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Modeling of Waste Processing Tools for Waste Management in Karanganyar Regency

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Abstract: Waste management is a pressing issue today, with a significant amount of waste remaining unaddressed from its source, including at the Sukosari Landfill in Karanganyar Regency. This study aims to identify an effective, efficient, and environmentally friendly incineration-based waste processing tool to overcome waste problems in Karanganyar Regency specifically, and in other regions generally. The method employed involves comparing two waste processing tools: an incinerator and the "Predator Sampah Sedeng" tool. The comparison methodology includes tool specifications, criteria assessment, and scoring evaluation.

The environmentally conscious community of Sedeng Hamlet, Tawangmangu, created the "Predator Sampah Sedeng" waste processing tool for waste management at the smallest community level, such as Neighborhood Associations (RT), Community Units (RW), and villages. This waste processing tool is capable of handling all types of waste, including those currently unmanageable like used diapers and glass fragments, thereby enabling complete waste management at the village level.

The "Predator Sampah Sedeng" tool is a result of creativity and innovation, utilizing waste (used oil) as fuel, is environmentally friendly, can be made from recycled materials, and is capable of generating energy that can be used to support other activities, thus providing appropriate energy. From waste to blessing for all, it is capable of providing economic value for both the implementers and the environment carrying out waste processing activities.

The conclusion drawn from the tool specifications, comparative criteria assessment, and scoring values is that the "Predator Sampah Sedeng" tool is more effective, efficient, and environmentally friendly. This includes: 1) effectiveness, capable of processing 1,500 kg of waste per day within 8 hours, and capable of processing diapers, styrofoam, and glass; 2) efficiency, as the "Predator Sampah Sedeng" tool is very easy to use, has low operational costs due to using waste (used oil) as fuel, and has a very affordable manufacturing cost of Rp. 40,000,000. Additionally, the heat produced is utilized for baking food, drying maggots, and saunas (hot steam baths), while the generated electricity is stored in three 100 A batteries; 3) environmental friendliness, as the emitted smoke does not pollute the environment due to being equipped with a 10m chimney from ground level with a simple filter, and the resulting ash by-product can be utilized as a planting medium and has economic value for sale.

Keywords*: Tool Modeling, Waste Management, Effective, Efficient, Environmentally Friendly, All-Type Waste Processing Machine.*

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I. INTRODUCTION

➢ *Background:*

Rapid population growth, swift urbanization, and consumption patterns that are not balanced with existing waste management systems have led to waste-related problems in Indonesia in general, and specifically in Karanganyar Regency.

Waste management in Karanganyar Regency faces various challenges that require an integrated approach involving the government, community, and private sector. The Sukosari Landfill (TPA) in Jumantono District receives approximately 222 tons of waste per day, mostly originating from households and tourist areas. This condition results in waste piles reaching up to 14 meters high, polluting the air and potentially contaminating groundwater if left unaddressed. Although the landfill area has been expanded, the site is already operating beyond its capacity and cannot

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accommodate the continuously increasing volume of waste. Furthermore, waste processing equipment provided by China has not been operational due to technical constraints and a lack of skilled personnel.

Research indicates that around 41.2% of the community in the Karanganyar Health Center's working area does not manage waste properly. Despite good knowledge and attitudes towards cleanliness, a lack of facilities and awareness contributes to poor waste management practices. In light of these issues, there is a need for effective, efficient, and environmentally friendly waste processing equipment models to address waste problems in Karanganyar Regency specifically, and in other regions generally. Waste handling in a region is a shared responsibility of both the government and the community. Complete waste management at the village level is one method to minimize waste sent to landfills. As a form of environmental awareness and responsibility, environmental communities serve as key partners for the government in contributing to waste management.

SAHABAT ALAM is one such community empowerment initiative that is environmentally conscious and concerned. Driven by concerns over waste problems, the Sahabat Alam community has been motivated to focus on waste processing by utilizing recycled materials with community involvement and empowerment. They primarily address waste generated from community activities by developing a waste disposal tool called the "Predator Sampah Sedeng," which is capable of processing all types of waste, including diapers, styrofoam, glass, and so forth.

➢ *Research Purpose and Objectives:*

The purpose of this waste processing equipment modeling is to compare two waste processing tools: the incinerator owned by the Karanganyar Regency Environmental Agency and the "Predator Sampah Sedeng" waste predator, an innovation developed by the community of Sedeng Hamlet, Beji, Tawangmangu Village, Tawangmangu District. Through this research and analysis, an effective, efficient, and environmentally friendly waste processing tool will be identified for waste management in Karanganyar Regency specifically, and can be recommended for waste management in other regions.

Fig 1 Predator Sampah Sedeng Waste Destroyer to minimize Waste entering Sukosari Jumantono Karanganyar Landfill

II. METHODOLOGY

➢ *Determination of Equipment:*

The waste processing equipment to be compared is as follows:

- Tool A: Incinerator
- Tool B: Predator Sampah Sedeng

➢ *Establishment of Comparison Criteria :*

The criteria for effectiveness, efficiency, and environmental friendliness are presented in the table below:

Table 1 Determination of Comparison Criteria

Criteria	Definition
Capacity (kg/day)	Kilograms of waste per day that can be processed
Operational Cost	Energy, fuel, and labor required
Effectiveness	How optimally waste is processed (e.g., into compost, ash, or energy)
Processing Effectiveness	Level of processing effectiveness (types of waste that can be processed)
Processing Time	Time required to complete one processing cycle
By-Product	Whether useful products are generated (compost, gas, energy, etc.)
Environmental Emission	Whether the tool is environmentally friendly and does not pollute air/soil
Ease of Use	Level of automation, maintenance, and training required
Price	Initial investment for tool purchase

➢ *Data Collection*:

Technical data for the equipment will be obtained from product specifications, case studies, journals, trials, or user interviews.

➢ *Data Analysis Method :*

A quantitative method (scoring method) will be used by assigning a value (1–5) to each tool per criterion. The tool with the highest total score will be considered more effective, efficient, and environmentally friendly.

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III. RESULTS AND DISCUSSION

➢ *Existing Conditions of Karanganyar Regency Landfill:*

The condition of the waste processing site in Karanganyar Regency, namely the Sukosari Landfill in Jumantono District, is very concerning. The Sukosari Landfill receives approximately 222 tons of waste per day, mostly originating from households and tourist areas. This situation leads to waste piles reaching up to 14 meters high, polluting the air and potentially contaminating groundwater if left unaddressed. Although the landfill area has been expanded, the site is already operating beyond its capacity and cannot accommodate the continuously increasing volume of waste. Additionally, waste processing equipment donated by China has not been activated due to technical issues and a shortage of expert personnel.

Improperly managed waste can lead to several negative impacts on the environment, public health, and socio-economic aspects. These impacts are as follows:

- *Environmental Impacts:*

✓ Soil and groundwater contamination: Decomposing organic waste and hazardous waste (such as batteries, electronics) can seep into the soil, contaminating wells and agricultural land.
✓ River and water channel pollution: Improperly disposed waste often ends up in rivers, causing blockages, floods, and damage to aquatic ecosystems.
✓ Greenhouse gas emissions: Decomposing organic waste in open landfills produces methane (CH_4), a greenhouse gas more potent than CO_2.
✓ Unpleasant odors and visual pollution: Unmanaged waste piles lead to a squalid and uncomfortable environment.

- *Impacts on Public Health:*

✓ *Disease Spread:*

Accumulated waste becomes a breeding ground for disease vectors such as flies, rats, and mosquitoes (causing dengue fever, leptospirosis, diarrhea).

✓ *Air Pollution:*

Open burning of waste produces toxic smoke (including dioxins and furans) which is harmful to the respiratory system.

✓ *Infections and Injuries:*

Residents or workers who come into direct contact with waste are susceptible to skin infections and injuries from sharp objects.

- *Socio-Economic Impacts:*

✓ *Decreased Aesthetic Value and Tourism:*

Karanganyar is known for its natural tourism potential (such as Tawangmangu, Grojogan Sewu). A polluted environment reduces tourist interest.

✓ *Increased Emergency Management and Healthcare Costs:*

The government has to allocate larger budgets for medical treatment, cleanup of illegal dumps, and environmental rehabilitation.

✓ *Reduced Agricultural Productivity:*

Plastic or metal waste contaminating agricultural land disrupts soil fertility and crop yields.

- *Social Risks & Conflicts:*

✓ Citizen complaints about odors and waste piles that can lead to social conflicts.
✓ Community rejection of landfill locations or waste incineration if not managed professionally and environmentally friendly.

- *Analysis Results:*

To address the negative impacts of waste, it is necessary to model an effective, efficient, and environmentally friendly waste processing tool that will minimize waste entering the Sukosari Landfill. To obtain such a waste processing tool model, two waste processing tools using incineration methods will be compared.

➢ *Equipment Specifications:*

- *Incinerator*:

General Technical Specifications of Waste Incinerators:

✓ *Combustion Capacity*
Range: 10 kg/hour to >500 kg/hour
Adjusted to the volume of waste to be handled

✓ *Combustion Chamber*

▪ Primary chamber: for initial waste combustion
▪ Secondary chamber: for burning residual gases from the first combustion
▪ Material: heat-resistant steel (mild steel/SS), refractory lining

✓ *Operational Temperature*

▪ Primary chamber: 800–1000 °C
▪ Secondary chamber: ≥ 1000 °C (in accordance with Indonesian Ministry of Environment standards)

✓ *Auxiliary Fuel*
▪ Diesel, LPG, natural gas, or flammable waste (for hybrid incinerators)

▪ Automatic/manual burner

✓ *Control System*
▪ Control panel for temperature, combustion time, and blower Automatic temperature sensor
▪ Timer for automatic combustion

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✓ *Air & Emission System*

Primary and secondary air blowers for oxygen supply

Exhaust gas filtration system (scrubber, cyclone separator, activated carbon filter, etc.)

Chimney with height ≥ 3 meters

Emission levels comply with quality standards (e.g., CO, NOx, particulates, dioxins/furans)

✓ *Construction Material*

- Inner lining: fire bricks resistant up to 1400 °C
- Outer layer: 3–5 mm steel plate, coated with heat-resistant paint

✓ *Dimensions (estimated for small capacity)*

- Length: 1.5–3 meters
- Height: 2–4 meters
- Weight: can reach >1 ton (depending on design and capacity)

✓ *Additional Features*

- Wheels for portability (on small types)
- Ash tank and discharge door
- Exhaust gas cooling system (for advanced models)

- *Predator Sampah Sedeng Waste Destroyer:*

The operational process scheme of the Predator Sampah Sedeng tool can be briefly described as follows:

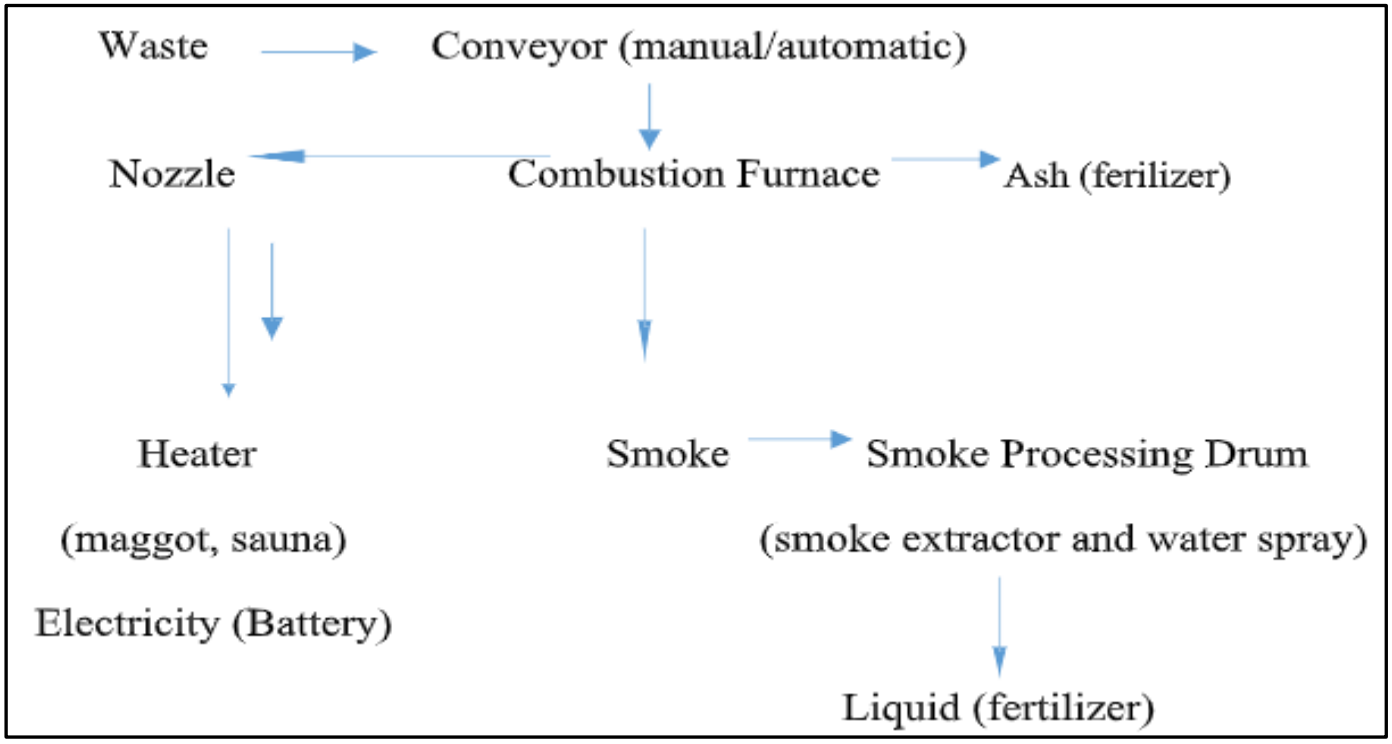

Fig 2 Predator Sampah Sedeng Waste Destroyer

The detailed requirements for supporting equipment for the construction of a community-scale waste predator tool with a processing capacity of 500kg of waste are as follows:

Table 2 Predator Sampah Sedeng Tool Specifications

NO	NAME	QUANTITY	USE
1.	Drums	6 pieces	Main material for combustion furnace and smoke trap
2.	2” Blower	2 pieces	Smoke extractor
3.	Stove	2 pieces	Combustion
4.	0.5” Iron Pipe	3 bars	Piping connections
5.	0.5” L Blow	25 pieces	Piping connections
6.	0.5” T	10 pieces	Piping connections
7.	Brass Faucet	6 pieces	Piping connections

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NO	NAME	QUANTITY	USE
8.	Water Pump	1 piece	Spray
9.	Gas Cylinder (used LPG, if pink)	1 piece	For steam boiler
10.	Used Freon Gas Cylinder	4 pieces	Nozzle Flange
11.	Iron Pipe, 50cm diameter, minimum 10mm thickness	3 meters	Ash filter grate from combustion
12.	Iron Plate, 5mm thickness	1 sheet (140x210cm)	Lining for combustion
13.	Chimney	3 meters	Smoke extraction
14.	Double Nipple	10 pieces	Pipe connector
15.	Double Thread	10 pieces	Pipe connector
16.	Double Socket	10 pieces	Pipe connector
17.	Automatic Valve	2 pieces	Flow safety
18.	4” PVC	4 meters	Water channel
19.	4” PVC L	4 pieces	Waste water channel
20.	14 mm Rebar	3 bars	Combustion grate
21.	4” Iron Pipe	0.5 meters	Stove connector

Note: The above requirements are for the construction of a community-scale tool with a processing capacity of 500 kg of waste. For Temporary Waste Collection Sites (TPS) with a processing capacity of 1,000 kg – 1,500 kg, twice the listed materials are required.

The combustion ash and smoke-trapping liquid have undergone fertilizer parameter testing at the Soil Science Laboratory of the Faculty of Agriculture, UNS, with the following results:

Table 3 Laboratory Test Results of Combustion Ash and Smoke-Trapping Liquid

No	Parameter	Unit	POC (Liquid)	Ash
1.	C, Organic (Walkey & Black)	%	1.07	24.97
2.	Macro Nutrients			
	N Total	%	0.10	0.39
	N Organic	%	0.04	-
	P2O5	%	0.02	0.2
	K2O	%	0.10	2.54
3.	Moisture Content	%	-	9.33
4.	pH	-	8.44	11.97
5.	C/N Ratio	-	-	64.03
6.	Heavy Metals			
	Arsenic (As)	ppm	0.0036	0.0036
	Mercury (Hg)	ppm	0.050	0.044
	Lead (Pb)	ppm	< 0.001	0.3870
	Cadmium (Cd)	ppm	0.0034	0.1550
	Chromium (Cr)	ppm	0.6074	2.1333
	Nickel (Ni)	ppm	0.0208	0.3124
7.	Contaminant Microbes			
	E. Coli	MPN/mL	< 3	
	Salmonella sp	MPN/mL	< 3	

Source: Sample testing results from the Ministry of Education, Culture, Research and Technology, Sebelas Maret University, Faculty of Agriculture, Soil Science Study Program

The waste predator tool has several advantages and differences compared to similar inventions, including:

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- Does not use electricity.
- Uses used engine oil or used cooking oil as ignition fuel, and then utilizes waste itself.
- Minimal (almost no) smoke produced; smoke is captured and managed.
- The volume of residual ash from combustion is very small; for every 1 ton of mixed waste, approximately 38 kg of ash residue is produced, and this ash can be used as a mixture for organic fertilizer with an ash:compost ratio of 1:30/40.
- Capable of generating electricity with a capacity appropriate to the design of the tool (depending on the processed waste capacity); for a 500kg waste processing capacity over 6 hours of operation, 12 volts 30 A is generated, which can be stored in 3 batteries with a capacity of 100 A each.
- Produces hot steam that can be utilized for other activities such as drying maggots and saunas (steam baths).
- All types of waste can be incinerated, including diapers, bones, glass fragments, styrofoam, and others.

This tool is highly beneficial and highly probable to be implemented in communities, from the smallest scope such as Neighborhood Associations (RT) and other communities. Although still in the process of refinement, this tool has already been used to handle waste processing in several locations. There are currently 5 operational tools: 1 as a prototype in Beji, Tawangmangu (River Hill area), 3 within Neighborhood Associations (RT) in Tawangmangu, and 1 tool at the Bulu Jaten TPS. The 3 RTs that utilize this tool are:

- RT 01, Banjarsari Village, Tawangmangu
- RT 02, Banjarsari Village, Tawangmangu
- RT 05, Banjarsari Village, Tawangmangu

Currently, tools are being processed for Temporary Waste Disposal Sites (TPS), specifically at TPS Tengklik, which is in the testing phase, and TPS Beruk Jatiyoso, which is in the assembly phase, along with several orders from environmental activists for waste management in their areas. The amount of waste that can be handled is 500kg – 1,000 kg per day; however, this is heavily influenced by the working hours and performance of the operating personnel and the commitment of the management.

➢ *Criteria Assessment:*

Table 4 Comparison Criteria Assessment of Incinerator and Predator Sampah Sedeng

Criteria	Incinerator (A)	Predator Sampah SEDENG (B)
Capacity (kg/day)	Medium–High (100 – 10,000 kg/day)	1,500 kg
Operational Cost	High	Low, uses used oil as fuel
Effectiveness	High (90–99%)	High (99%)
Processing Effectiveness	Medium (cannot process diaper waste)	High (capable of processing diaper waste, styrofoam, glass)
Processing Time	Fast	Fast (8 hours)
By-Products	Ash, heat, gas	Ash, heat, electricity
Environmental Emission	High (without control) / Medium (with filter)	Low (smoke)
Ease of Use	Medium	Easy
Price	High (Rp 100 million – billions)	Low Rp 40 million - Rp 45 million

➢ *Assessment (Scoring):*

Table 5 Scoring Assessment of Incinerator and Predator Sampah Sedeng Tool

Criteria	Incinerator (A)	Predator Sampah SEDENG (B)
Capacity	2	4
Operational Cost	1	5
Effectiveness	3	5
Processing Effectiveness	2	5
Processing Time	3	5
By-Products	4	4
Environmental Emission	1	5
Ease of Use	2	5
Price	1	5
Total Score	**19**	**43**

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IV. CONCLUSION

The discussion from the waste processing equipment modeling for addressing waste problems in Karanganyar Regency yields the assessment that the Predator Sampah Sedeng has a high processing capacity, capable of processing 1,500 kg of waste per day with an 8-hour processing time. This tool is highly effective as it can process diapers, styrofoam, and glass. The by-products generated are ash, which can be used as a planting medium, and heat, which can be utilized for food ovens, drying maggots, and saunas (steam baths). The electricity generated is stored in 3 batteries with a capacity of 100 A each, and the emitted smoke does not pollute the environment because it is equipped with a 10-meter chimney from ground level with a simple filter. The Predator Sampah Sedeng tool is very easy to use, has low operational costs due to using used oil as fuel, and the manufacturing cost is very affordable, ranging from Rp. 40,000,000 to Rp. 45,000,000. From this description, it can be concluded that the Predator Sampah Sedeng tool is more effective, efficient, and environmentally friendly, making it suitable for use by the Karanganyar Regency Environmental Agency to manage waste in Karanganyar Regency, and can be used to solve waste problems starting from the village level, thereby minimizing waste entering the landfill. With this waste processing equipment modeling, waste problems in Karanganyar Regency in particular, and in other regions/cities in general, can be resolved.

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