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Problem Tree Analysis of Plastic Waste Accumulation on The Tuban Coast and Decision Making Using the Rational Model

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Abstract

Abstract: The coastal areas of Tuban Regency are facing an urgent ecological pollution crisis due to the massive accumulation of plastic waste, which has led to a decline in environmental quality and high levels of microplastic contamination in the waters. This study aims to identify and formulate the most appropriate and optimal public decision-making steps to resolve the plastic waste problem in the coastal areas of Tuban. The method used is a descriptive qualitative approach based on a literature review. The analytical framework integrates Problem Tree Analysis to logically diagnose the root causes of the problem (such as the lack of Integrated Waste Processing Facilities and community waste disposal behavior), as well as the Rational Model to formulate, evaluate, and determine the best solution from various available alternatives. The results of the analysis indicate that the most effective and comprehensive solution is to combine the establishment of Integrated Waste Processing Facilities (IWPFs) with the adoption of RECYFUEL pyrolysis technology. This applied technology has been proven capable of thermally decomposing waste, converting 1 kg of marine plastic waste into 300–400 ml of diesel-equivalent alternative fuel. The conclusion of this study indicates that the implementation of public policies integrating RECYFUEL infrastructure and technology is not only effective in reducing the volume of plastic pollutants along the coast but also capable of creating self-sustaining economic empowerment for local communities, which aligns with the achievement of the Sustainable Development Goals (SDGs).

Introduction

Tuban Regency occupies a strategic location with a coastline stretching 65 kilometers along the northern coast of East Java; astronomically, it is situated at coordinates 6.40°–7.14° South Latitude (SL) and 111.30°–112.35° East Longitude (EL) (Putri, 2023). Like other regions in Indonesia, Tuban's coastal area has a tropical climate with rainy and dry seasons occurring from October to May and July to September (Cuimbra, 2021). Given its tropical climate, this coastal region holds immense potential for marine resources, aquaculture, and capture fisheries, which are identified as the primary drivers of local economic growth. However, this immense potential is currently threatened by an environmental degradation crisis caused by the accumulation of plastic waste pollution, which continues to rise over time (Putri, 2023). The buildup of plastic pollutants demands urgent intervention as it has caused various multidimensional losses for both the community and the coastal ecosystem.

According to data compiled by the Tuban Regency Department of Environment and Transportation (DLHP) in 2022, the amount of waste generated in the region has reached an

alarming level of 505 tons per year, with a daily average of 1.4 tons. This volume represents an increase of approximately 13 tons compared to the previous year. Of the total waste, household waste accounted for the highest percentage at 35% or approximately 138.15 tons, followed by waste from market areas at 129 tons, public facilities at 55.95 tons, and office areas (Putri, 2023). This alarming situation is clearly evident in Tuban's coastal tourist areas, particularly at the Panyuran Beach tourist zone. From August to October 2020, visitor numbers at the beach reached 25,199 people, a figure directly correlated with the high volume of waste generated. A 14-day observation at Panyuran Beach revealed that out of the total 400 kg of waste generated, plastic materials were overwhelmingly dominant, comprising 101 kg of recyclable plastic and 198 kg of non-recyclable plastic waste (Kusumawati & R., 2023).

The complexity of the plastic waste accumulation crisis in the waters off northern Java is inextricably linked to the high volume of waste carried in from riverbank areas where water flows directly into the sea (Fajar, 2020). Furthermore, this is also heavily influenced by the misguided mindset of coastal communities who still view the sea as a final disposal site for their household waste (Joesidawati et al., 2025). In addition to household waste, fishing activities in Fish Auction Sites (FAS), such as the FAS in Palang Village, also exacerbate the situation because the packaging system for seafood products remains heavily reliant on single-use plastics, which are ultimately discarded around the site. Limited waste bank infrastructure and low human resource capacity force communities to maintain conventional management methods, namely allowing waste to pile up or disposing of it manually through open burning, which actually releases dioxin toxins into the air (Joesidawati et al., 2025).

Ecologically, biologically, and economically, the accumulation of plastic pollutants has direct destructive impacts, such as the damage to fishermen's nets caused by entanglement in plastic materials, reduced fish catches due to disruption of coastal ecosystems, and the loss of the aesthetic value of coastal landscapes, which diminishes the appeal of tourist destinations (Joesidawati et al., 2025); (Putri, 2023). The most latent threat stems from the mechanical and photooxidative fragmentation of these macroplastic materials into microplastic particles measuring less than 5 millimeters (Putri, 2023). A comprehensive study in the waters of Kolam Labuh and the Blangor River, Palang Subdistrict (Tuban Regency) in 2023 found extremely high levels of microplastic contamination. Microplastic abundance in the seawater of these waters reached $40,000 \pm 11,357.82$ particles/m³, with a composition of 48.75% fragments, 44.58% fibers, and 6.67% granules (Sidiqi et al., 2023). In the sediment, the abundance reached 226.67 ± 83.27 particles/m³ (Sidiqi et al., 2023). Fourier Transform Infrared (FTIR) analysis confirmed that Tuban waters have been contaminated by hazardous polymers such as Polyvinyl Chloride (PVC), Polyethylene (PE), and High-Density Polyethylene (HDPE), which pose a risk of accumulating in the marine biota food chain (Sidiqi et al., 2023).

In response to this marine pollution emergency, the Tuban Regency Government has indeed implemented various interventions and proactive measures. From a regulatory perspective, the local government has issued policy instruments such as Tuban Regency Regulation No. 12 of 2025, signed on December 30, 2025, regarding Waste Management (Tuban Regency Government, 2025). In terms of public campaigns, the Tuban DLHP actively carries out awareness-raising activities, one of which is through the "Exchange Plastic Waste for Plant Seedlings" program during Earth Day on April 27, 2025, which distributed high-yielding, productive seedlings (such as Miki avocados and Bawor durians) in exchange for residents' recyclable waste. According to Bambang Irawan, Head of the DLHP, this waste

sorting education program is aimed at building awareness starting at the household level, as prevention at the source is considered crucial (Yolency, 2025).

Although the above initiatives are positive, the provision of facilities and temporary campaigns have not yet yielded permanent results and have not been able to resolve coastal issues at their root. Therefore, a systematic evaluation framework is needed to formulate holistic policies. Through the application of the second Problem Tree analysis model, the root causes of the problem can be visualized hierarchically; it was found that one of the main causes is the lack of priority given to the development of Integrated Waste Management Facilities (TPST) at the sub-district and village levels, resulting in 61% of community waste not being served by collection services (Putri, 2023). Following these findings, the Rational Model approach was used to evaluate various logical alternative solutions, such as enhancing education, constructing TPSTs, and integrating technological innovations (Putri, 2023). Based on a comparison of effectiveness, a combined decision-making approach involving the construction of TPST facilities and the application of technology to manage marine plastic waste into materials with economic value is the most optimal choice (Putri, 2023).

One of the most promising and practical applications of applied technology today is the use of the RECYFUEL (RECYcled plastic as FUEL) pyrolysis reactor in Palang Village (Joesidawati et al., 2025). This environmentally friendly machine works by decomposing PP, PE, and PS waste without an oxygen supply at temperatures of 300–500°C into economically valuable liquid products (Joesidawati et al., 2025). Through this conversion process, every 1 kg of plastic waste can produce approximately 300–400 milliliters of alternative fuel equivalent to diesel (Witra, 2025); (Joesidawati et al., 2025). This strategic initiative yields dual benefits; besides reducing plastic pollution volume by 50% in Tuban’s coastal environment (Joesidawati et al., 2025), the innovation successfully empowers the “Putera Bahari” youth group to establish a new, financially viable business venture (Witra, 2025). The implementation of such technology-based policies not only effectively addresses water pollution but also supports the vision of achieving the Sustainable Development Goals (SDGs), specifically SDG 7 (Clean Energy), SDG 8 (Inclusive Economic Growth), and SDG 14 (Marine Ecosystems) (Joesidawati et al., 2025).

Although previous studies have demonstrated the extent of biological exposure to pollutants and proposed technical solutions involving recycling and technological innovations, there remains a gap in formulating and selecting a public policy framework for addressing the issue. The scientific novelty of this study lies in the integration of the Problem Tree Analysis diagnostic framework combined with the Rational Model decision-making method to holistically evaluate the problem of coastal plastic waste in Tuban. Unlike previous studies, which tended to focus narrowly on laboratory tests or device prototypes, this research maps the cause-and-effect relationships of structural cultural issues hierarchically, to subsequently evaluate and determine the most effective, efficient, and comprehensive public policy alternatives—such as combining the provision of TPST facilities with the adoption of RECYFUEL technology.

Given the complexity of the issues outlined above, the main research question in this study is: “What is the most appropriate decision-making approach to address the public issue of plastic waste on the coast of Tuban City?” In line with this research question, this study aims to identify and formulate the most appropriate and optimal decision-making steps to resolve the public issue of the plastic waste emergency in the coastal areas of Tuban City.

Method

This study employs a descriptive qualitative approach based on a literature review (collection of secondary data). The data collected and analyzed are drawn from various existing sources, including government regulations. The use of this secondary data is focused on exploring issues from upstream to downstream without conducting primary observations or statistical tests. To address the research problem, the methods employed are divided into two main, interconnected analytical frameworks.

The first stage uses the second model of the Problem Tree approach to visually represent cause-and-effect relationships logically. This method guides the researcher through systematic steps: identifying the main problem (the accumulation of plastic waste on the Tuban coast), analyzing the resulting impacts or consequences, identifying the root causes of the problem, breaking down these causes to their underlying levels, and organizing them into a comprehensive Problem Tree diagram. Through this method, readers can view a structured mapping of the problem.

Once the root causes and their impacts have been identified, the next step is to use the Rational Model to find the most optimal solution. This approach involves a series of sequential steps, starting with defining and diagnosing the problem based on the results of the Problem Tree, establishing resolution objectives, and exploring various alternative solutions. Researchers then evaluate each available alternative solution (such as raising awareness, establishing an Integrated Waste Processing Facility (IWPF), and developing technology) by comparing their advantages and disadvantages, to ultimately select the best decision that is most effective and efficient.

This series of methods is designed so that readers can understand exactly how the process of identifying plastic waste problems on the Tuban coast was carried out, leading to the final proposed decision of building an IPFW and developing waste processing technology.

Results and Discussion

Analysis of the Problem of Plastic Waste Accumulation on the Tuban Coast Using a Problem Tree

a. Identifying and Formulating the Main Issues.

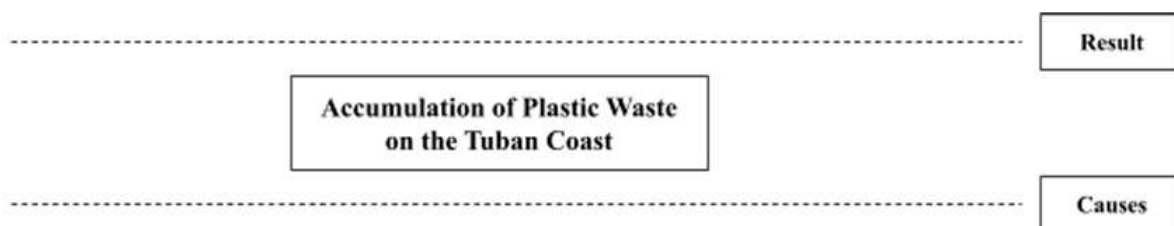


Figure 1: Identification and Formulation of the Main Problem
 Source: Compiled by the researcher, 2026

b. Conduct an analysis of the consequences or impacts of the main issues.

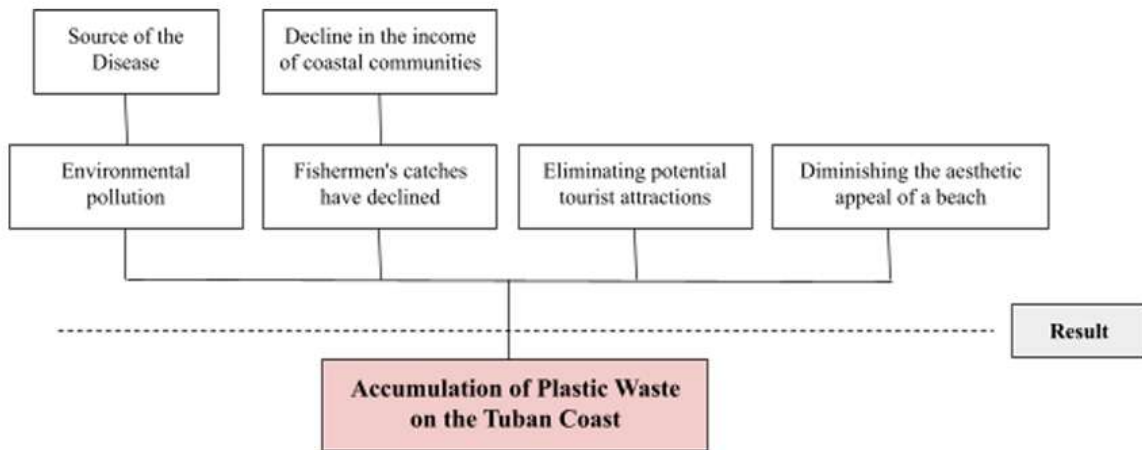


Figure 2: Analysis of the Consequences or Impacts of the Main Problem
 Source: Compiled by the researcher, 2026

c. Conduct an analysis of the consequences or impacts of the main issues.

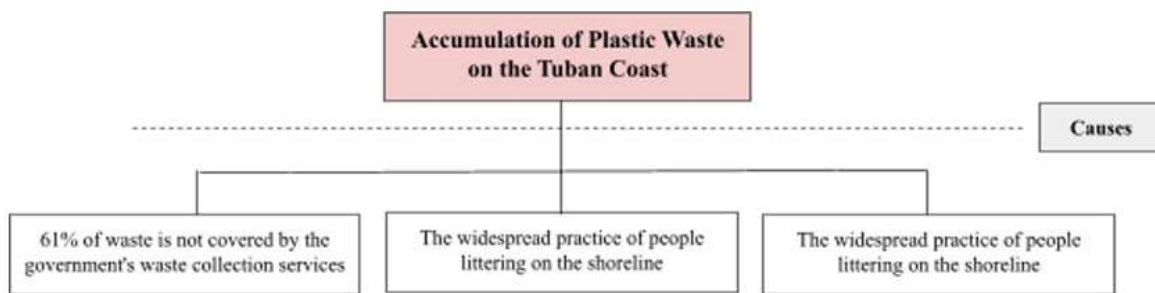


Figure 3 Analysis of the Causes of Major Problems
 Source: Compiled by the researcher, 2026

d. Further analyze the root causes of the first-level causes.

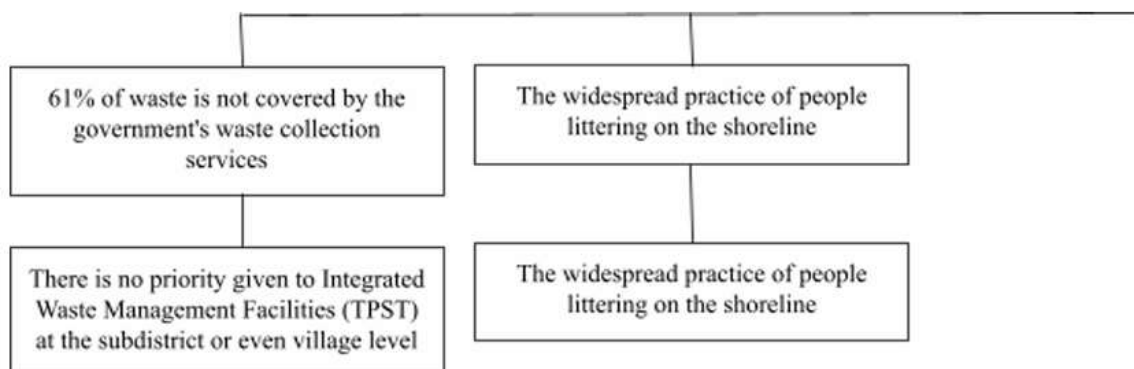


Figure 4: Causes of First-Level Causes
 Source: Compiled by the researcher, 2026

e. The fifth step is to construct the overall problem tree.

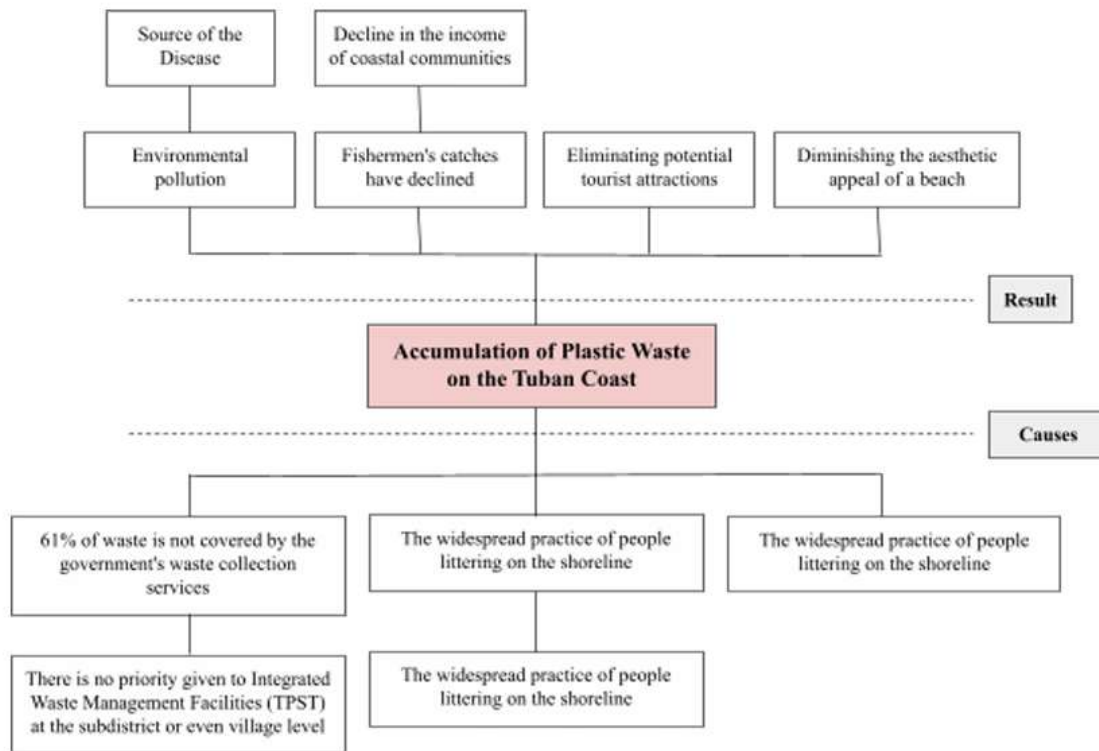


Figure 5: Overall Problem Tree
 Source: Compiled by the researcher, 2026

Decision-Making Regarding Plastic Waste Accumulation on Tuban’s Coastline Using the “Rational Model”

a. Identifying and Formulating the Main Issues

The shoreline in several coastal areas of Tuban is experiencing a massive accumulation of plastic waste. This situation is caused by continuous illegal dumping by local residents and the lack of adequate waste collection points in Tuban’s coastal villages.

b. Establishing Objectives

Given these severely detrimental conditions, the government aims to manage and address the accumulated plastic waste along the shoreline, as well as conduct public awareness campaigns and implement special oversight for local residents regarding plastic waste generated by the community.

c. Seeking Alternative Solutions

As decision-makers, the researcher offers the following alternatives: 1) Raising public awareness. 2) Expanding or establishing Integrated Waste Processing Facilities (IWPFs). 3) Developing technology. 4) Implementing government policies.

d. Further analyze the root causes of the first-level causes.

Table 1 Root Causes of First-Level Causes

Alternative Solutions	Advantages	Disadvantages
Raising public awareness	<ul style="list-style-type: none"> - Has a positive and long-term impact - Relatively inexpensive 	<ul style="list-style-type: none"> - Membutuhkan waktu yang lama untuk membuahkan hasil - Membutuhkan komitmen seluruh masyarakat
Expanding or establishing Integrated Waste Treatment Facilities (IWTFs).	<ul style="list-style-type: none"> - Has a positive short-term impact - Creates new job opportunities 	<ul style="list-style-type: none"> - Requires significant funding and adequate infrastructure - Requires support from many stakeholders
Technological development.	<ul style="list-style-type: none"> - Creating long-term positive impact - Opening up new business opportunities 	<ul style="list-style-type: none"> - Requires intensive research and development - Requires substantial investment
Implementation of government policies.	<ul style="list-style-type: none"> - Has a positive short-term impact - Promotes the growth of the plastic recycling industry 	<ul style="list-style-type: none"> - Requires commitment from the government and the private sector - Requires intensive outreach and education

Source: Compiled by the researcher, 2026

e. The fifth step is to construct a comprehensive problem tree.

Judging by the efforts undertaken by the Tuban Regency government regarding plastic waste management along the Tuban coastline, the results have not yet been satisfactory. For this reason, the researcher proposes an additional alternative solution to the Tuban Regency government: to expand or establish Integrated Waste Processing Facilities (IWPFs). The addition or establishment of Integrated Waste Processing Facilities (TPSP) in village areas is proposed because residents may face difficulties accessing existing waste disposal sites, which are currently limited to certain areas. Therefore, the addition or establishment of Integrated Waste Processing Facilities (TPSP) serves as a foundational step in reducing the accumulation of plastic waste along the coastline.

The second solution proposed by the researchers is to develop technology for managing plastic waste that has already accumulated along the coast, so that this plastic waste also receives government attention regarding how to reduce such accumulation. Technologies that the Tuban government could potentially implement include converting plastic waste into fuel oil (BBM) or constructing plastic waste incinerators—though these must, of course, take into account air quality and the pollution they may cause in the future.

Conclusion

Based on the discussion presented in the previous chapter, the researcher has drawn the following conclusions:

1. The researcher used the second model of the Problem Tree analysis method to analyze the problem of plastic waste accumulation along the Tuban coastline. The following is the Problem Tree diagram resulting from several stages of analysis:

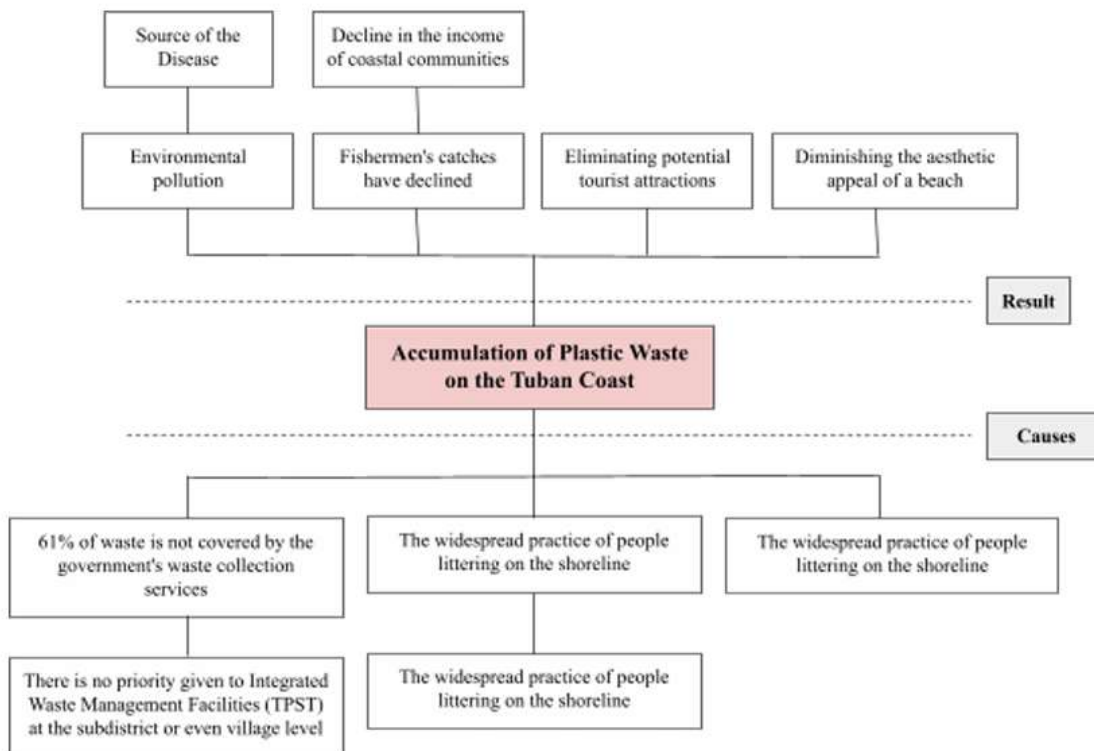


Figure 6: Problem Tree for Identifying Plastic Waste on the Tuban Coast
 Source: Compiled by the researcher, 2026

2. In response to these issues, the researcher proposes the following alternatives: 1) Raising public awareness. 2) Expanding or establishing Integrated Waste Treatment Facilities (IWTFs). 3) Developing technology. 4) Implementation of government policies.
3. After evaluating and comparing the alternative solutions, the appropriate decision to address the accumulation of plastic waste along the coast of Tuban is to expand or establish Integrated Waste Processing Facilities (IWPFs) and advance technology

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