Research Paper

Environmental Cost Evaluation of Food Industry Waste

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Abstract
Referring to environmental economic theory, production activities can have impacts (costs or benefits) for third parties not directly involved. Food industry waste that pollutes the environment is a form of negative externality. This study aims to conduct a comprehensive evaluation of the environmental costs caused by food industry waste and assess the effectiveness and economic efficiency of various waste management alternatives. The results of this study are expected to contribute to the development of more economically just environmental policies and encourage the food industry to be more responsible in maintaining environmental sustainability through a measurable and data-driven approach. The estimated environmental costs of food industry waste can reach tens of millions of rupiah per year, depending on the scale of the industry, the type of waste, the location, and the management method. By internalizing these costs, the industry can be more encouraged to adopt more responsible waste management technologies.

Keywords *Environment, Cost, Food, Waste, Sustainable*

INTRODUCTION

The food industry is a sector that plays a strategic role in the national and global economy. Its rapid growth, coupled with increasing consumer demand for food products, has made this sector a significant contributor to Gross Domestic Product (GDP), job creation, and increased food security. However, despite its economic contribution, the food industry is also one of the largest contributors of waste, in solid, liquid, and gaseous forms, which negatively impact the environment if not managed properly.

Waste generated from food production processes typically contains high levels of organic matter, with significant Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), as well as the potential for odor and groundwater pollution. In many cases, small and medium-sized enterprises (SMEs) in the food sector lack adequate waste management systems, either due to limited financial resources or a lack of awareness about the importance of sustainable environmental management. This triggers environmental degradation, ecosystem damage, and impacts the health of communities surrounding industrial areas.

From an environmental economic perspective, pollution caused by food industry waste can be categorized as a form of negative externality, namely a social cost borne not directly by the business operator, but by the surrounding community and environment. Therefore, it is important to evaluate the environmental costs arising from food industry waste. This evaluation includes not only estimating ecological and health losses, but also calculating environmental restoration costs and potential long-term economic losses. Furthermore, alongside the development of sustainable development principles and corporate social responsibility (CSR), various environmentally friendly and economically efficient waste management alternatives have emerged. Several

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approaches, including anaerobic processing technology, utilizing waste as a raw material for energy (waste-to-energy), recycling organic waste into compost, and implementing circular economy principles, have been implemented in various countries and industries. However, implementing these alternatives still faces challenges in terms of investment costs, regulations, and technology adoption.

This study aims to conduct a comprehensive evaluation of the environmental costs of food industry waste and assess the effectiveness and economic efficiency of various waste management alternatives. The results are expected to contribute to the development of more economically just environmental policies and encourage the food industry to be more responsible in maintaining environmental sustainability through a measurable and data-driven approach.

1. Problem Formulation

Based on the background described, the research problems in this study are as follows:

a. What are the types and characteristics of waste produced by the food industry?
b. How are the environmental costs of food industry waste estimated, both ecologically and economically?
c. What is the environmental quality index in Bantul Regency?
d. What policy recommendations or strategies can be proposed to sustainably reduce the environmental impact of the food industry?

2. Research Objectives

This research aims to:

a. Identify the types, volumes, and characteristics of waste generated from the food industry production process.
b. Estimate the environmental costs resulting from suboptimal waste management.
c. Analyze the environmental quality index in Bantul Regency.
d. Provide recommendations for effective, efficient, and sustainable waste management strategies or policies for the food industry.

3. Research Benefits

a. Academic Benefits

- Adding to the literature and scientific studies in environmental economics, particularly regarding the valuation of environmental costs in the food industry sector.
- Providing a conceptual and empirical basis for further research on sustainable industrial waste management.

b. Practical Benefits

- Providing information to food industry players regarding the environmental impacts and hidden costs of poorly managed waste.
- Providing consideration for industrial management in implementing more efficient and environmentally friendly waste management alternatives.
- Providing input to the government or policymakers in developing more targeted environmental regulations based on economic data.

LITERATURE REVIEW

This research is based on several key theories and concepts in environmental economics and waste management, including:

Externality Theory

This refers to environmental economic theory, which states that production activities can have impacts (costs or benefits) on third parties not directly involved in the production process. Food industry waste that pollutes the environment is a form of negative externality.

Polluter Pays Principle

This principle states that businesses that cause pollution are required to bear the costs of environmental remediation. Environmental cost evaluation can be used as a basis for calculating environmental compensation or incentives.

Environmental Economic Valuation Theory

Economic valuation is used to measure the monetary value of environmental damage, such as decreased water or air quality, or health losses. Relevant methods include Cost of Illness, Willingness-to-Pay, or Replacement Cost.

Cleaner Production Concept

Cleaner production is a preventative approach to industrial environmental management, with the goal of reducing waste at the source and increasing the efficiency of raw material and energy use.

Circular Economy

This concept emphasizes the reuse of resources through the principles of reduce, reuse, and recycle (3R), and creating economic value from waste, such as converting waste into energy or compost.

RESEARCH METHOD

Research Type

This research is quantitative, descriptive, and evaluative, using an environmental economics approach.

Data Sources

- Primary data: Field observations, interviews with industry players, and questionnaires to the surrounding community (if necessary).
- Secondary data: Industrial production report documents, waste data, previous valuation studies, environmental regulations, and academic literature.

Data Collection Methods

- Documentation studies (waste reports, production balance sheets, etc.)
- Interviews with production managers, waste managers, and/or environmental agencies
- Direct observation at waste production and processing sites

Data Analysis Techniques

1. Waste Identification and Classification
- Type, volume, and characteristics of waste
2. Environmental Cost Valuation
   Using approaches such as:
- Replacement Cost
- Cost of Illness

- Avoided Cost
- Willingness to Pay (if using community surveys)

3. Waste Management Alternative Analysis

- Technical and economic evaluation of waste management methods (investment costs, operational costs, environmental benefits)

4. Cost-Benefit Analysis (CBA)

- Comparing the environmental costs of waste with the costs and benefits of alternative waste management methods.

FINDINGS AND DISCUSSION

A. Types of Food Industry Waste

In general, waste from the food industry can be divided into three main categories:

1. Solid Waste

- Raw material residue (fruit peels, seeds, bones, fish heads, meat scraps, etc.)
- Process waste (pulp, fiber, scale from machinery)
- Packaging materials (plastic, paper, cardboard, metal)

Characteristics: Generally organic (easily biodegradable), can cause unpleasant odors if not promptly processed, has the Potential to become raw material for compost or animal feed, and in some cases, contains chemical contaminants from the processing process.

2. Liquid Waste

For example, wastewater from washing ingredients, equipment, and cooking processes; liquid residue from fermentation or food processing; condensate water; sauces; or food additive solutions.

Characteristic: Contains high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Furthermore, another characteristic is:

- May contain fat, protein, sugar, enzymes, and microorganisms
- If discharged without treatment, it can cause a decline in the quality of surface and groundwater
- pH can vary (acidic or alkaline, depending on the process)

3. Gaseous Waste

For example, emissions from heating or combustion processes, vapors, odors, or ammonia gas from fermentation or decomposition, and Carbon emissions from fossil-fuel-powered equipment.

Characteristics:

- Contains fine particulates and greenhouse gases (GHGs) such as CO_2 and CH_4
- Pungent odors can cause environmental and health problems
- Usually difficult to control without equipment such as scrubbers or biofilters

Table 1. General Characteristics of Food Industry Waste

Characteristics	Explanation
High organic content	Most waste is biodegradable

Characteristics	Explanation
High moisture content	Especially fresh liquid and solid waste
Rapid decomposition	Requires prompt handling to prevent pollution
Potential odor	Foul odor from protein and carbohydrate decay
Nutritional content	High in protein, fat, and carbohydrates – can be reused
Varying pH	Can be acidic (from fermentation) or alkaline (from washing with detergent)

B. Estimating the environmental costs of food industry waste, both ecologically and economically, depends heavily on: Waste type (solid, liquid, gas), Waste volume and characteristics, Disposal or management method, Industrial location (near residential areas, rivers, agricultural land, etc.), Applicable regulations. However, in general, the following are methods and estimation approaches that can be used.

Environmental Cost Components

1. Ecological Impact Cost

Table 2. Direct impact on nature and ecosystems.

Components	Impact	Cost Estimation
Water pollution	Deterioration of river water quality due to high BOD/COD liquid waste	Rp 10–50 million/ton BOD/year (water recovery & treatment costs)
Soil damage	Infertile soil due to solid or liquid waste containing heavy metals/detergents	Rp 5–20 million/hectare for soil remediation
Polluted odor and air	Air pollution due to organic waste decomposition or gas emissions	Rp 2–10 million per affected location for odor mitigation
Loss of biodiversity	Decreased fish/aquatic biota populations due to waste entering rivers	Difficult to convert directly into cash, but can be done using ecosystem valuation methods (up to hundreds of millions, depending on the scale of the impact)

2. Economic Costs (Socio-Economic Impact Cost)

Table 3. Indirect Impacts on The Economy and Society

Impact	Components	Cost Estimation
Increased skin and digestive diseases, and respiratory infections (ARI) around waste disposal sites	Public health costs	Rp 500,000 – 2 million/person/year (medical costs and lost productivity)
Wastewater damages soil and irrigation water quality	Decreased agricultural productivity	Rp 10–30 million/hectare/year (crop losses)
Loss of public trust or product boycotts	Damage to corporate reputation	Indirect, but can result in billions of rupiah in lost sales
Government-imposed pollution	Environmental fines or compensation	Can reach Rp 100 million – billions, depending on the severity of the violation (see Environmental Law)

Table 4. Environmental Cost Estimation Method

Method	Short Explanation
Cost of Illness (COI)	Calculating the cost of treatment and productivity losses due to environmental diseases
Replacement Cost	Calculating the cost of replacing damaged resources or environmental functions
Avoided Cost	Measuring the costs that could be avoided if pollution were prevented in the first place
Willingness to Pay (WTP)	Asking the public how much they would be willing to pay to avoid pollution
Shadow Pricing	Using shadow prices to assess the value of environmental resources that do not have a market price

A food factory produces:

- 30 m^3 of wastewater/day with a BOD of 2,000 mg/L
- Wastewater is discharged untreated into a nearby river

Cost Estimate:

1. River water recovery:

BOD = 2,000 mg/L × 30 m^3 = 60,000 g/day = 60 kg/day

60 kg/day × Rp 40,000/kg (recovery cost)
= Rp 2.4 million/day → Rp 876 million/year

2. Public health impact (e.g., 200 families affected)
   = 200 × Rp 1 million = Rp 200 million/year

3. Total estimated environmental costs per year
   = Rp 876 million + Rp 200 million = ± Rp 1.1 billion/year

Conclusion
The estimated environmental costs of food industry waste can reach hundreds of millions to billions of rupiah per year, depending on the scale of the industry, the type of waste, the location, and the management method. By internalizing these costs, the industry can be more motivated to adopt more responsible waste management technologies.

3. Food Industry Waste Management Alternatives and Their Effectiveness

Waste management alternatives are differentiated based on the type of waste: solid, liquid, and gas. Strategies generally follow the 3R principle (Reduce, Reuse, Recycle) and a circular economy approach.

A. Solid Waste
   1. Composting
      Description: Converting organic waste (fruit peels, vegetables, pulp) into compost., Effectiveness:
   - Low cost
   - Environmentally friendly
   - Reduces waste volume by 60–70%
   - Requires land and time for decomposition
   2. Animal Feed
      Description: Waste rich in protein and carbohydrates is used as an ingredient in animal feed (e.g., leftover bread, tofu dregs). Effectiveness:
   - Economical and beneficial
   - Must be sterile or processed to prevent disease
   - Requires permits/regulations for food safety
   3. Biogas Production (Anaerobic Digestion)
      Description: Organic waste is fermented to produce biogas (CH_4) and liquid fertilizer. Effectiveness: Produces renewable energy, requires initial investment (digester installation). Suitable for medium to large industries.
   4. Inorganic Material Recycling
      Processing plastic, metal, or paper packaging for reuse or sale to recyclers. Effectiveness: Reduces plastic waste, but requires a good waste sorting system.

B. Liquid Waste
   1. Wastewater Treatment Plant (WWTP/IPAL)
      It physically, chemically, and biologically treats liquid waste before it is discharged into the environment. Effectiveness: Mandatory for large-scale industries, effectively reduces BOD/COD by up to 90%. High construction and operational costs.
   2. Reuse for Non-Hygienic Processes

Treated wastewater is reused for non-consumption purposes (e.g., watering gardens, engine cooling). Effectiveness: Conserves clean water. Requires an adequate filtration system.

3. Constructed Wetland
   Uses aquatic plants (such as water hyacinth) to filter wastewater. Effectiveness: Low cost, aesthetic, and environmentally friendly, effective for small to medium flow rates

C. Gas Waste and Emissions
   1. Biofilters and Scrubbers
      Filter gases and odors from fermentation or decomposition processes with absorbent materials (charcoal, soil, etc.). Effectiveness: Reduces odors and gas particles, moderate cost, requires regular cleaning or replacement.
   2. Carbon Capture
      Captures CO_2 from combustion or fermentation processes. Effectiveness: Rarely used in the food industry, expensive technology.

Table 5. Comparison of Alternative Effectiveness (Score 1–5)

Alternatives	Cost	Impact Reduction Effectiveness	Ease of Implementation	Total Score (1–5)
Composting	Low	Medium– High	Easy	4
Animal feed	Low	High	Moderate	4
Biogas	Medium- High	High	Moderate	4
WWTP / WWTP	High	High	Difficult (requires permits and fees)	3.5
Wastewater reuse	Medium	Medium	Moderate	3.5
Artificial wetland	Low	Medium	Easy	4
Biofilter for gas	Medium	Medium	Easy	3.5

Important Notes: A combination of methods is often more effective than relying on a single solution. Factors such as industry scale, product type, location, and regulations determine the best option. Government incentives or environmental tax-based policies can encourage the adoption of waste management technologies.

Comparison of Environmental Costs and Implementation Costs of Waste Management Alternatives

A. Comparison Concept

The comparison is conducted using a Cost-Benefit Analysis (CBA) approach, namely: Are the costs of waste management lower than the costs of environmental damage and socio-economic impacts that would result if the waste were not managed?

Table 6. Comparing Components

Components	Environmental Costs (if waste is not managed)	Waste Management Implementation Costs
Public health	Treatment costs, lost productivity	Zero or very low if waste is managed properly
Water/soil/air pollution	Environmental restoration costs, agricultural losses, etc.	Installation costs for WWTP, composter, and biofilter
Fines/legal compensation	Government sanctions (Environmental Law)	Routine permit and processing operational costs
Reputation and business risks	Loss of public trust, product boycotts	Internal education and CSR costs
Long-term effects	Ecosystem damage, permanent damage	Controllable preventative costs

Simple Simulation (Medium Industry Scale): for example, a food industry produces 30 m^3 of liquid waste per day (high BOD and COD) plus organic solid waste (200 kg per day).

Table 7. If Not Managed (Environmental Costs per Year)

Components	Estimated Cost (Rp/year)
River water restoration	900 million
Community compensation	200 million
Reputational/market damage	300 million
Potential legal fines	100 million
Total Environmental Costs	± Rp 1.5 billion

Table 8. If Managed (Implementation Cost per Year)

Management Alternatives	Estimated Cost (Rp/year)
Mini WWTP	400 million (operational and equipment amortization)

Management Alternatives	Estimated Cost (Rp/year)
Solid waste composter	50 million
Biofilter or simple odorization system	30 million
Training and waste management	20 million
Total Management Costs	± Rp 500 million

Comparison Results

Environmental costs without management: Rp 1.5 billion/year, whereas proper waste management costs: Rp 500 million/year. This means that every Rp 1 spent on waste management can avoid Rp 3 in losses. Efficiency: 66% savings in social and environmental costs. Main Conclusion: The implementation costs of alternative waste management are generally much lower than the environmental costs incurred if waste is disposed of improperly. This applies to almost all types of food industries, especially in sensitive locations (near residential areas, rivers, agricultural areas, or conservation areas). Industry actors do not feel indirect environmental costs and are often overlooked. However, in the long term, environmental damage can be much more expensive, both economically and legally. Government incentives such as tax cuts or equipment assistance can accelerate the adoption of more effective waste management systems.

Recommendations for Policies or Strategies to Sustainably Reduce the Environmental Impact of the Food Industry

1. Implementation of the "Polluter Pays" Principle
   Food industries that produce waste must bear the costs of environmental management and recovery. Strengthened through regulations based on externality costs (environmental tax or liquid waste charges).
2. Incentives for Eco-Friendly Industries
   Tax reductions or subsidies for industries that use waste processing technologies, utilize waste as new products (compost, animal feed, biogas), and have ISO 14001 certification (environmental management).
3. Standardization and Enforcement of Laws
   Strict enforcement of quality standards for liquid and solid waste in accordance with Government Regulation No. 22 of 2021 concerning Environmental Protection and Management. Regular inspections and administrative sanctions will be implemented for violators.
4. Facilitation of Clean Technology for Food SMEs
   Local governments provide affordable and efficient technology for small industries (communal wastewater treatment plants, composting machines, 3R training). In addition, cross-sector collaboration (private sector, NGOs, academia) can be carried out for the development of appropriate technology.

Recommendations for Industry Players

1. Implementation of Cleaner Production, optimizing production processes to reduce waste at the source, not just managing waste at the end. Examples: water efficiency, waste separation from the start, and minimizing residual materials.
2. Utilization of Waste as New Resources Waste should not be discarded but processed into

value-added products. Examples include using pulp as animal feed, converting liquid waste into biogas or fertilizer, and transforming organic solid waste into compost. This strategy supports the circular economy.

3. Transparency and Environmental Reporting
   Prepare Environmental Impact Reports (EIR) or Sustainability Reports periodically as a form of social and environmental responsibility.
4. Community Involvement and Education.
   Involving the surrounding community in monitoring impacts and environmental education, and enhancing environment-based CSR.

B. Collaborative Approach

Table 9. Collaborative Approach

Actors	Strategic Role
Government	Regulation, incentives, and law enforcement
Industry	Commitment to waste management and resource efficiency
Academics	Research and waste treatment technology
Community	Social oversight and consumer pressure
NGOs	Advocacy and mentoring for MSMEs

Conclusion Strategic Recommendations

Reducing the environmental impact of the food industry is not enough just by processing waste at the end of the process. It must be built on:

- Efficient production design
- Firm but supportive policies
- Incentives for behavior change
- Partnerships between industry, government, and communities

Current Environmental Programs and Policies

1. Focus Group Discussion (FGD): Environmentally Friendly Business in the Food Industry
   The Bantul Regency Cooperatives, SMEs, and Trade Office (DKUKMPP) held a Focus Group Discussion (FGD) on August 5, 2025, with the theme "Environmentally Friendly Business in the Food Industry," at Lingkar Timur Street, Manding. This event demonstrated a focus on strengthening sustainable food industry practices.

2. PROPER Evaluation by the Bantul Environmental Agency (DLH)
   The Bantul Regency DLH has announced that it will conduct a PROPER (Company Performance Rating Program for Environmental Management) evaluation. This evaluation encompasses waste management, as well as air and water quality monitoring, indicating that the food industry is being targeted for stricter environmental management.

3. Environmental Conditions and Quality of Life Indicators through Environmental Quality

Index (IKLH) – 2021–2023

Based on the Bantul Regency RPJPD, the following are the developments in environmental indicators:

- IKA (Water): Decreased from 56 (2021) to 36.67 (2022), then increased to 39.83 in 2023.
- IKU (Air): Increased from 83.28 (2021) to 88.16 (2023).
- Land Cover Index (IKL): Increased in 2022 (45.45), decreased to 40.35 (2023).
- Total IKLH increased from 58.51 (2022) to 59.52 (2023)—still in the "moderate" category. While not specific to the food industry, water and air quality data are relevant, given that industrial waste can impact these indicators.

CONCLUSIONS

Summary

Table 10. Research Summary

Category	Latest Information
Industrial Environment Discussion	Focus Group Discussion "Environmentally Friendly Business in the Food Industry" – August 2025
Regulation and Evaluation	PROPER Evaluation by the Environment Agency for the Food Industry
Environmental Conditions (2021–2024)	IKA (Eco-Friendly Business) increased slightly, IKU (Industry-Based Infrastructure) increased, IKL (Infrastructure-Based Infrastructure) fluctuated; IKLH (Infrastructure-Based Infrastructure) remained stable in the moderate category
MSME Waste Management Innovations	Program for processing tofu waste into organic fertilizer and digital marketing training

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