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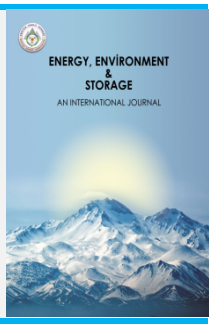

Investigation of Solid Waste Management (SWM) in Coastal Settlement: Makassar City, Indonesia

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ABSTRACT. Solid waste management is among the most popular urban environmental problems in many developing countries due to increasing urban, economic, and industrial activities. Indonesia is a developing country with many coastal settlements, such as Makassar City. This study aims to determine Waste Management on the coast of Makassar City, namely the "Kawasan Pelabuhan", a slum settlement. An investigation was carried out regarding waste generation, storage, and collection. The population of this study was 119 houses/households consisting of permanent and semi-permanent houses partially built over the sea on the coast. The method used in this research is quantitative and qualitative. The analysis results show that the volume of waste generated is around 58% organic and 42% inorganic, with an average of 1.8 kg per household for organic waste and 1.31 kg for inorganic waste. Most houses use individual bins; only houses on the main road get communal collection and storage services.

Keywords: Solid Waste, Waste Management, Waste Generated, Coastal Settlement

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1. INTRODUCTION

Solid Waste Management (SWM) is a scientific discipline related to the control of generation, storage, collection, transfer, transportation of waste, and waste treatment [1]. Currently, SWM is one of the most popular urban environmental problems in many developing countries due to the increasing urban, economic, and industrial activities [2] [3]. Poor municipal waste management practices can result in soil, water, and air pollution [4].

The problem of waste management is also a problem that Indonesia faces as a developing country. Countries with long coastlines are highly prioritized regarding coastal waste and public participation issues [5]. Indonesia is the largest archipelagic country; most of its main cities are in coastal areas, and one is Makassar City. Makassar City is the gateway to Eastern Indonesia, a dynamic metropolis [6] with a population of 1.5 million [7] and the densest population concentration in coastal areas, including along rivers and canals. The coast of Makassar City has experienced drastic urbanization, so it has transformed become a metropolis in the last 15 years [8].

The ever-increasing population will go hand in hand with production waste generation, so this condition must be balanced with waste management. Without adequate waste management, an estimated 80% of the land will end up in the sea [9], [10]. Based on observations from slum area data in Makassar City (Mayor Decree No. 1301/050.13/2021), coastal areas are mostly dominated by slum areas with mild, moderate, and severe levels [6]. Waste management facilities are only 8% of slum settlements [6]. The "Kawasan Pelabuhan" slum area is one of the slum areas on the north coast of Makassar City, which is the research location.

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This study aims to determine the Solid Waste Management activities that occur in the slum area "Kawasan Pelabuhan", including characteristics of generation, storage, and collection. This research will provide insight into SWM that applies in coastal areas of developing countries and will become the basis for stakeholders in managing SWM.

2. MATERIALS AND METHODS

2.1 Location of Study

The study is in "Kawasan Pelabuhan", located in the north part of Makassar. **Fig. 1** shows a map of Indonesia, and the arrow points to the study area's location (5.110958 E,119.4248602 S).

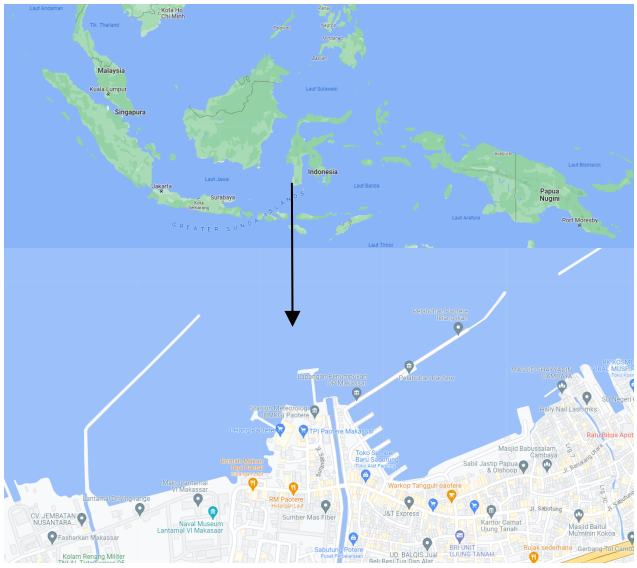

Fig. 1. Location of study

Fig. 2. The condition of the Kawasan Pelabuhan coastal area

The slum settlement in the New Port area is in Cambayya Village in **Fig 2**, with a population of 6,428 people, a total of 1,267 families, and a population density of 12,128 people/km2.

2.2 Characteristics of Settlement

The city keeps experiencing rapid economic development, population, urbanisation, and expansion of residential areas. Those who choose to live in slum areas are mostly urbanites who want to be close to workplaces in the city but cannot buy decent land [7].

The high price of land in the city centre makes some of them occupy vacant public lands such as road shoulders, riparian areas, riverbanks, and canal banks. This settlement is generally semi-permanent housing, which continues to grow with the inadequate physical condition of the building and the environment; this is known as the slum area [3]. This phenomenon occurs in Makassar City, Indonesia.

The Mayor's Decree on Slums of 2021 has designated 20 urban areas as slums with a total area of 428 hectares, most of which are in riparian and coasts. The coastal settlement in Makassar City was originally formed from a fisherman settlement [6]. The history of Makassar City was developed from the coastal area by fishermen who utilised marine resources as the source of life [6]. However, a vast city development transforms this settlement into a slum with limited facilities for life. One of their big problems is waste management. "Kawasan Pelabuhan" is one of the coastal settlements in North Makassar, also located at the edge of the big canal. Most of the people built their wooden houses over the sea. This settlement included part of its low-income class area. The areas with poor social services and amenities are shown in Fig 3.

Fig. 3 Settlement conditions

Buildings Characteristics in the "Kawasan Pelabuhan" settlement are divided into two types, including permanent and semi-permanent buildings shown in **Fig 3**. Most of the semi-permanent (red colour) buildings were built over the sea. The building was built over the land boundary. Moreover, the street in this settlement is a narrow alley about 50 cm in width or less, making it difficult to do several activities, including waste management.

2.3 Material

The tools and materials used in the waste generation survey process as shown in **Fig 4** are:

a. The digital scales used are hand digital scales with accurate, fast, and efficient measurement results to carry anywhere. Each surveyor is equipped with a digital scale.
b. The volume measuring tool is a box that has a volume value description.

c. Plastic bags are given to residents as containers to facilitate the process of weighing waste.
d. Masks and gloves are additional tools used by surveyors in carrying out the weighing process because of the unpleasant odour and the condition of the organic waste, which is sometimes watery.
e. The camera is used for documentation and recording all ongoing activities.
f. As a tool for recording survey results, smartphones use Google Forms to make data collection more efficient.

Fig. 4. Materials and tools

2.4 Method

This research uses SNI 19-3964-1994 as a standard issued by the Indonesian government to take and measure sample generation and composition of urban waste. This method aims to get the amount of waste generation used in waste planning and management.
Sampling locations for waste generation are divided into 2 main groups, namely:
1) Housing consisting of:
(1) permanent high income;
(2) moderate-income semi-permanent;
(3) non-permanent low income
2) non-housing consisting of:
(1) shops;
(2) office;
(3) school;
(4) market;
(5) roads;
(6) hotels;
(7) restaurants, eating houses;
(8) other public facilities.

In this study, we limit ourselves by taking a special sample of residential areas. Permanent housing represents high-income settlements, semi-permanent settlements represent moderate income, and non-permanent settlements represent low incomes.

The condition of a permanent house is made of concrete or bricks that stand firmly, and a semi-permanent building is an independent building, such as a hut or cottage, built with locally available materials. For example, such as wooden planks, sun-dried bricks, straw or other vegetable materials for the purpose of private residence. Non-permanent buildings are temporary buildings, materials that last only a short time or can mean buildings that can be moved, and their useful life is not more than 10 years.

In this research area, there are no non-permanent buildings, and there are only two types of buildings: permanent and semi-permanent as shown in **Fig.6.**
Total population (housing units) = 119 housing units consisting of 57 units of permanent houses; and 62 units of semi-permanent houses.
(S1) = proportion of the number of permanent housing/ high-income households = 48%
(S2) = proportion of the number of semi-permanent housing/ moderate-income households = 52%

This research was conducted through several activities:
2.4.1 The questionnaire survey
This activity was carried out to discover people's lifestyle in "Kawasan Pelabuhan". Questionnaires were distributed to 119 respondents living in two types of houses (permanent and semi-permanent). The questionnaire asks about the resident's environmental characteristics in waste management (storage, sorting, collecting, transportation) and their current behaviour.

Fig. 5. Waste generation survey process

2.4.2 Field observation of waste generation
Each household is given labelled waste plastic. Each household that became the research sample was asked to fill a garbage bag and sort organic and inorganic waste. This process lasts for 8 consecutive days. Every day a surveyor will come to weigh the waste in each sack, measure the volume, and keep records shown in **Fig.5**. In addition to measuring waste generation, at the same time a questionnaire survey was conducted regarding the characteristics of the local community from the aspects of education, economy, employment, and family structure. The housewife or the head of the household was selected as the person who was the respondent to the questionnaire. The questionnaire was made as an open question on Google form, and the surveyor read the question and filled in the answer column according to the answer given by the respondent.

2.4.3 Direct interview
In-depth interviews with key informants were required in this study. Key informants are considered capable of providing information about the object of research. In-depth interviews are open-ended questions and answers to obtain data about participants' intentions – how to describe their world and explain or express their feelings about important life events [11].

This interview was conducted to explore the waste generated every day by households. A total of 5 homemakers who are female leaders in the community were selected to be interview subjects as respondents. In

addition, interviews were also conducted with village heads as respondents who were considered to know the activities of their residents.

Examples of questions given in general regarding how the local community behaves in disposing of garbage, what is the system for collecting and transporting waste (waste collection equipment, collection frequency, collection organisers, transportation routes), and container systems.

In-depth interviews are very important because local people with secondary and lower education levels need more knowledge about waste management. It is common for some residents to be less open in providing information because they fear various things, so this approach is considered better for gathering information.

2.4.4 Mapping

A mapping process is carried out to report collection services and routes.

2.5 Sample

The population in the solid waste survey is housing units living in the coastal settlement area of "Kawasan Pelabuhan". The research population was determined, considering the location in the coastal area and the mouth of the canal so that it has more urgency than the other locations.

The research location is the "Kawasan Pelabuhan", one of the coastal slum settlements in Makassar City with an area of around 1.97 Ha in 2021. Then 119 houses were selected as the study population located at the mouth of the canal with the characteristics of permanent and semi-permanent buildings.

Determination of waste generation samples follows the provisions of the Indonesian National Standard (INS) 19-3964-1994 (Measurement Method of Collection and Composition of Municipal Solid Waste Samples).

The sample size is determined using the formula from SNI 19-3964-1994 as in Equations (1) and (2):

$$S=Cd\sqrt{PS} \quad (1)$$

Cd is the domestic coefficient (0.5 for average/small city), and Ps is the total population. The sample size (S) is divided by the number of household members (n) to count the number of household samples.

$$K=\frac{S}{n} \quad (2)$$

Furthermore, the house chosen as the sample was taken randomly according to the agreement that the family was willing to participate in the waste collection process. This survey has challenges due to the habits of some residents who sometimes immediately throw the trash into the sea. Besides, residents are not accustomed to sorting trash and need help understanding the differences between organic and inorganic waste.

2.6 Analysis

Waste generation data from recording primary data in the field are inputted and analysed statistically. Likewise, the data from the questionnaire results were then analysed using statistical primary data tabulations. A descriptive analysis was performed for in-depth interviews to check the answers and incorporate them into the report. Finally, an overlay map is used to determine the service area for waste collection and waste storage.

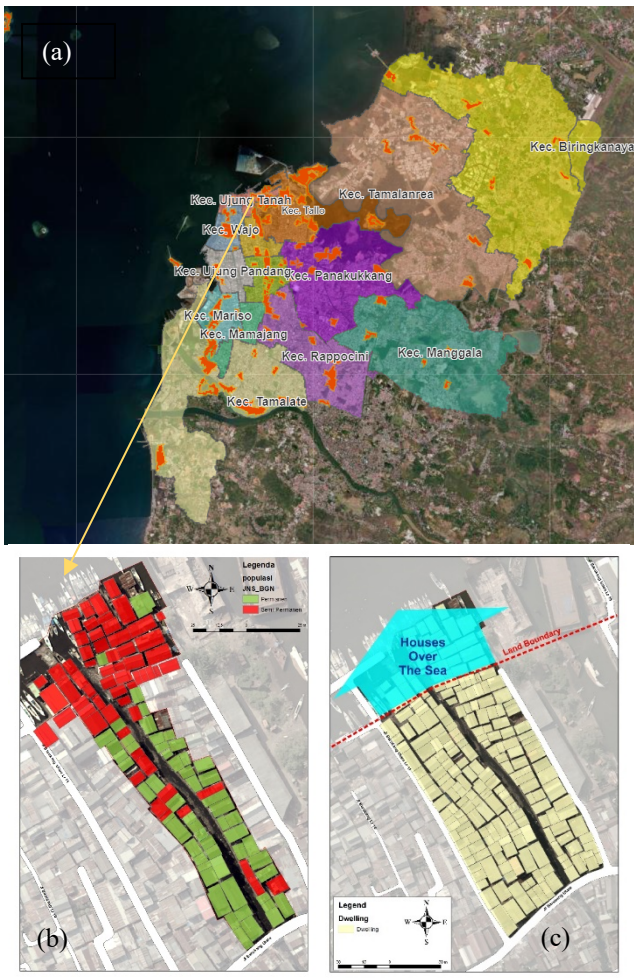

Fig. 6 (a) Distribution of slum settlements in Makassar City (b) Location of survey (c) Orientation of the building towards the sea

3. RESULT AND DISCUSSION

3.1 Characteristics of Respondents

Of the total respondents were 119 households, 35% were male, and the remaining 65% were female. Most of the respondents were female, as solid waste management encourages the participation of females. The average age of the respondents is above 40 years. Five people and 4 people dominate each house, but up to 12 occupied houses.

Based on the level of education, most of the respondents (34%) did not receive a formal education, this was quite related to their livelihood, which was dominated by the informal sector, and 66% of the respondents had several levels of formal education such as only graduating from elementary school (19.1%), (17.2%) graduating from high school, (11.3%) diploma, and (18.3%) undergraduate.

Regarding the job category, (71%) are self-employed, and (29%) of respondents are government employees. The livelihoods of the head of the family are daily labourers

(41%) and fishermen (35%). This condition is supported by the coastal area near the sea and the port area, allowing them to work in the informal sector as casual daily labourers at the port. The average earner (50%) has 66 USD/month earnings, up to 132 USD/month, and only a small percentage earn above 199 USD/month.

3.2 Waste Generation Result

Fig 7. describes the result of the waste generation survey of waste weight from 34 research samples of 34 houses. From this survey, the average waste generation was 1.8 kg of Organic Waste per day per house and inorganic waste 1.31 per day per house.

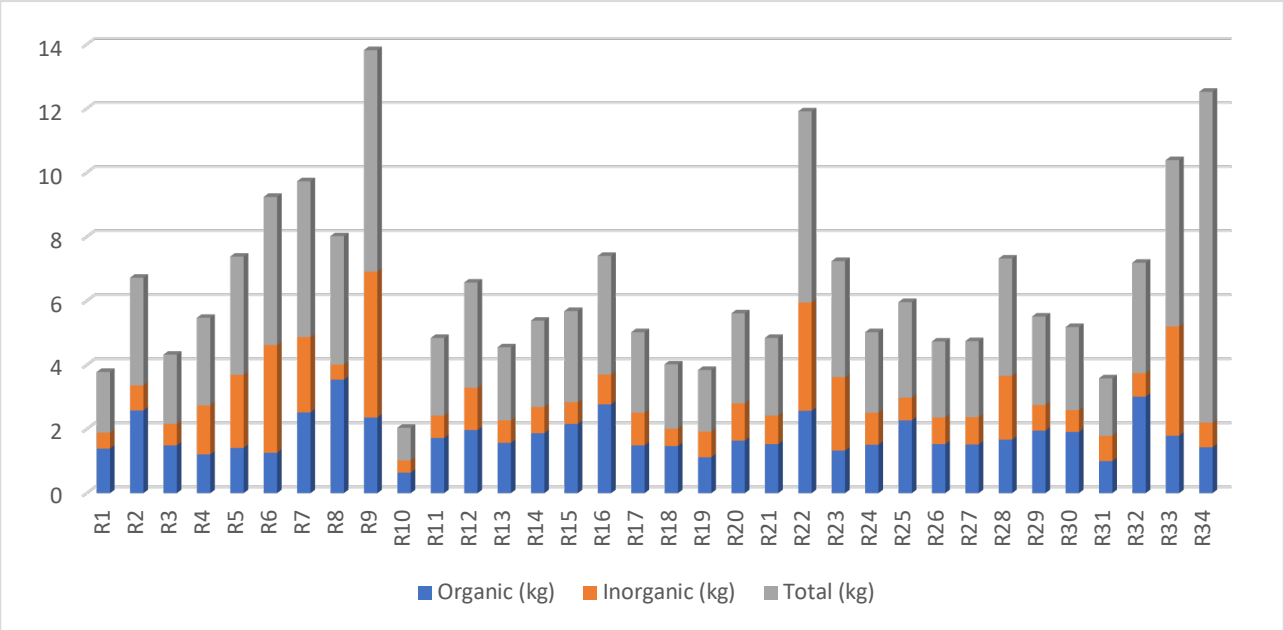

Fig. 7 Waste generation based on the waste weight in kg (R1-R34 as sample code).

Table 1 Survey results of the average volume of organic and inorganic waste generation

Sample Code	Average volume of organic waste generation/house (liter/house)			Sample Code	Average volume of organic waste generation/house (liter/house)		
	Organic	Inorganic	Total		Organic	Inorganic	Total
R1	3.83	5.00	9	R18	4.00	5.33	9
R2	4.50	7.00	12	R19	1.33	7.83	9
R3	2.83	7.17	10	R20	3.67	8.83	13
R4	2.17	9.83	12	R21	4.17	9.00	13
R5	2.67	17.33	20	R22	7.83	16.00	24
R6	2.00	20.83	23	R23	3.33	13.33	17
R7	8.33	14.83	23	R24	3.67	8.50	12
R8	9.67	2.83	13	R25	7.83	7.50	15
R9	5.67	12.17	18	R26	4.50	8.33	13
R10	2.83	4.17	7	R27	4.67	8.67	13
R11	3.17	3.17	6	R28	5.50	14.67	20
R12	5.83	2.00	8	R29	6.50	8.00	15
R13	3.83	4.17	8	R30	6.17	7.00	13
R14	5.17	4.83	10	R31	2.17	8.00	10
R15	6.33	5.50	12	R32	9.33	7.00	16
R16	9.00	5.50	15	R33	5.17	22.00	27
R17	3.83	8.17	12	R34	3.67	7.33	11

The volume of waste generated in the "Kawasan Pelabuhan" coastal area was dominated by 58% organic waste and 42% inorganic waste as shown in **Fig. 8**. This waste was potentially thrown into the water bodies without proper waste management. Compared to other big cities in Indonesia, biodegradable organics were 68% in Jakarta and 72.41% in Surabaya [12]. The values for the cities of Jakarta and Surabaya differ higher because the data from the two cities is a total of one city and does not specifically describe coastal areas. There is also another cause where the people who live in the "Kawasan

Pelabuhan" are middle to lower-class people who are economically difficult, so they have a limited variety of food and do not have food waste behavior. Refers to other developing countries in Asia, shown the same existing conditions, the solid waste generation was high because of the population, and the main component of SW is decomposable [12], Whereas, in Asian developed countries, such as Japan, Singapore, Taiwan, and South Korea, these values were generally less than 45% [13].

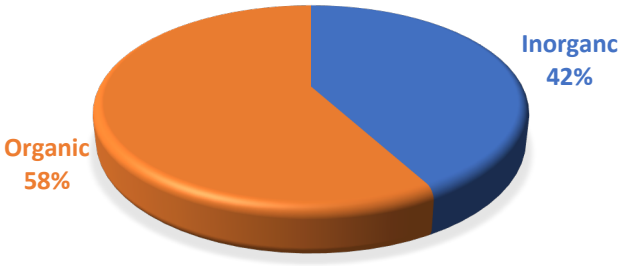

Fig. 8. Average percentage of weight of organic and inorganic (waste/house/kg)

Solid waste generation depends on lifestyle, habits, food, living standards, season, and commercial activities degree [14]. The highest fraction of organic waste is in the low-class area [15]. However, managing waste is a complex activity that requires appropriate technical solutions, cooperation between all stakeholders, and sufficient organization capacity [16]. Furthermore, the urban waste composition is changing recently with the increasing single use of packing materials and plastics [3], [17].

3.3 Storage System

The existing container system was used as an individual and communal system. Each family collected waste from individual containers and brought it to a communal container located on the main road in a residential area. Some families potentially directly throw their waste into the water bodies, especially those who live over the sea or in front of the canal.

The survey results show that 80% of the community did not yet separate their waste because of a lack of materials, knowledge, and motivation. Citizens need to be educated to keep bins for waste storage at the source and stop littering on the water bodies and streets.

Waste disposal has become a serious problem worldwide, especially in developing countries [18]. Problems such as ecological imbalances and certain diseases have taken over the world, causing damage to the natural environment and its resources [19]. Many biological species are on the verge of extinction due to a worsening ecological imbalance. This condition is due to the widespread use of non-biodegradable waste, such as plastic and the hazardous chemicals used to synthesise it. It can also cause soil, water, and air pollution, harming human health [20] [21]. This condition certainly requires serious and continuous efforts to overcome it. On the other hand, organic waste can also pollute water bodies by increasing BOD and COD [22].

3.4 Collection System

Transportation is important to SWM because waste not collected and transported will cause environmental problems [1]. The collection in the location of the study is carried out frequently, almost every day, and a cleaning fee is charged to the people.

Fig. 9. Visualization of collection service and route.

However, not all households receive good collection services. The type of collection vehicle is a three-wheeled motor. Visualization of the collection service and route is shown in **Fig. 9.**

The challenge in the waste collection process in this area is the narrow roads that are difficult for waste transport vehicles to pass. In some slum areas, families still lack access to waste collection sites [6]. Cleaning costs are also considered to be a burden for the middle to lower-economic communities who live there.

Based on **Fig. 9**, a collection route by vehicle was shown in the dotted red line so that most of the settlements do not get a collection service (shown in the light-yellow area).

Community participation has a direct bearing on the efficiency of SWM. Without a basic facility for storing and collecting waste from sources, communities are prone to dumping waste on the streets, open spaces, drains, and water bodies in the vicinity creating unsanitary situations [17] [3].

4. CONCLUSION

In general, waste management in the "Kawasan Pelabuhan" Coastal Settlement has not gone well due to the characteristics of the settlements, the characteristics of

the residents, and the lack of MSW facilities. The waste generated in the "Kawasan Pelabuhan" is dominated by 58% organic and 42% inorganic waste, and most residents do not have access to waste collection points. Hence, domestic waste has the potential to enter water bodies. Serious attention is needed in implementing SWM in coastal areas by adding facilities that are by the characteristics of the local area and community development activities to improve the local community's lifestyle. Additional research is needed to calculate the type of waste and the potential amount of waste that enters the water bodies.

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