Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

ISSUES RELATING TO WASTE TRANSPORT SYSTEM IN SEKUPANG BATAM CITY

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ABSTRAK

Untuk mencegah agar tempat sampah atau wadah sampah tidak meluap dan sampah terpantau tidak berserakan dijalan, maka diperlukan pengangkutan sampah yang disimpan di depot penampungan sampah secara berkala. Untuk menjaga kondisi higienis di kota, pembuangan sampah di tempah penyimpanan sementara (TPS) harus disediakan. Melihat latar belakang tersbut, maka penelitian dilakukan untuk mengevaluasi system pengangkutan sampah di Kecamatan Sekupang tahun 2022. Pada tahun 2022, Kecamatan Sekupang memiliki luas wilayah 68,30 km^2 dengan jumlah penduduk 156.283 jiwa. Peneliatian ini bertujuan untuk menganalisis metode transportasi pengangkutan sampah, pengelolaan transportasi pengangkutan sampah, dan permasalahan terkait dengan transportasi sampah di Kecamatan Sekupang. Metode yang digunakan untuk mengevaluasi permasalahan pengangkutan sampah adalah metode *Hauled Container System (HCS), Stationary Container System (SCS),* pengumpulan data dengan observasi lapangan, studi literatur, dan studi dokumentasi. Pengamatan dilakukan di 4 lokasi TPS di Kecamatan Sekupang yang akan dibawa ke TPA Punggur. Hasil kajian menunjukkan bahwa proses pengangkutan sampah di Kecamatan Sekupang cocok menggunakan HCS dan SCS. Sedangkan permasalahan yang terjadi adalah kurangnya armada kendaraan pengangkut sampah untuk mengangkut 110 ton per hari. Selain itu, akses jalan kendaraan pengangkut sampah ke TPS atau sumber dari rumah ke rumah tidak memadai sehingga membutuhkan lebih banyak pekerja untuk mengumpulkannya langsung sebelum dimasukkan ke dalam truk. Sehingga dengan penambahan satu unit *dump truck* berkapasitas 2,5-ton dan satu unit *arm roll truck* berkapasistas 2-ton untuk 4-unit bak penampung di setiap TPS akan dapat memenuhi kebutuhan pengangkutan sampah yang dihasilkan. Selain itu, dengan akses jalan yang lebih baik dan penambahan kendaraan pengangkut sampah lainnya akan memudahkan proses pengangkutan sampah di Kota Batam.

Kata kunci : Sistem Pengangkutan Sampah, Alat Transportasi Sampah, TPA, TPS

ABSTRACT

To prevent waste bins or containers from overflowing and waste from being observed scattered on streets, transportation of the waste kept in waste storage depots at regular intervals was required. In order to preserve hygienic conditions in cities or towns, frequent waste removal from temporary waste storage depots (TPS) must be provided. Looking at this background, it was the object of discussion for the evaluation of the waste transportation system in Sekupang District in 2022. In 2022, the Sekupang District had an area of 68.30 km^2 with a population of 156,283 people. This study aimed to analyze the method of transportation for transporting waste, the management of transportation waste, and problems related to transportation of waste in the District of Sekupang. The methods used to evaluate the issues of transportation of waste were the Hauled Container System (HCS), Stationary Container System (SCS) methods, data collection by field observation, literature studies, and documentations studies. Observation were made at 4 TPS locations in Sekupang District which would be taken to the Punggur Landfill. The results of the study show that the waste transport process in Sekupang District was suitable for using HCS and SCS. While the problem that occurred was the lack of a fleet of waste transportation

Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

vehicles to transport 110 tons per day. In addition, the road access for the waste transportation vehicles to the TPS or sources from house to house was inadequate which required more workers to collect it directly before it was put into the truck. Therefore, with addition of one dump truck with a capacity of 2.5 tons and one unit of arm roll truck with a capacity of 2 tons for 4 units of container tubs at each TPS, it would be able to meet the needs for transporting waste produced by residents of Sekupang District. Also, with better road access and the addition of other waste transport vehicles, it would facilitate the process of transporting waste in Batam City.

Keyword : Waste Transportation System, Waste Transportation Equipment, Landfill

1. INTRODUCTION

Solid waste refered to waste material which come from household activity, office, resort, hotel, restaurant, industry, constructions, and even old steel from old vehicles[1]. Waste problems were crucial in environment which was parallel with the population enhancement where year by year caused increasing of waste production but lack of awareness by society [2]. Besides, environmental pollution would happen in waste management without efficient methods and technique.

There were several factors that affect the waste arising which were population, socioeconomic conditions where higher condition would produce more waste, and technology advances for managing the waste or production itself [3]. A good waste management was needed for every city government. It was a system that connected with waste arsing control, collecting, transfer and transport, and processing [4]. Government could control and optimize the process of transferring and transporting waste to landfill with specified the optimal route of dump truck [5].

Waste transportation had received considerable attention in waste management system. It was a sub-system that aim to bring waste disposal from transfer location or waste sources to the landfill [6]. Also, with optimizing the sub-system could bring easy, fast and affordable picking-up process.

Sekupang's waste would be deported to Telaga Punggur Sanitary Landfill that had two point five hectares (2,5ha) surface areas that located around twenty to thirty kilometres away [7]. From interviews with the Population and Civil Registration Services as well as Sekupang District Environmental Services, Sekupang had sixty-eight point three zero kilometre squares (68,30 km^2) areas and one hundred fifty-six thousand and two hundred eighty-three (156.283) populations which produced waste around one hundred and ten tons (110 tons) everyday that being one of the reason the research was carried out.

2. LITERATURE REVIEW

The movement of waste from municipal waste to radioactive or hazardous waste over a particular region by trains, tankers, trucks, barges, or other vehicles was referred to as transportation [14]. The collection, transfer, and disposal of solid waste necessitated a substantial expenditure in waste management equipment and vehicles, as well as the infrastructure that enables this machinery to operate properly [15]. As a result, waste transportation consumed the majority of the overall budget for solid waste management and can be a significant financial commitment for many shot-distance wastes transporters. Also, potential of pollution released during waste transportation could be varies; the more hazardous the waste and the greater the volume carried, the more serious the environmental or human health consequences if an accident occurs. Besides, waste spills and pollutant releases from traffic accidents and railway collisions could contaminate the air, water, and soil [14].

2.1 Waste Management System

Organizations used a streamlined procedure called a waste management systemn or garbage disposal to get rid of, minimize, reuse, and avoid trash [16]. Additionally, it refered to a strategy that businesses used to effectively handle wastes from their point of inception until disposal. Recycling, decomposition, incineration, refused to energy, and waste reduction were a few potential waste removal techniques. Unsanitary conditions brought on by improper city solid garbage dumping could result in environmental pollution and outbroke of vector-borne diseases, which were illness transmitted by rodents and insects

Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

[17]. It was also explained the administration of solid waste involved intricate technological difficulties. They also present a broad range of management and solution challenges in the areas of administration, economy, and society.

Waste management system in Indonesia had been written in Indonesia Nasioanl Standard that the increasing of population would reduce the carrying of the infrastructure [4]. The pattern of waste management in many regions in Indonesia was still divided into two (2) groups management, namely between the management carried out by the community from generation, container, transportation, and final disposal or destruction or up to Temporasy Shelters (TPS) and management carried out by government that served the transportation of waste from TPS to Landfill [4]. Also said, management by integrated management of waste by the government or private parties appointed by government in general had not been implemented much, except in a few big cities in Indonesia.

2.2 Waste Transportation

Waste transportation was an activity that bring waste from transfer location or from waste source into landfill [8]. From Table 1, it was shown how to choose the waste transportation machinery based on road condition and pattern of waste collection pattern.

Table 1. Waste Transportation Machinery Choosing Process Based on Waste Collection [8]

Waste Collection Pattern	Road Conditon	Machinery
Direct Individual	Wide and adequate	-Mini truck L-300 -Dump truck
Indirect Individual	Narrow street or alley	-Garbage carts and garbage motorbike tricycles to temporary dump site -Dump truck and Mini Truck L-300 from temporary dump site to landfill
Direct Communal	Hazardous waste such as flammable liquids, radioactive substance, corrosive substances [9]	
Indirect Communal	Organic materials such as fruits, vegetables, tree branches, flowers and grass trimming (EPA,2016)	

Generally, there were several types of waste transportation in Indonesia. Garbage carts with one-meter cubic volume were used in indirect waste collection method and usually used in narrow street or alley. From Ibnu also said Garbage Motorbike Tricycles were used from waste sources to temporary dump site. It was bigger than garbage carts but lack of waste sorting area compared to dump truck.

On the other side, Compactor Truck was one of the best waste transportations [10]. From Figure 1, truck was equipped with compaction tools that giving more space to contain the waste and suitable for communal collection and transportation. It gave cleaner and more hygienis system for collecting the waste. With more treatment of waste at the time of collection, it was a fairly expensive tool to obtain in a waste collection system [10].

Figure 1. Compactor Waste Collection Truck [18]

There was also an Arm Roll Truck where this truck transported and carried hydraulic containers [10]. This truck was more practical and faster in operation which did not require a lot of manpower and also provided cleaner and healthier results which is shown in Figure 2.

Figure 2. Arm Roll Waste Collection Truck [19]

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Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

But it had disadvantages where hydraulics was often damaged, maintenance costs were more expensive and locations were needed for placement and removal [10].

2.3 Waste Transport Methods

Waste transport was one important component and required calculation sufficiently thorough, with the aim of optimizing required transport time in the system especially if there was a waste transfer facility on a large enough scale that had to handle waste, the location of the waste destination point was relatively far away, the transfer facility was a meeting point for the entry of waste from various areas, and traffic problems on the path to the target point of waste destination [10]. Besides, the determining factor in the choice of technique management of waste transportation to be applied were topographic conditions, environment service area, social conditions, economy, community participation, amount and type of waste [11]. The process of transporting waste to the landfill included the following treatment stages: container, collection, transfer and transport. From Damanhuri, there were several qualifications for waste collection transportation such as the transport must be equipped with waste cover, at least with a net, and some more in Table 2.

Table 2. Waste Transport Requirements [10]

No.	Requirements
1	Transport must be equipped with trash cover, at least with a net
2	Maximum body height of 1.6 meters
3	Capacity adjusted to the condition or class the path to be traversed
4	Better have some leverage
5	The truck body or bottom of the container should be equipped with a waste water guard

Damanhuri explained there were two types of waste transport methods which were Hauled Container System (HCS) and Stationary Container System (SCS).

Hauled Container System (HCS)

HCS was a waste collection system where the waste container could be moved and taken to the final disposal site [12]. It is also told that there was a transport patterns in this system that was a container emptying pattern, where an arm roll truck containing empty containers would be brought to the Temporary Disposal Site (TPS) and exchanged with fully filled containers. This system was usually used for commercial areas.

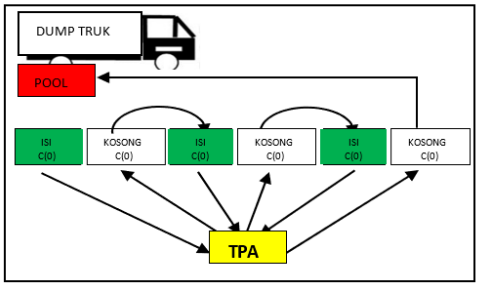

Figure 3. HCS Method 1 [13]

There were several waste collections patterns in HCS such as container tub emptying system method 1, method 2, method 3 [13]. Figure 3 below shows the container tub emptying system method 1. This first method started with the empty arm roll truck to the first temporary disposal site then brought the container to the landfill. After emptying the container, it would put the empty container back to the place where it taken [13]. Then it would be repeated to the last container in the last temporary dump site.

In Figure 4, method 2 is shown as the empty arm roll truck to first temporary disposal site was changed with the fulfilled container then brought to landfill [13]. Continued from landfill with empty container from first temporary disposal site to second temporary disposal site and changed with fulfilled waste container then went back to landfill. Continuously until the last container was changed.

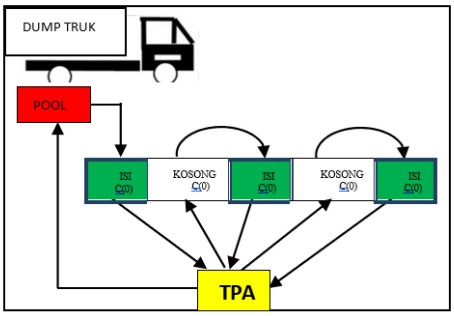

Figure 4. HCS Method 2 [13]

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Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

While method 3 of HCS started with no container arm roll truck went to the first temporary disposal site and bring the container to landfill. After emptying the container, the container brought to the second temporary disposal site and changed with fulfilled container then brought back to landfill. Continously to last temporary disposal site then the empty container from last disposal site would be brought to the first temporary disposal site as shown in Figure 5.

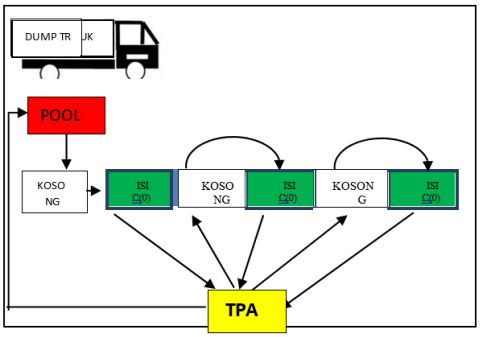

Figure 5. HCS Method 3 [13]

Stationary Container System (SCS)

Stationary Container System (SCS) was a waste collection system in which the collection container was not moved around (fixed) [10]. These collection containers could be either liftable or non-liftable container. SCS was a housing system intended to serve residential areas. As shown in Figure 6, truck from landfill went to the first source of waste poured into the container truck, continously to another source until the container was full then went to the landfill [10].

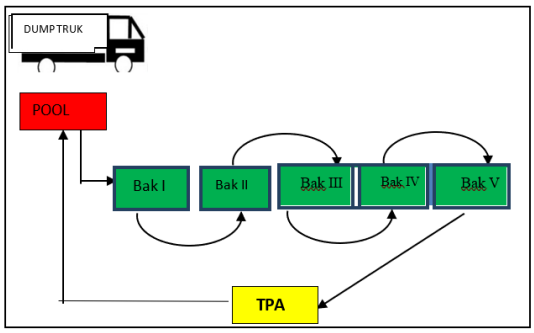

Figure 6. SCS method [13]

3. RESEARCH METHOD

This study focused on the Sekupang waste transportation system problems in order to achieve the research goals. To achieve this goal, observation or field survey methods, literature studies, and documentation studies. Observations were made at four TPS locations in Sekupang District which would be taken to the Punggu Landfill. Also, calculations using the HCS and SCS methods were chosen for this study.

3.1 Data Collection

Primary data was obtained from the Batam City Environment Service Office, including data the amount of volume of landfill waste, number of locations for temporary waste disposal sites, the amount of time required in the transportation of waste transportation (per day rotation), and types of waste transport vehicles from temporary waste disposal site to landfill.

While the secondary data that would be collected was demographic data, location layouts, maps of Batam City, population data of Batam City, data on the number of operational facilities for Batam City garbage trucks, and regional regulations on waste management and local government policies on waste management.

3.2 HCS Method

Hauled Container System had some of calculation that required to analyse the waste transportation.

3.2.1 Haul Time Calculation

Haul time was the time required to get to the location where the container would be transported. The calculation method was as follows [10]:

$$\boldsymbol{H = a + b.x} \qquad (3.1)$$

where
H: Haul Time (hours)
a: The speed of the waste transport vehicle (hour/rite)
b: The speed of the waste transport vehicle (hour/km)
x: Return Distance (km)

3.2.2 P_{HCS} Calculation

P_{HCS} was the time it took to get to the next container location after placing the empty container at the previous location, the time to pick up the full container and the time to return the empty container (rite)

$$\boldsymbol{P_{HCS} = pc + uc + dbc} \qquad (3.2)$$

where
P_{HCS}: Pick up time (hour/rite)
pc: Time to transport the filled container (hour/rite)
uc: Time to empty the container (hour/rite)

Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

dbc: Time to cover the distance from container to another container (hour/rite)

3.2.3 T_{HCS} Calculation

T_{HCS} was the calculation time per rite.

$$T_{HCS} = P_{HCS} + S + H \quad (3.3)$$

where
T_{HCS}: Rite Time (hour/rite)
P_{HCS}: Pick up time (hour/rite)
S: Loading and unloading time at tps or landfill (hour/rite)
H: Haul Time (hours)

3.2.4 Trip Per Day Calculation for HCS (Nd)

The number of trips per vehicle per day for the system HCS could be calculated by:

$$N_d = \frac{[H(1-w)-(t_1+t_2)}{T_{HCS}} \quad (3.4)$$

where
N_d: Total trip per day (rite/day)
H: Working Hour (hour/day)
w: Off-route factor (drag time as friction)
t_1: Time form vehicle pool (garage) to first container on the working day (hours)
t_2: Time from the last container to the garage (hours)
T_{HCS}: Rite Time (hour/rite)

3.3 SCS Method

This method was a waste collection system in which the collection container was not carried around (stay). These collection containers could be either liftable or non-liftable containers. SCS was a high-rise container system intended to serve residential areas [10].

3.3.1 P_{SCS} Calculation

Calculated P_{SCS} or the time needed to load waste from the first location to the last location.

$$P_{SCS} = C_T(Uc) + (np-1)(dbc) \quad (3.5)$$

where
P_{SCS}: Pick up time (hour/rite)
C_T: Number of containers emptied per rite (cont/rite)
Uc: Container emptying time (hours/rite)
Np: Number of container location taken per trip (loc/rite)
dbc: Time wasted moving from one location to another container location (hours/loc)

3.3.2 T_{SCS} Calculation

T_{SCS} was the calculation time per rite.

$$T_{SCS} = P_{SCS} + S + a + bx \quad (3.6)$$

where
T_{SCS}: Rite Time (hour/rite)
P_{SCS}: Pick up time (hour/rite)
S: Loading and unloading time at tps or landfill (hours/rite)
a: The speed of the waste transport vehicle (hour/rite)
b: The speed of the waste transport vehicle (hour/km)
x: Return Distance (km)

3.3.3 Trip Per Day Calculation for SCS (Nd)

The number of trips per vehicle per day for the system SCS could be calculated by:

$$N_d = \frac{Vd}{V.\,r} \quad (3.7)$$

where
N_d: Total trip per day (rite/day)
Vd: Total waste volume per day (m^3/day)
V: Container Volume per rite(m^3/rite)
r: Compation ratio

3.3.4 Working Hours Needed Per Day (H)

Time needed for SCS per day could be calculated as:

$$H = \frac{(t_1+t_2)+Nd(Tscs)}{(1-w)} \quad (3.8)$$

where
N_d: Total trip per day (rite/day)
T_{SCS}: Rite Time (hour/rite)
t_1: Time form vehicle pool (garage) to first container on the working day (hours)
t_2: Time from the last container to the garage (hours)
w: Off-route factor (drag time as friction)

4. RESULT AND DISCUSSION

The results and analysis of data gained from Sekupang Waste Transportation System.

4.1 Patterns of Waste Collection and Transportation in Sekupang District

Waste from residential sources was transported by waste pick-up truck by cleaning workers and the collected at temporary disposal site (communal waste containers), then transported to landfill. The waste collection was done by placing communal waste containers in certain locations, but still need to pay attention to the condition of the containers so that the area around the containers remained clean and the containers were endeavored to had covers.

Determination of the most suitable waste collection pattern in Sekupang District was carried out by obtaining the highest rank or highest percentage from the selection of waste collection pattern criteria. There were three types of waste collection patterns in Sekupang District such as

Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

the direct individual pattern namely the waste from the house was transported directly to the landfill, the indirect individual pattern that the waste from the house was transported to the temporary disposal site to the landfill, and the direct communal pattern namely waste from communal containers serving an area was transported to landfill.

The landfill was located in The Nongsa sub-district, precisely at the Punggur landfill. From direct interviews with workers at the Batam City Environment Service, the number of temporary disposal site in Sekupang District was four (4) where in the sites of Mentarau, Marina, Tanjung Riau, and Tiban Kampung as shown in Table 3.

Table 3. Sekupang District Temporary Disposal Site

Temporary Disposal Site	Arm Roll Containers
Mentarau	2
Marina	2
Tanjung Riau	1
Tiban Kampung	1

From same interview, it was collected that the total amount of waste gathered from January to May in 2022 was around thirteen million kilograms (13kg) that is detailed in Table 4 below. While the average waste collected per day around ninety-one kilograms or a hundred tons.

Table 4. Total Waste Gathered from January to May 2022

Months	Total Amount Per Month (kg)
January	2.674.880
February	2.461.820
March	2.893.670
April	3.050.210
May	2.631.840
Total	**13.712.420**
Average Per Months	**2.742.484**
Average Per Days	**91.416,13**

4.2 Waste Transportation Methods

It was used the second method of Hauled Container System (HCS) in Sekupang District where from observation that the arm roll truck from Punggur landfill brought to the first TPS with empty container changed with the fulfilled container then went back to landfill. Furthermore, the first empty container that had been emptied into the landfill was placed at the next second TPS location and the filled tub was changed and transported to the landfill. And so on, the arm roll truck rotation cycle with the second method of HCS system where the tub was filled by the local community.

Table 5. Total Calculation Time per Rite

TPS	Distance (x) in km	Haul Time (H) in min	P_{HCS} (min)	T_{HCS} (min)
Mentarau	29	64,8	30	94,6
Marina	23	55,2	30	85,2
Tanjung Riau	35	84	30	114
Tiban Kampung	26	62,4	30	92,4
			Average T_{HCS}	**96,55**

From Table 5, shows that the longest distance from temporary disposal site (TPS) to Punggur landfill was Tanjung Riau. It took around a hundred minutes from TPS to landfill and going back to TPS. While the shortest was the Marina Site which only twenty-three kilometers distance from TPS to Punggur landfill. From all, it was calculated that the average time for transporting the waste per rite was ninety-six point five minutes which was more that an hour to finish a cycle of the waste transportation.

On the other hand, the types of waste transportation from house to house to TPS was used Pick-Up Truck and from TPS to landfill was used Arm Roll Truck with detailed capacity in Table 6 below. It shows that the Pick-Up Truck capacity could bring around fourty-two (42) tons per day and sixty (60) tons per day for Arm Roll Truck.

Table 6. Types of Waste Transportation

Types	Total Units	Average Capacity (tons)	Ritation (trip)	Total waste transported
Pick-Up Truck	15	0,7	4	42
Arm Roll Truck	6	2	5	60

In addition, the process of transporting waste in Sekupang District with the Stationary Container System (SCS) pattern used a dump truck type

Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
E-ISSN 2599-0616
P ISSN 2614-5979

vehicle. Waste that was on Poros Province Street was transported into a dump truck by the crews or car personnels until the dump truck was full and then transported to the Punggur Landfill. The process of transporting waste in the Sekupang District to the landfill by using a dump truck took time, which based on the observations will be detailed in Table 7 below.

Table 7. Types of Waste Transportation for SCS

Types	Total Units	Average Capacity (tons)	Ritation (trip)	Total waste transported
Compactor	1	2,5	2	5
Dump Truck	6	2,5	2	30

4.3 The Requirement of a Waste Transportation Unit Amount of Waste Produced in Sekupang District through 2022

Based on Tabel 6 and 7, it was evaluated that Waste Transportation System in Sekupang was one arm roll truck with two tons capacity had five trips so it could carry an average of ten tons in one day. While one compactor truck with two-point five capacity had two trips then it would carry an average five tons per day and a dump truck with capacity of two-point five tons had two trips could carry an average five tons in one day.

As a result, the Sekupang District's waste transportation system could only move about ninety-five (95) tons of waste every day. However, the calculation for the quantity of waste showed that the waste piles in Sekupang District produce a hundred and ten (110) tons per day with 156.283 residents.

Waste Generated
= 0.7 kg x the number of residents per region
= 0.7 kg x 156.283
= 109.398,1 tons ≈ 110 tons / day

From the formula above, it could be concluded that there was a need for additional garbage transportation for Sekupang District. From an evaluation of the number of waste transportation, it was necessary to at least added one arm roll with a capacity of two tons that had five trips so it could carry an average of ten tons in a day and one dump truck with a capacity of two-point five tons that had two trips so it could carry an average of five tons per day. With that, the waste transportation system in Sekupang District could pick a hundred and ten tons per day.

5. CONCLUSION AND RECOMMENDATION

There were currently six dump truck for waste transport and one compactor with a capacity of two-point five tons, and six units of arm roll trucks with a capacity of two tons and fifteen units of pick-up trucks. It was concluded that the most suitable transportation system and waste collection pattern for Sekupang District area using the HCS and SCS methods which with indirect individual, direct individual, and direct communal patterns. Namely by collection by waste pick-up officers from waste sources and then collected in temporary disposal sites before being taken to the Punggur Landfill, this was due to the fact that most of the road conditions were difficult for trucks to pass directly.

With a volume of waste generated at 110 tons per day, the waste that was successfully transported was 95 tons per day. The need for additional vehicle units according to the analysis was one unit for a dump truck with a capacity of two-point five tons and one unit of arm roll truck with a capacity of two tons for 4 units of a two tons capacity container in each TPS.

It is recommended to add a backup unit for waste transportation vehicles so that if there was damage or a breakdown, a unit which was a backup vehicle could be used so that there was no expansion of wate. Besides, there was a need for ongoing socialization of the importance of disposing of trash in the nearest waste container or TPS so that there was no expansion of waste outside the scope of the TPS or containers that had been provided by the Environmental Service.

ACKNOWLEDGEMENT

Special thanks are extended to Faculty of Engineering Universitas Riau Kepulauan for invaluable and stimulating support for this research.

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Sigma Teknika, Vol. 6, No.1 : 214-222
Juni 2023
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