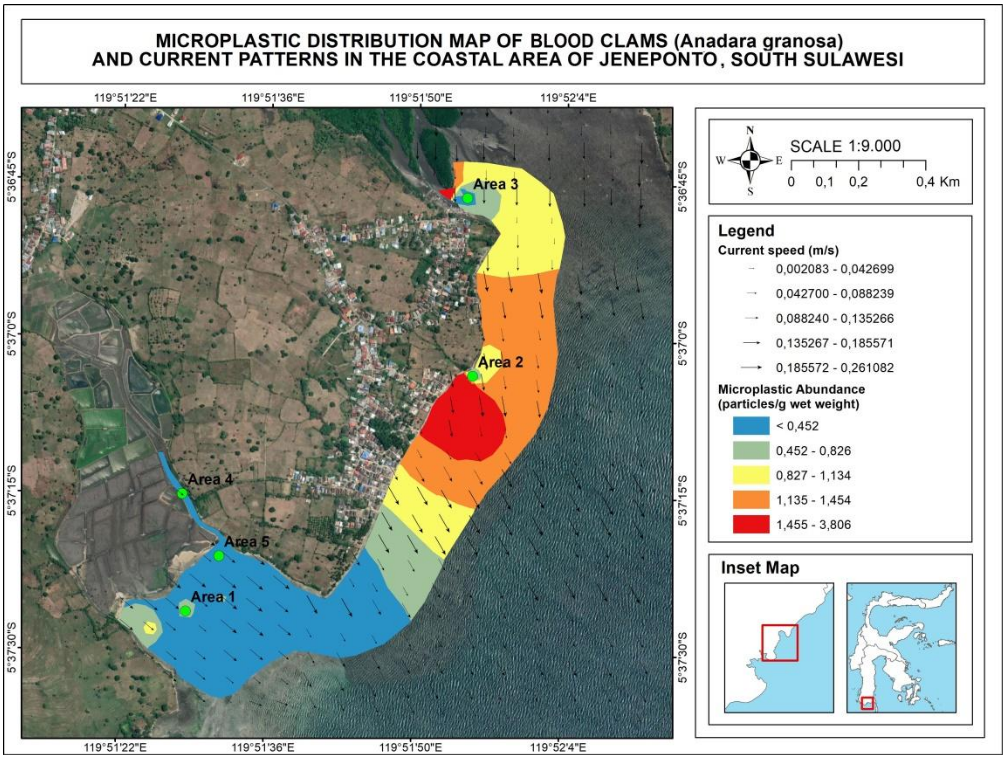

Figure 5

Microplastic Distribution Map of Blood Clams (*Anadara granosa*) and Current Patterin in The Coastal Area of Jeneponto, South Sulawesi

The distribution of contamination values can be seen in Figure 13 and Figure 14 above. The highest average abundance is 1.455 - 3.806 particles/g (wet weight) with red visualization.

In comparison, microplastic contamination is lowest at <0.452 particles/g (wet weight) with a blue colour. The interpretation of the colour provides information that the part is blue with very low contamination, green with low contamination, yellow with moderate contamination, orange with high contamination, and red with very high contamination. Very high microplastic contamination was found in mangrove ecosystems and residential waters, while very low levels were found in river areas and estuaries.

Based on the spatial map above also shows wind speed and direction and currents in the coastal area of Tarowang District, Jeneponto Regency ranging from 0.07-9.07 m/s originating from the north (mangrove ecosystem) towards the southeast (ocean) to current velocity ranges from 0.002-0.26 m/s also from the north (mangrove ecosystem) to the southeast (ocean).

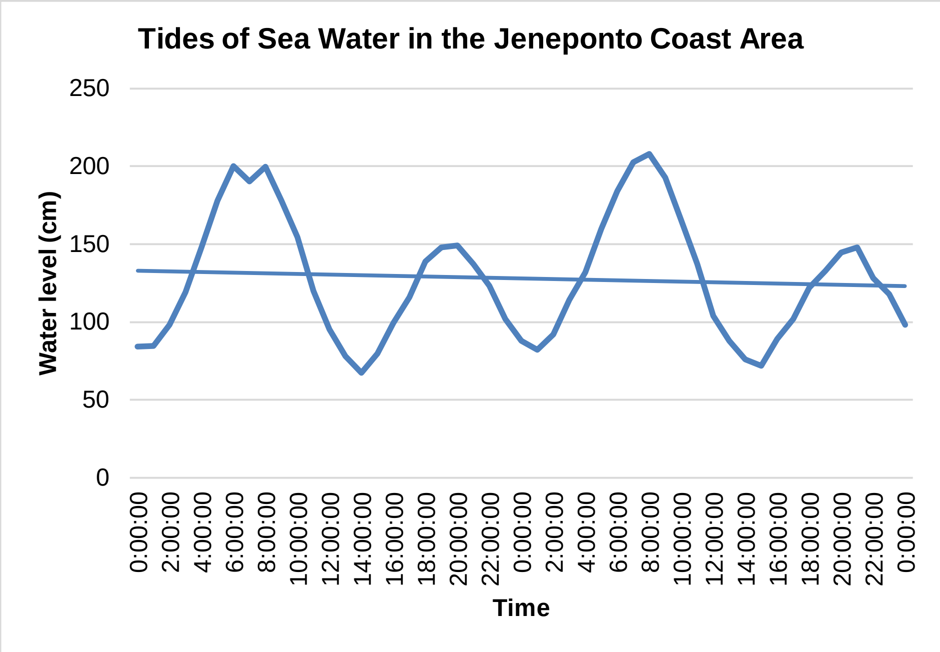

Figure 6 shows that the tides in the waters of Jeneponto Coast Area are at the highest tide, namely at a water level of 208 cm and the lowest at a water level of 67.3 cm.

Discussion

Blood clam samples (Anadara granosa) were examined by preparing shell samples at the Culinary Laboratory, Department of Nutrition, Faculty of Public Health. Sample preparation was carried out to remove organic matter in blood clams using 10% Potassium hydroxide (KOH) solution. After preparation, the blood clam samples were visually examined at the Marine and Fisheries Sciences Ecotoxicology Laboratory, Hasanuddin University, to see whether or not there was microplastic contamination. Observations were made using a microscope with a magnification of x4.5 to identify the number of microplastics and the shape of the microplastics (Tuhumury C and Ritonga, 2020).

1. Analysis of the Presence of Microplastics in Blood Clams (Anadara granosa)

a. Presence of Microplastics in Blood Clams (Anadara granosa)

Microplastics in blood clams (Anadara granosa) in all areas where blood clams (Anadara granosa) were collected indicate that microplastic contamination has occurred in these areas. There were 5 microplastic particles in the river area, 10 microplastic particles in the estuary area, 13 in the offshore area, 19 in the mangrove forest area, and 21 in residential waters.

In this study, the presence of microplastics in the coastal area of Jeneponto was due to the domestic activities of the surrounding community and the unavailability of waste management facilities and infrastructure, which caused waste, especially plastic, to enter water areas. In addition, the coast of Tarowang District is also a strategic fishery area where there are many fishermen's activities going back and forth to save their boats after carrying out fishing activities at sea and are also used to store damaged boats which also cause the presence of microplastics in this area (UNEP, 2016; Andrady, 2011; Defontaine et al., 2020)

The existence of microplastics in the waters cannot be separated from the presence of inorganic waste that enters the waters (Tuhumury C & Ritonga, 2020). Household activities such as washing synthetic clothes and fishing activities with nets (Listiani et al., 2021), activities of fishermen who go back and forth to save their boats, and some fishermen keep damaged boats (Hurley R & Rothwell, 2018).

Blood clam (Anadara granosa) in this study was contaminated with microplastics; this is because blood clam is a type of organism that lives on aquatic substrates and is a filter feeder and has been known to be a marine biota that has the potential to absorb microplastics quite high in the presence of microplastics in waters (Yona et al., 2021)). Related research, which aligns with this research, was conducted in Tanjung Tiram Waters, Ambon Bay. The results showed that microplastics were found in blood clams in areas very close to community settlements, with as many as 421 microplastic particles (Tuhumury C and Ritonga, 2020).

b. Forms of Microplastics in Blood Clams (Anadara granosa).

The form of microplastics in blood clams (Anadara granosa) found in Jeneponto Coast consists of two types: line or fibre and fragments dominated by microplastics, with 60 lines or fibre forms found and 8 types of fragments found. The form of microplastic found is influenced by the condition of the coast, which is the area where the majority of the population who work as fishermen and keep boats in the area live, as well as the behaviour of coastal communities who throw garbage on the beach due to the unavailability of waste transportation and management facilities.

In line with research conducted by Yona, Samantha and Kasitowati (2021) in the Waters of Banyuurip Village, Gresik, the results showed that the type of microplastic in blood clams was dominated by fibre as much as 75%, followed by fragments (20%) and films (<2%).

Browne et al., (2011) suggested that microplastic fibres in the form of fibres have characteristics that resemble fibres originating from boat ropes that lean on tidal areas that experience friction and then break down into plastic particles with very small sizes in the waters. Fibre is usually found along the coast because this microplastic waste comes from residential areas that work as fishermen.

This form also comes from synthetic fabrics, which can be released from washing clothes, fishing nets, industrial raw materials, household appliances, and plastic bags designed to be degraded in the environment or due to weathering of plastic products. Meanwhile, microplastics with this type of fragments come from pieces of plastic with strong polymers ((Dewi et al., 2015; Di & Wang, 2018). Scott et al., 2019), in his research he stated that fragment-type microplastics do not easily accumulate in all biota bodies found because their abundance in the waters is smaller than fibre-type microplastics.

This is why microplastic types of fragments, shaped like plastic fragments, have less chance of accumulating in the body of shells than types of fibre. Fragments found in blood clams show that microplastic pollution also comes from household waste in plastic bags, plastic packages, drinking bottles, gallon fragments and others thrown into the sea (Fitri & Patria, 2019).

In other related research conducted by Chavarry & Law, (2019) in the Pangkal Babu Mangrove Forest Area, West Tanjung Jabung Regency, Jambi, the results showed that line or fibre was the most common form of microplastic found in fibre shell samples with 180.6 ± 21.22 particles/individual and 4.1 ± 0.43 particles/g shellfish. The fibre form is the most common type of microplastic found in A.

granosa in the Pangkal Babu mangrove forest. Microplastic fibre types are widely used to manufacture clothing/synthetic fabrics and fragmentation of monofilament fishing nets and ropes (Mohamed Nor & Obbard, 2014). Meanwhile, the shape of the fragments and films found in blood clams show that microplastic pollution also comes from household waste in the form of plastic bags, plastic packaging, drinking bottles, gallon chips and others that are thrown into rivers and the sea.

This research aligns with that Patricia Blair et al., (2021) conducted at the Muang Ngam Fishery Market in the Singhanakorn District, Songkhla Province, Southern Thailand. The results showed that the total microplastic concentration in blood clams was 4.71 ± 0.06 n/g (fresh weight) and 2.64 ± 0.01 n/individual. Microplastics found in all species samples consisted mostly of microplastic fibres, and black colour was predominant; microplastic contamination was present in Thai commercial seafood species.

2. Spatial Distribution Analysis of Microplastic Contamination in Blood Clams (Anadara granosa) Based on Current, Wind and Tidal Patterns.

Based on the laboratory's results, observations were then analyzed spatially using the kriging interpolation model with the help of mapping software (ArcGIS 10.8), software used to view the spatial distribution of data at observation locations on the Jeneponto Coast.

The results of this study indicate microplastic contamination in blood clams (Anadara granosa) in the spatial analysis of this study divided into five value ranges, namely <0.452 with blue visualization, 0.452-0.826 with green visualization, 0.827-1.134 with yellow visualization, 1.135-1.454 with orange visualization, and 1.455 - 3.806 with red visualization. The range of values obtained from calculating microplastic abundance in blood clams (Anadara granosa) in each collection area is obtained from the abundance of microplastics.

This study interprets the colour and provides information that the parts are blue with very low contamination, green with low contamination, yellow with moderate contamination, orange with high contamination, and red with very high contamination (Widigdo et al., 2021). To analyze the level of microplastic contamination in blood clams (Anadara granosa) at five observation locations, each of which took 5 sample points, was calculated by microplastic abundance. Calculating microplastic abundance can be used to determine how big microplastic pollution's impact is in a sample (Samantha, 2019). The analysis of the abundance of microplastics in this study indicates that blood clams (Anadara granosa) consumed by people from the Jeneponto Coast have been contaminated with microplastics.

The results showed that the highest microplastic contamination in blood clams was found in the mangrove ecosystem area at point 4 of 3.806 particles/gram wet weight. However, there was also high plastic contamination at points 2, 4 and 5 in residential waters. At the same time, the lowest was at points 2 and 4 in the offshore area, point 5 in the river area and point 5 in the estuary area, with an abundance of 0.00 particles/gram wet weight or no microplastic contamination.

Spatial analysis is a technique that can be used to explore data related to spatial data that has a coordinate system. Spatial analysis in this study was carried out to visualize the distribution of microplastic contamination in blood clams (Anadara granosa) at each location for taking blood clams (Anadara granosa) consumed by the public.

Spatial analysis is carried out using an interpolation model, a method or mathematical function for estimating values at locations where data is unavailable. According to Burrough et al., (2015) interpolation is the process of predicting the value at a point that is not a sample point based on the values of the sampled surrounding points. The new values are determined based on existing data at observation sample points. With this interpolation step, spatial analysis can be carried out accurately. D.L. Krige developed this method to estimate the value of the mined materials. This model assumes that the distance and orientation between data samples show spatial correlation. This model provides a measure of error and confidence. This model also uses a semivariogram representing the spatial differences and values between all pairs of data samples. This semivariogram shows the weights used in the interpolation (ESRI, 1996).

The high level of microplastic contamination in blood clams (Anadara granosa) in the mangrove ecosystem area is the highest, with an abundance of microplastics of 3.806 particles/g (wet weight), because a large amount of waste, especially plastic waste trapped in mangrove forests due to the function of mangrove forests as a biological filter for marine debris originating from land and sea, causing an abundance of microplastics in areas which are natural habitats for blood clams (Anadara granosa) causing an abundance of microplastics which so that it also contaminates marine biota that lives in the ecosystem (Fitri & Patria, 2019).

The results of this study indicated that there was also very high microplastic contamination in residential water areas, with microplastic contamination in blood clams (Anadara granosa) of 3.139 particles/gram (wet weight) and 1.530 particles/gram (wet weight). The high contamination of microplastics in residential waters on Jeneponto Coast is due to many household activities, such as washing clothes and fishing with nets which produce microplastic particles from synthetic materials.

This research is in line with that carried out by Listiani et al., (2021), explaining that blood clams (Anadara granosa), which have a habitat in mangrove sediments, are very vulnerable to pollution by various pollutants, especially microplastics, in addition to degraded plastic because there is trash around the location. The scattered plastic comes from settlements, streams, and garbage stuck in mangrove trees.

The results of this study indicate that the current velocity obtained in the waters of Jeneponto Coast is a maximum current speed of 0.002 m/s and a maximum current speed of 0.26 m/s. The current pattern distribution map results are dominated by current characteristics from the north (mangrove ecosystem), which passes through residential waters and then heads southeast towards the open sea. In the coastal waters of Jeneponto Coast, this tidal pattern occurs with the highest water level of 208 m and the lowest water level of 67.3 cm. Differences in sea level elevation caused changes in the speed and direction of tidal currents in certain waters (Purba et al., 2022).

The current pattern in the waters of Jeneponto Coast, the results obtained are dominated by tidal currents because they have a pattern of movement similar to or close to the pattern of the tides that occur. The pattern of currents that move back and forth, namely when the tide approaches the coast, and when it recedes away from the coast, the currents in these waters can be categorized as being dominated by tidal currents (S. Hadi & Radjawane, 2011).

Discharges originating from activities from land to sea waters enter through the river channel. Ocean waters and ocean currents also play a role in the spread of microplastics. Ocean currents are the movement of seawater masses horizontally and vertically (Hutabarat and Evans. Stewart M., 1985; Triatmodjo, 2016). The dominant currents in coastal waters are tidal and ebb. Tidal currents are the horizontal movement of water bodies towards and away from the coast, along with changes in the rise and fall of sea level (Wulandari et al., 2022). In line with research conducted by Rafsanjani et al. (2021), current movements strongly influence the distribution of marine debris in coastal areas. The movement of water masses or currents can carry waste in the waters for quite a long distance. Wind gusts and tides strongly influence currents in coastal areas or the movement of water masses.

The current and wind direction moves from the north (mangrove ecosystem) through residential waters and then to the southeast (ocean), causing many residential waters areas to be traversed by plastic waste or microplastic particles originating from the north (mangrove ecosystem). Compared to other areas, the dominant current direction causes the distribution of microplastics to be southeast, where the distribution direction follows the current (Purba et al., 2022).

This study found very high microplastic contamination in residential waters because this coastal area is a strategic area for economic activities, especially fishing. Many fishing activities in this area anchor their boats on the beach in tidal areas. Several damaged shipwrecks and fishing gear in the form of nets are also found on the coast and are suspected of contributing to microplastics in the waters. Shipwrecks and their furniture inside, made of plastic and nets, will undergo a process of degradation and contribute microplastic particles to coastal areas and into the oceans.

This study also revealed that coastal communities still throw garbage into coastal areas due to the unavailability of waste management facilities and infrastructure, so this behaviour is still often carried out. As a result, this activity resulted in the entry of plastic contamination into the oceans and degraded the environment. Therefore, residential areas have much microplastic contamination.

This research is in line with Hiwari et al. (2019) which revealed that coastal residential areas have great potential to produce plastic waste. The resulting plastic waste contributes to microplastic contamination in coastal areas, especially plastic bags and food or beverage packaging the form of plastic (Garcia et al., 2019).

Meanwhile, the lowest microplastic contamination was found in river and estuary areas with very low microplastic abundance ranging from 0.487 particles/gram to 0.00 particles/gram (wet weight) or no microplastic contamination. The river area will also experience a decrease in water quality due to garbage dumped into the river; the most dominant type found is plastic. However, the river area at the research location is a pond area that is less populated, so there is less domestic activity which can cause microplastic contamination in the waters. This study found different results from research conducted on the Brantas River, a densely populated area, indicating 47 particles/individuals in bivalves (Wijayanti et al., 2021).

The results of this study are also in line with those carried out by Azizah et al. (2020) which showed that the most microplastics were found in river estuaries at Kartini Beach, Jepara Regency, Central Java, namely at river mouths at TPI (Fish Auction Place) as many as 643 particles/50 g sediment, followed by the BBPBAP River Estuary (Brackish Water Aquaculture Center) 499 particles/50 g of sediment and at least at station 2 totalling 438 particles/50 g of sediment.

In the western part (rivers and river estuaries) of Jeneponto Coast, currents are heading southeast with relatively slow current speeds. At the same time, the direction of currents and winds coming from the north (mangrove ecosystem area) and west (river area) is heading to the southeast. The current speed in the north is also quite large compared to other locations, so the river and estuary areas are less contaminated with microplastics compared to other areas due to the lack of sources of microplastic contamination and are not traversed by currents originating from the north (mangrove ecosystems) and residential water areas with very high microplastic contamination.

This study also obtained that microplastic contamination in offshore areas with moderate to very low contamination, namely between 0.974 particles/g (wet weight) to 0.0 particles/g (wet weight), is lower when compared to mangrove ecosystem areas and residential waters is due to a lack of domestic activities because the population density living in this area is quite low. Hence, this area is less contaminated with microplastics; besides that, the community only uses the area to collect blood clams (Anadara granosa) for daily consumption of side dishes.

This study is different from the research conducted by Laila et al. (2020) in the water area in Mangunharjo Village, Tugu District, Semarang City, which showed an average yield of microplastic abundance in coastal ecosystems of 8,107 particles/m^3 because this area including beaches where there are still frequent fishing activities and industrial activities around the Mangunharjo coastal area such as the plywood, plastic and ceramic industries.

The contamination of offshore areas, which is higher than the areas of estuaries and rivers, is in line with research conducted by (Laila et al., 2020), which shows that several factors make coastal ecosystems higher or different in microplastic abundance from rivers, one of which is the factor is the speed of the water or currents that can carry plastic from downstream to ocean waters. Tides also affect the presence of microplastics on higher beaches. According to Cauwenberghe et al. (2013)), the abundance of microplastics in the tidal zone at the highest tide limit is higher than at the lowest low tide. There is a significant difference between the two.

3. Impact of Microplastic Contamination on Blood Clams (Anadara granosa)

The contamination of microplastic in the coastal area of Jeneponto Coast on blood clams (Anadara granosa) can impact ecology. The people in the area's habit of consuming shellfish as a daily side dish causes health risks through ingestion, accumulation and translocation. The European Union Commission in 2017 stated that microplastics are of particular concern because they have negative effects on the environment, aquatic life, biodiversity, and possibly on human health due to their small size, which facilitates absorption and bioaccumulation by organisms or the complex toxic effects of the chemical mixtures that comprise it (Backhaus & Wagner, 2020).

a. Impact of Microplastics on Ecology

Microplastics, which include plastic waste and synthetic fibre, are very dangerous for marine life; microplastics are caused by dumping waste directly into the sea or from rivers that flow into the sea due to the absence of waste management facilities and domestic activities and fishing activities. Microplastic contamination that occurs in coastal areas on Jeneponto Coast will have an impact on ecology.

Microplastics can be dangerous because their fibre can inhibit the digestive system of biota or living creatures such as fish and shellfish. The accumulation of waste in the digestive tract can cause a false feeling of fullness, which causes the fish to experience a decreased appetite. Various forms of microplastic can damage the organs of fish or shellfish, not only parts of the digestive system, but can spread to other organ systems (Laila et al., 2020). Wright et al. (2013), microplastics that enter the animal's body can accumulate in the digestive tract, causing injuries due to microplastic scratches.

Microplastics have various toxicological effects on different organisms. The gut microbiota is closely related to host health and is a target of toxicity for certain pollutants, including microplastics. The fact is that more and more studies have proven that microplastics can not only interact with microorganisms directly but also function as carriers of other pollutants and interact with microorganisms indirectly (Lu et al., 2019).

Microplastic impacts waters and marine biota, which also harms ecosystem health. Microplastics The ecosystem health perspective put forward by Ishak (2019) categorizes the high abundance of microplastics that enter the environment becomes pollution, where microplastics act as a pollutant, a waste product of human life. These pollutants can spread worldwide, knowing no place, no matter how far.

Plastic waste eaten by marine organisms due to food errors and fishing nets that float in the waters past the sea catch marine life long after the nets have been left by fishermen. Microplastic pollution in waters contains toxic substances that can kill organisms quickly and affect reproductive success or organism physiology.

b. Impact on Health

The results showed that microplastics had occurred in blood clams (Anadara granosa) consumed by people in coastal areas on Jeneponto Coast as daily food or side dishes. This contamination will be able to have an impact on humans who consume it. This health risk can arise if there is a process of ingestion or inhalation by consuming blood clams (Anadara granosa); ingested microplastic particles will accumulate in the human digestive tract, excreted within hours or days or translocated from the digestive tract to body tissues (Daud, 2019). Until now, the WHO has not set an allowable intake or maximum limit for microplastics in the human body ((Rahmadhana, 2022).

Microplastic is now a pollutant that is composed of chemical compounds that can have an impact on health. Plastic toxicity can result from the original polymer matrix (e.g. polymer, residual monomer), additives not bound to the matrix, products obtained after degradation processes and adsorbable contaminants. In addition, the toxicity of microplastics also depends on their small size.

Evaluate or provide an assessment of the risks of polymers or their compounds in microplastics; it is determined based on the highest negative impact (Rodrigues et al., 2019).

Supported by Carbery's research which states that microplastic particles can cause biomagnification and bioaccumulation in the human body resulting in health impacts on humans, including skin irritation, respiratory problems, diseases of the circulatory system, digestion and problems of the reproductive system (Carbery et al., 2018).

4. Handling the Risk of Microplastic Contamination in Blood Clams (Anadara granosa).

When the aquatic environment is contaminated with sewage, shellfish accumulate and pose a health risk when consumed raw or cooked. Three processing processes have been used to make these shellfish suitable for consumption. First, it is heated (cooking) so that it can be used to destroy pathogens before consumption. Second, mussels harvested from polluted areas can be replaced in clean areas (areas free from pollution) so that the shells can be cleaned or self-cleaned. This process is called 'relaying' or 'container relaying'. Third, the 'natural cleaning' process can be carried out in a controlled environment by immersing in a tank filled with clean seawater to allow the waste contaminants to be washed away. This process is called 'cleaning' or 'controlled purification', or depuration (Saputri, 2020).

Depuration is an effort to reduce/eliminate microplastic contaminants, one of which is by using a water circulation system. This study aims to determine the effect of depuration on microplastic contamination in shellfish. Putro (2007) also said that depuration is a very important step to reduce the content of various contaminants in clams. Various depuration periods are used worldwide, ranging from a few hours to several days.

One way to provide consumers with a sense of security regarding the consumption of food, especially shellfish, is by eliminating or reducing some of the hazardous materials from the biological, chemical or physical hazards sector (Sulmartiwi et al., 2019). The depuration method is principally a purification step for biota such as clams caught in polluted waters, and then a cleaning or depuration process is carried out; the purpose of this depuration process is to reduce the risk of bacterial contaminants and some heavy metals which are harmful to human health (Gabr & Gab-Alla, 2008). Depuration can potentially reduce the content of the heavy metal Cadmium in shellfish (Nikmah, 2017).

Conclusions and Recommendations

The conclusions from the results of the study entitled "Spatial Distribution of Microplastic Contamination in Blood Clams (Anadara Granosa) on the Jeneponto Coast, South Sulawesi Province" are as follows:

1. Microplastic content in blood clams (Anadara granosa) was found at all sampling locations, with the highest microplastics in residential waters and the lowest in river areas, with 21 particles and 5 particles, respectively. Two forms of microplastic are found, namely line or fibre and fragments; the type of microplastic is dominated by line type.

2. The abundance of microplastics in blood clams (Anadara granosa) in Jeneponto Coast is highest at point 4 in the mangrove ecosystem of 3.806 particles/gram wet weight. However, there is also high plastic contamination at point 2 of 1.052 particles/gram (wet weight), point 4 is 3.139 and point 5 is 1.530 particles/gram (wet weight) in residential water areas. In contrast, the lowest contamination is at points 2 and 4 at offshore locations and point 5 in river and estuary areas of 0 .00 particles/gram (wet weight) or no microplastic contamination was found.

3. Spatial distribution of microplastic contamination in blood clams (Anadara granosa) using the interpolation model in Coastal Areas of Tarowang District, Jeneponto Regency sequentially from highest to lowest contamination, namely in mangrove ecosystem areas, residential waters areas, offshore areas, estuary areas river to the river area. The high level of microplastics in the mangrove ecosystem area and residential water areas is based on sources of plastic pollution originating from settlements and the trapping of plastic waste in the mangrove ecosystem area, besides that the distribution of

microplastic contamination is influenced by currents and winds moving from the north (mangrove ecosystems) which through residential waters then heading southeast (off seas).

The Recommendation in this study are for the Community Steps to prevent the risk of microplastics from consuming microplastics in blood clams (Anadara granosa) are by using the depuration method to eliminate microplastics in the blood clams (Anadara granosa) consumed. For the Government, Efforts are needed to control microplastic contamination in blood clams (Anadara granosa) by taking remedial steps, namely the local government policy, to provide waste management facilities, especially plastic waste, develop regulations on waste management in coastal areas, establish a supervisory body to control plastic waste by the local government. For the next researcher, more blood clams (Anadara granosa) samples can be conducted to represent each coverage area and describe a more detailed spatial distribution. Further research can be carried out using environmental health risk analysis to carry out a more in-depth analysis of the microplastic content that can interfere with public health and can measure the risk when consuming blood clams (Anadara granosa) regularly.

Reference

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596–1605. https://doi.org/https://doi.org/10.1016/j.marpolbul. 2011.05.030

Avio, C. G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., D'Errico, G., Pauletto, M., Bargelloni, L., & Regoli, F. (2015). Pollutants Bioavailability and Toxicological Risk from Microplastics to Marine Mussels. *Environmental Pollution*, *198*, 211–222. https://doi.org/https://doi.org/10.1016/j.envpol. 2014.12.021

Azizah, P., Ridlo, A., & Suryono, C. A. (2020). Mikroplastik pada Sedimen di Pantai Kartini Kabupaten Jepara Jawa Tengah. *Journal of Marine Research*, *9*(3), 326–332. https://doi.org/10.14710/jmr.v9i3.28197

Backhaus, T., & Wagner, M. (2020). Microplastics in the Environment: Much Ado about Nothing? A Debate. *Global Challenges*, *4*(6), 1900022. https://doi.org/10.1002/gch2.201900022

Badan Pusat Statistik Kabupaten Jeneponto. (2021). *Jeneponto Dalam Angka 2021*.

Barboza, L. G. A., Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin*, *133*(May), 336–348. https://doi.org/10.1016/j.marpolbul.2018. 05.047

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. *Environmental Science & Technology*, *45*(21), 9175–9179. https://doi.org/10.1021/es201811s

Burrough, P. A., McDonnell, R. A., & Lloyd, C. D. (2015). *Principals of Geographical Information System*. Oxford University Press.

Carbery, M., O'Connor, W., & Palanisami, T. (2018). Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. *Environment International*, *115*(December 2017), 400–409. https://doi.org/10.1016/j.envint.2018.03. 007

Cauwenberghe, L. Van, Vanreusel, A., Mees, J., & Janssen, C. R. (2013). Microplastic Pollution in Deep-sea Sediments. *Environmental Pollution*, *182*, 495–499. https://doi.org/10.1016/j.envpol.2013.08. 013

Central Bureau of Statistics for Jeneponto Regency. (2021). *Jeneponto in Numbers 2021*.

Chavarry, J. M., & Law, K. L. (2019). Microplastic contamination on Anadara granosa Linnaeus 1758 in Pangkal Babu mangrove forest area , Tanjung Jabung Barat district , Jambi. *Journal of Physics: Conference Series*, *1281*. https://doi.org/10.1088/1742-6596/1282/1/012109

Cho, Y., Shim, W. J., Jang, M., Han, G. M., & Hong, S. H. (2019). Abundance and characteristics of microplastics in market bivalves from South Korea. *Environmental Pollution*, *245*, 1107–1116. https://doi.org/10.1016/j.envpol. 2018.11.091

CIEL. (2019). *Platik and Health: The Hidden Costs of A Plastic Planet*. https://www.ciel.org/plasticandhealth/

Daud, A. (2019). *Dampak Mikroplastik Pada Kesehatan Masyarakat*. FKM Unhas.

Daud, A. (2020). *Dampak Mikroplastik dan Nanoplastik pada Lingkungan dan Kesehatan*. PT.Global Indoasia Mandiri.

Daud, A., & Mahmuda Dullah, A. A. (2013). *Perspektif Analisis Risiko Lingkungan dan Kesehatan*. Smart Writing.

de Sá, L. C., Oliveira, M., Ribeiro, F., Rocha, T. L., & Futter, M. N. (2018). Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? *Science of the Total Environment*, *645*, 1029–1039. https://doi.org/10.1016/j.scitotenv.2018.07.207

de Souza Machado, A. A., Kloas, W., Zarfl, C., Hempel, S., & C Rillig, M. (2018). Microplastics as an emerging threat to terrestrial ecosystems. *Glob Chang Biol*, *24*(4), 1405–1416. https://doi.org/10.1111/gcb.14020

Defontaine, S., Sous, D., Tesan, J., Monperrus, M., Lenoble, V., & Lanceleur, L. (2020). Microplastics in a salt-wedge estuary: Vertical structure and tidal dynamics. *Marine Pollution Bulletin*, *160*(May), 111688. https://doi.org/ 10.1016/j.marpolbul.2020.111688

Delya, I., Diansyah, G., & Melki. (2021). *Analisis Kelimpahan Mikroplastik pada Saluran Pencernaan Kerang Darah (Anadara Granosa) di Perairan Sungsang, Kabupaten Banyuasin Sumatera Selatan*. Univesitas Sriwijaya.

Dewi, I. S., Budiarsa, A. A., & Ritonga, I. R. (2015). Distribusi Mikroplastik pada Sedimen di Muara Badak, Kabupaten Kutai Kartanegara. *Depik*, *4*(3), 121–131. https://doi.org/10.13170/depik.4.3.2888

Di, M., & Wang, J. (2018). Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. *Science of the Total Environment*, *616*, 1620–1627.

Digka, N., Tsangaris, C., Torre, M., Anastasopoulou, A., & Zeri, C. (2018). Microplastics in mussels and fish from the Northern Ionian Sea. *Marine Pollution Bulletin*, *135*(February), 30–40. https://doi.org/10.1016/j.marpolbul.2018. 06.063

Environmental Systems Research Institute. (1996). *ArcView Spatial Analyst: Advanced Spatial Analysis Using Raster and Vector Data*. ESRI.

ESRI. (2008). *Deterministic Methods for Spatial Interpolation*.

Fitri, S., & Patria, M. P. (2019). Microplastic contamination on Anadara granosa Linnaeus 1758 in Pangkal Babu mangrove forest area, Tanjung Jabung Barat district, Jambi. *Journal of Physics: Conference Series*, *1282*(1), 12109. https://doi.org/10.1088/1742-6596/1282/1/012109

Gabr, H. R., & Gab-Alla, A. A.-F. (2008). Effect of transplantation on heavy metal concentrations in commercial clams of Lake Timsah, Suez Canal, Egypt. *Oceanologia*, *50*(1), 88–93.

Garcia, B., Fang, M. M., & Lin, J. (2019). Marine Plastic Pollution in Asia: All Hands on Deck! *Chinese Journal of Environmental Law*, *3*(1), 11–46. https://doi.org/10.1163/24686042-12340034

Hadi, B. S. (2013). Metode Interpolasi Spasial dalam Studi Geografi (Ulasan Singkat dan Contoh Aplikasinya). *Geomedia: Majalah Ilmiah Dan Informasi Kegeografian*, *11*(2), 235–252.

Hadi, S., & Radjawane, I. . (2011). Arus laut. In *Institut Teknologi Bandung*. ITB Press.

Hartmann, N. B., Huffer, T., Thompson, R. C., Hassellov, M., Verschoor, A., Daugaard, A. E., Rist, S., Karlsson, T., Brennholt, N., & Cole, M. (2019). Are we speaking the same language ? Recommendations for a definition and categorization framework for plastic debris. *Environmental Science and Technology*. https://doi.org/10.1021/acs.est.8b05297

Hiwari, H., Purba, N. P., Ihsan, Y. N., Yuliadi, L. P. S., & Mulyani, P. G. (2019). Kondisi Sampah Mikroplastik di Permukaan Air Laut Sekitar Kupang dan Rote, Provinsi Nusa Tenggara Timur.

Pros Sem Nas Masy Biodiv Indon, *5*(2), 165–171.

Hurley R, W. J., & Rothwell, J. (2018). Microplastic contamination of river beds significantly reduced by catchment-wide flooding. *Nat Geosci*, *11*(251), 7. https://doi.org/10.1038/s41561-018-0080-1

Jaya, I. G. N. M., Tantular, B., & Zulhanif. (2017). Optimalisasi GeoDa Dalam Permodelan dan Pemetaan Penyakit di Kota Bandung. *Journal Matematika Dan Ilmu Pengetahuan Alam UNPAD*, *1*(2), 83–92.

Karami, A., Golieskardi, A., Keong Choo, C., Larat, V., Galloway, T. S., & Salamatinia, B. (2017). The presence of microplastics in commercial salts from different countries. *Scientific Reports*, *7*(April), 1–9. https://doi.org/10.1038/srep46173

Kosuth, M., Mason, S. A., & Wattenberg, E. V. (2018). Anthropogenic contamination of tap water , beer , and sea salt. *Plos One*, 1–18. https://doi.org/10.7910/DVN/IFCKDL.Funding

Laila, Q. N., Purnomo, P. W., & Jati, O. E. (2020). Kelimpahan mikroplastik pada sedimen di Desa Mangunharjo, Kecamatan Tugu, Kota Semarang. *Jurnal Pasir Laut*, *4*(1), 28–35. https://ejournal.undip.ac.id/index.php/pasirlaut/article/view/ 30524

Listiani, N. W., Insafitri, & Nugraha, W. A. (2021). Microplastic in different size of Cockle (Anadara granosa) at Kwanyar Waters, Bangkalan District, Madura. *Jurnal Sumberdaya Akuatik Indopasifik*, *5*(2), 169–180. https://ejournalfpikunipa.ac.id/index.php/JSAI/article/view/156/87

Lu, L., Luo, T., Zhao, Y., Cai, C., Fu, Z., & Jin, Y. (2019). Interaction between microplastics and microorganism as well as gut microbiota: A consideration on environmental animal and human health. *Science of the Total Environment*, *667*, 94–100. https://doi.org/10.1016/j.scitotenv.2019.02.380

Mason, S. A., Welch, V. G., & Neratko, J. (2018). Synthetic Polymer Contamination in Bottled Water. *Frontiers in Chemistry*, *6*(September). https://doi.org/ 10.3389/fchem.2018.00407

Maulana, P. B. (2021). *Pemodelan Pola Distribusi Mikroplastik di Perairan Pulau Lusi, Kecamatan Jabon, Sidoarjo*. Universitas Islam Negeri Sunan Ampel Surabaya.

Mohamed Nor, N. H., & Obbard, J. P. (2014). Microplastics in Singapore's coastal mangrove ecosystems. *Marine Pollution Bulletin*, *79*(1–2), 278–283. https://doi.org/10.1016/j.marpolbul.2013.11.025

Nikmah, M. (2017). *Potensi Penggunaan Cangkang Kerang Sebagai Filter Dalam Proses Depurasi Terhadap Kandungan Logam Berat Kadmium (Cd) Pada Kerang Bulu (Anadara Antiquata)*. Universitas Airlangga.

Patricia Blair, G., Towatana, P., Khokkiatiwong, S., Kongket, B., & Moh, J. H. Z. (2021). Microplastic Abundance in Blood Cockles and Shrimps from Fishery Market, Songkhla Province, Southern Thailand. *Sains Malaysiana*, *50*(10), 2899–2911.

Plastic Europe. (2018). Plastics – the Facts, An analysis of European plastics production, demand and waste data. In *Plastics Europe*.

Prata, J. C. (2018). Airborne microplastics: Consequences to human health? *Environmental Pollution*, *234*, 115–126. https://doi.org/10.1016/j.envpol. 2017.11.043

Purba, J. R. N. D., Setiyono, H., Atmodjo, W., Muslim, M., & Widada, S. (2022). Pengaruh Kondisi Oseanografi Terhadap Pola Sebaran Sedimen Dasar di Perairan Mangunharjo, Kota Semarang. *Indonesian Journal of Oceanography*, *4*(1), 77–87. https://doi.org/10.14710/ijoce.v4i1.13214

Putro, S. (2007). Perdagangan Produk Hasil Perairan : Molluska dan Permasalahannya. *Moluska Dalam Penelitian, Konservasi Dan Ekonomi*.

Rahmadhana, R. (2022). Literature Review: Determination Of Microplastic Content In Seafood? *VISIKES: Jurnal Kesehatan Masyarakat*, *21*(2).

Rodrigues, M. O., Abrantes, N., Gonçalves, F. J. M., Nogueira, H., Marques, J. C., &

Gonçalves, A. M. M. (2019). Impacts of plastic products used in daily life on the environment and human health: What is known? *Environmental Toxicology and Pharmacology*, *72*(January), 103239. https://doi.org/10.1016/j.etap.2019.103239

Samantha, D. C. (2019). *Analisis Kelimpahan Mikroplastik pada Kerang Darah (Anadara granosa) di Perairan Desa Banyuurip, Ujung Pangkah, Gresik, Jawa Timur*. Universitas Brawijaya.

Saputri, D. F. I. S. (2020). *Depurasi Mikroplastik pada Kerang Tude (Asaphis Detlorata) di Muara Sungai Lakatong Kabupaten Takalar, Sulawesi Selatan*. Universitas Hasanuddin.

Schwabl, P., Koppel, S., Konigshofer, P., Bucsics, T., Trauner, M., Reiberger, T., & Liebmann, B. (2019). Detection of Various Microplastics in Human Stool. *Annals of Internal Medicine*, *171*, 453–458. https://doi.org/10.7326/M19-0618

Schymanski, D., Goldbeck, C., Humpf, H., & Fürst, P. (2018). Analysis of microplastics in water by micro-Raman spectroscopy : Release of plastic particles from different packaging into mineral water. *Water Research*, *129*, 154–162. https://doi.org/10.1016/j.watres.2017.11.011

Scott, N., Porter, A., Santillo, D., Simpson, H., Lloyd-Williams, S., & Lewis, C. (2019). Particle characteristics of microplastics contaminating the mussel Mytilus edulis and their surrounding environments. *Marine Pollution Bulletin*, *146*, 125–133.

Shen, M., Ye, S., Zeng, G., Zhang, Y., Xing, L., Tang, W., Wen, X., & Liu, S. (2019). Can microplastics pose a threat to ocean carbon sequestration ? *Marine Pollution Bulletin*, *September*, 110712. https://doi.org/10.1016/j.marpolbul.2019.110712

Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in Seafood and the Implications for Human Health. *Current Environmental Health Reports*, *5*, 375–386.

Sugiyono. (2011). *Metode Penelitian Kuantitatif Kualitatif dan R&D*. Alfabeta.

Sulmartiwi, L., Saputra, E., & Pursetyo, K. T. (2019). Aplikasi Sanitasi Kerang dengan Metode Depurasi di Kawasan Kampung Nelayan Kerang Pantai Kenjeran, Surabaya. *Journal of Marine and Coastal Science*, *8*(1), 18–23.

Tuhumury C, N., & Ritonga, A. (2020). Identifikasi Keberadaan dan Jenis Mikroplastik pada Kerang Darah (Anadara granosa) di Perairan Tanjung Tiram, Teluk Ambon. *TRITON: Jurnal Manajemen Sumberdaya Perairan*, *16*(1), 1–7. https://doi.org/10.30598/tritonvol16issue1page1-7

UNEP. (2016). *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.*

Werorilangi, S., Noor, A., Samawi, M. F., Faizal, A., & Tahir, A. (2019). Sebaran Spasial Logam Pb, Cd, Cu, Zn dan Fraksi Geokimia di Sedimen Perairan Pantai Kota Makassar. *Jurnal Ilmu Kelautan SPERMONDE*, *5*(1), 21–28. https://doi.org/10.20956/jiks.v5i1.7029

Wicaksono, E. A., Werorilangi, S., Galloway, T. S., & Tahir, A. (2021). Distribution and Seasonal Variation of Microplastics in Tallo River, Makassar, Eastern Indonesia. *Toxics*, *9*(6), 1–13. https://doi.org/10.3390/toxics9060129

Widigdo, B., Imran, Z., Wulandari, D. Y., Marliana, A., & others. (2021). Spatial distribution of microplastic in sediment of the Citanduy River, West Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *744*(1), 12098.

Wijayanti, D. A., Susanto, C. A. Z., Chandra, A. B., & Zainuri, M. (2021). Identifikasi Mikroplastik pada Sedimen dan Bivalvia Sungai Brantas. *Environmental Pollution Journal*, *1*(2).

Wright, S. L., Rowe, D., Thompson, R. C., & Galloway, T. S. (2013). Microplastic ingestion decreases energy reserves in marine worms. *Current Biology*, *23*(23), R1031–R1033. https://doi.org/https://doi.org/10.1016/j.cub.2013.10.068

Yang, D., Shi, H., Li, L., Li, J., Jabeen, K., & Kolandhasamy, P. (2015). Microplastic Pollution in Table Salts from China. *Environmental Science and Technology*, *49*(22), 13622–13627. https://doi.org/10.1021/acs.est.5b03163

Yona, D., Samantha, C. D., & Kasitowati, R. D. (2021). Perbandingan Kandungan Mikroplastik pada Kerang Darah dan Kerang Tahu dari Perairan Desa Banyuurip, Gresik. *Indonesian Journal of Fisheries Science and Technology*, *17*(2), 108–114.

Yudhantari, C. I. A. S., Hendrawan, I. G., & Puspitha, N. L. P. R. (2019). Kandungan Mikroplastik pada Saluran Pencernaan Ikan Lemuru Protolan (Sardinella Lemuru) Hasil Tangkapan di Selat Bali. *Journal of Marine Research and Technology*, *2*(2), 48–52.