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Development of Reverse Logistics Scenarios for Inorganic Waste Recovery in Grobogan Regency - Indonesia

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Abstract. Reverse logistics is a model of the flow of goods that goes inversely from consumers back to producers to increase the value of goods without wasting any part of the goods (recovery). In this study, the waste management system in Purwodadi District, Grobogan Regency, has been evaluated and propagated using a reverse logistic network system, which is considered more efficient. In-depth interviews and observations were made to understand the flow of waste in each level of recyclers. The flow of plastic, paper, and metal waste were evaluated in this study because it dominates the composition of inorganic waste in Grobogan Regency. The results of the scenario indicate the potential use of a reverse logistic system because it shortens the flow time of waste from consumers to factories. Besides, environmental losses caused by the long process of waste management can be reduced. It is necessary to carry out further evaluation related to economic and environmental benefits due to the development of a reverse logistic scenario for plastic, paper, and metal waste.

1. Introduction

The increase in population is always accompanied by an increase in the amount of inorganic waste. Furthermore, that increase is often not matched by a proper waste management system [1]. Lack of community understanding in managing waste tend to be unsafe and potentially pollute the environment. Therefore, the action is needed to reprocess plastic, paper, and metal waste to reduce adverse effects on the environment. One scenario that can be done is to find out the flow of the waste starts from the consumer and come back to the factory (reverse logistic scenario) [2]. Reverse logistics is a model that focuses on maintenance, recycling, product return, repair, and product disassembly [3]. A reverse logistics network for recycling waste with minimum costs and environmental impacts is needed in waste management [4]. Reverse logistics is an environmentally friendly waste recycling practice by reusing and reducing the amount of material used [5]. Plastic, paper, and metal waste will be reprocessed through reverse logistics network system to be raw material for factories.

The waste problem can occur in most cities, including in Grobogan Regency, Central Java, Indonesia. Purwodadi District, as a district in Grobogan Regency, was chosen as the study area since it has many waste recycling agents compared to other districts in Grobogan Regency. The amount of plastic, paper, and metal waste generated in Grobogan Regency is 14,887.26 kg/day, 13,894.76 kg/day, and 8,932.35 kg/day, respectively. Purwodadi District is also a district with the largest population in Grobogan Regency, which is 139,296 inhabitants [6]. The reverse logistic system in Indonesia has been carried out by the informal sector [7]. However, it has not yet been discovered how the system's impact on environment and waste management. This study attempts to reconstruct the reverse logistic network

system in Purwodadi District, Grobogan Regency, Indonesia, through the evaluation of informal sector of waste management.

2. Research Methods

2.1 Sampling Methods

This research will be carried out in Purwodadi District, Grobogan Regency, Central Java, Indonesia. In this study, informal sector recycling actors such as scavengers, waste bank, collectors, dealers, and grinders/factories were interviewed to obtain relevant data. Figure 1 shows the administrative map of the Grobogan Regency and the study location. This research focuses on informal recycling agents to get information about the flow of inorganic waste into and out of business. That data is used to estimate suppliers and recipients of metal, paper, and plastic waste, each of which will look for the weight of managed, transported, and disposed the waste. The study began with a preliminary survey based on the reference to the rubble business data from the Grobogan District Regional Technical Implementation Unit, followed by selecting the sample location and collecting data using questionnaires and interviews. Since the detailed data of recycling agents are lack, then they are tracked using snowball sampling methods. As for the level of scavenger, there is no exact amount of data in Grobogan District. Then, scavenger surveys are conducted in a random sampling. The research method is illustrated in the Figure 2.

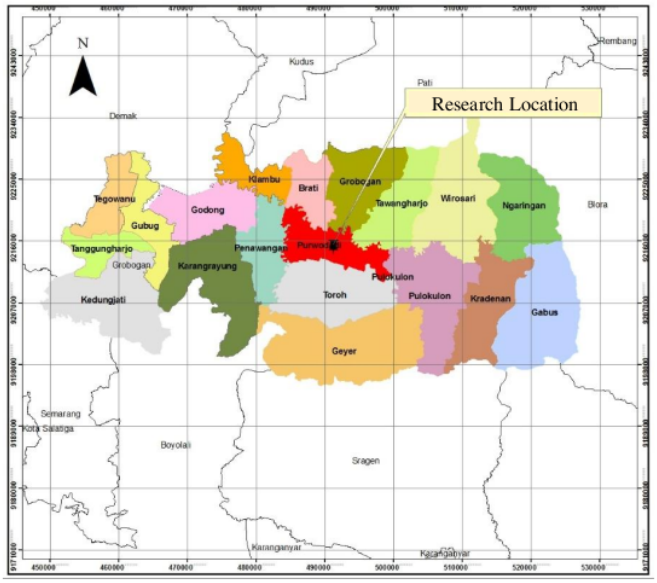

Figure 1. Research maps of Grobogan Regency

2.2. Data Analysis

Data on the amount of waste generation and the location of scavengers, waste banks, collectors I, collectors II, dealers, and grinders will be mapped into a waste management network in Purwodadi District. Identification of waste management flow in informal sector includes:

1. The route of the waste bank to collectors I, collectors II, dealers and grinders or factories
2. The collectors I route to collectors II, dealers, grinder and factory
3. The collectors II route sells their goods to the dealers, grinder, and factory
4. The dealers route sells goods directly to the factory
5. The grinder route sells its goods directly to the factory

The reverse logistics network scenario design is carried out to compare the existing conditions, with the optimization scenario with a centrally inorganic waste processing or known as material recovery facility (metal, paper, and plastic) in Purwodadi District. Scenarios to be made include scenario 1 based on existing conditions that are known from interviews with the perpetrators of metal, paper and plastic waste recycling in Purwodadi District and scenario two which are based on the optimization conditions of Purwodadi District waste collection by combining collectors I, collectors II and the dealers became material recovery facility (MRF).

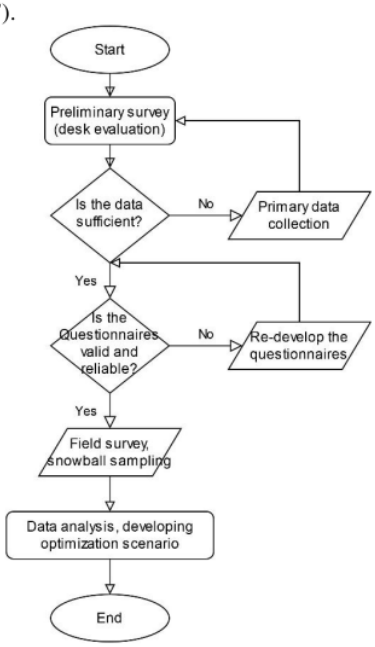

Figure 2. Research flow chart

3. Result and Discussion

3.1 Grobogan Inorganic Waste Management Practices

Waste in Purwodadi District comes from residential, shop, market, and street waste. Residents (waste bank) and informal sector sort and manage inorganic waste from those waste sources. Waste generation in Purwodadi District is 79,398.72 kg/day. This waste is dominated by organic waste (42.50%), and inorganic waste including plastic (18.75%), paper (17.50%), metal (11.25%), and others (10.00%). Waste sorting has not become a habit that can be implemented by the community. Scavengers or housing waste managers will later collect waste which still has economic value such as paper, plastic, and metal. At the same time, the residue will be taken by the waste transporters and waste managers who have collaborated with the community to the temporary waste storages. Waste collected at the temporary waste storages will be taken to the Ngembak landfill.

People who have sorted their waste, usually sell their waste to the waste bank located in their *Kelurahan*, or neighbourhood and untreated waste will be disposed of in the temporary waste storages. Waste can be disposed of directly by the residents to the nearest polling station or transported by officers with the obligation of citizens to pay the cost of waste transport. Besides residents, scavengers also have a role in waste reduction. Scavengers also take waste that has an economic value, which will be sold to waste collectors. Later the waste collectors sell their waste to the recycling industry, which processes the waste into raw material again.

The informal sector recycling actors, which include scavengers, waste banks, collectors I, collectors II, dealers, and grinders, play an essential role in reducing waste in Purwodadi District. In terms of management, the informal sector recycling actors are not related to the government. They set up this business at their own expense. Collectors do not always sell waste to the dealers but can also go to the grinder or factory. Therefore, the researchers classified recycling agents based on the weight of inorganic waste (paper, plastic, and metal) entering the warehouse per day, which can be seen in Table 1.

Table 1. Classification of recycling actors

Number	Recycling Actors	Weight of Waste Received per Day(kg/day)
1	Waste bank	≤ 30
2	Scavenger	≤ 50
3	Collectors I	50-500
4	Collectors II	500-1000
5	Dealers	>1000
6	Grinder	>1000

3.2 Existing Inorganic Waste Management Practices

After detailed observations and interviews in the field, there were found 16 inorganic waste recycling businesses and 14 waste banks in Purwodadi District that were used as research models. The 16 recycling businesses consist of 1 grinder, 5 dealers, 3 collectors II, and 7 collectors I. Meanwhile, among the 14 waste banks in Purwodadi District, there is 1 central waste bank in Purwodadi District. Therefore, scavengers are the critical factors in organizing inorganic waste recycling in the Purwodadi District. The scavenger sort waste which has economic value and does not. Later the disaggregated waste that has economic value will be sold to the closest collectors who have a purchase price they consider high [8].

A waste bank is a place of waste management that applies the 3R system. There are 14 waste banks in Purwodadi district, and one of them is the central waste bank. Waste generated from the waste bank is waste coming from the customer of the waste bank itself. Waste collected is waste that has an economic value in the form of inorganic waste (paper, plastic, and metal). The waste bank weighs once a month. The waste collection will be sorted according to types. The results of the collection of sorted waste will be sold to collectors of recycled waste from customers. Waste that is not sold will later be used as handicrafts in the form of decorations, which can later be marketed and sold to the public. At the waste bank, weighing, sorting, and shipping processes are sold to collectors.

Collectors I is the first level intermediary who will take inorganic waste (paper, plastic, and metal) in more quantities than scavengers and waste banks. The input of inorganic waste produced by collectors I per day is equal to 50-500 kg/day. Seven recycling businesses are collectors I in Purwodadi District. Waste generated from the collectors I is delivered by scavengers, waste banks, and the community. The activities that occur at the collectors I is weighing, buying waste from scavengers, waste banks and residents, sorting and shipping to larger businesses. Collectors I usually have a means of transportation in the form of a pickup car to transport its waste. Collectors I usually have a permanent scavenger to supply its waste.

Collectors II is a waste recycling business that has a purchasing capacity above Collectors I, in terms of the place and scope of waste supply services. Three recycling businesses become collectors II in Purwodadi District. Waste entering from collectors II comes from scavengers, waste banks, and collectors I. In collectors II, there is a weighing process, purchasing inorganic waste from scavengers, waste banks, or collectors I, sorting, and shipping to a more significant recycling business. Collector II usually has a small truck to transport waste from his business to other businesses for sale, or to partners who have collaborated to buy the waste.

Dealer is a waste recycling business with an inorganic waste purchasing capacity of above 1 ton per day. Five recycling businesses are used as dealers in Purwodadi District. The waste that comes from the city comes from scavengers, waste banks, collectors I, and collectors II. There is a weighing process, purchasing inorganic waste, storage, sorting, pressing, and shipping to the mill or grinder. For presses

used are still simple box presses made of wood. The dealer uses a truck to transport waste that will be brought.

Grinder/factory is a final waste recycling business that processes inorganic waste. The selling price in the grinder is already high because it has been through a process of sorting, washing, and grinding. There are grinding machines that are driven by diesel engines. Inorganic waste milling business found in Purwodadi District is a plastic waste grinding business. Paper and metal waste grinding are not yet available in Purwodadi District or Grobogan District, so that the waste must be sent outside the city. The trade route for inorganic waste in Purwodadi District can be seen in Figure 3. From this figure, it can be seen that waste transported from scavengers and waste banks will be taken to collectors I, collectors II, and dealers. From the waste suppliers, the waste will be taken to the grinder and the waste processing factory according to their respective types.

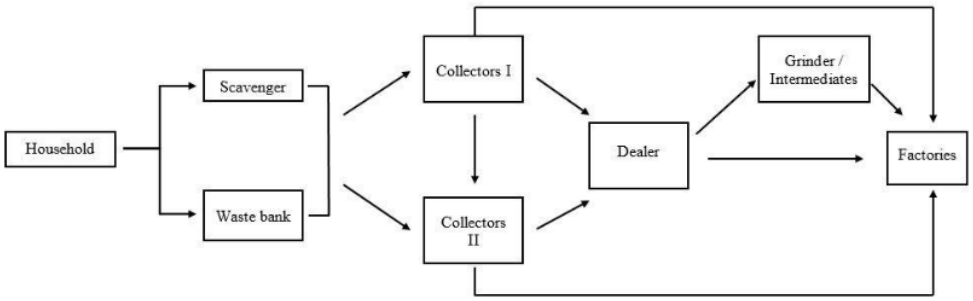

Figure 3. The role of recycling actors in Purwodadi District

3.3 Development of Reverse Logistic Scenario in Grobogan District

Recycled plastic waste by recyclers are in the form of beverage bottles, sauce bottles, ketchup bottles, cooking oil bottles, buckets (soap containers, basins), pipes, clear crackle, glass mineral water, bottle caps, children's toys, electronic devices, and household appliances. Whereas, for the type of paper waste, eight types of waste are traded by recyclers, including white paper, cardboard, duplex, books, newspapers, cement paper, opaque paper, and magazines. The types of metal waste sold by recyclers are iron B, iron A, aluminum cans, metal cans, zinc, copper, aluminum metal, brass, and stainless steel. The reverse logistics network in Purwodadi District has a diverse chain.

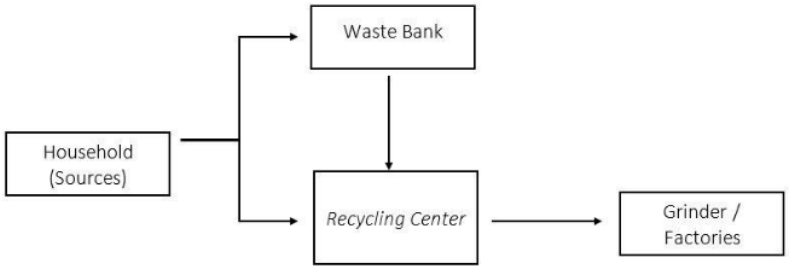

Figure 4. Reverse logistics network systems of inorganic waste in Purwodadi District

The flow of material can be from the waste bank to collectors, dealers, and factories, or from the dealers directly to the grinder. This condition happens due to differences in price quotations and agreements that have been set by sellers and buyers of inorganic waste (plastic, paper, and metal) or to partners who have collaborated to buy their waste. Recycling businesses are independently looking for buyers and suppliers of waste for them. However, the difference in price quotations can be reduced by

creating a recycling unit (material recovery facility - commonly abbreviated as MRF) that can accommodate waste and maintain the stability of the selling and buying prices of each type of waste. Figure 4 shows the reverse logistics path for the three types of waste following the results of a survey that was conducted.

4. Conclusion

The design of reverse logistics scenarios in Purwodadi District is based on existing data from inorganic waste recycling (plastic, paper, and metal). In this study, there is a network map of inorganic waste management (plastic, paper, and metal) through the concept of reverse logistics. The scenario that has been designed has taken into account several factors, such as the sorting place, reprocessing unit, and the amount of waste managed. The scenario of combining the location of collectors I, collectors II, and dealers in a focus recycling centre whose main activities are weighing, sorting, pressing, and transporting is considered capable of optimizing the reverse logistic network system because centralizing waste management might be able to cut costs and greenhouse gas emissions generated. Further research is needed to understand the impact of the proposed optimization scenario. The use of this reverse logistic network system is a way to improve waste management systems in Purwodadi District, Grobogan Regency

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