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STUDY OF ENVIRONMENTAL IMPACT IMPROVEMENT FOR SHRIMP FEED PRODUCTION COMPANIES

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ABSTRACT:
The fishing sector in Indonesia plays an important role in driving the national economy. Shrimp exports have increased from 162,256 tons in 2015 to 239,227 tons in 2020. Shrimp farming relies on proper management of shrimp feed. Inadequate feed management can result in organic waste build-up, harming shrimp growth, survival, and production efficiency. This research identifies the potential environmental impacts of a shrimp feed production process unit based on the gate-to-gate approach, with shrimp feed as its main product. Environmental impact identification is conducted using the Life Cycle Assessment (LCA) method using Microsoft Excel as tools. The LCA stages consist of goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and data interpretation. The method used is ReCiPe 2016 (H) midpoint impact assessment. Based on the results of the LCA study analysis, an environmental impact reduction scenario analysis is performed using an environmental program. The environmental impact assessment using LCA indicates that in the production process of 1 ton of shrimp feed, the most dominant environmental impacts are global warming potential (228,127 kgCO_2eq), and freshwater eutrophication (0,000175 kgPeq). In the production process of shrimp feed, the largest contribution to the environmental impact comes from the Boiler unit and Wastewater Treatment Plant (WWTP). Then, Analysed efforts to deal with environmental impacts on the shrimp feed production process uses the Analytical Hierarchy Process (AHP) method.

Keywords: Life Cycle Assessment, ReCipe 2016 Method, Shrimp Feed Production

INTRODUCTION

The fisheries sector in Indonesia plays a crucial role in national development, particularly through export earnings (Gephart et al., 2017). Shrimp is one of the key products contributing to export activities. The Ministry of Maritime Affairs and Fisheries has set a target to increase shrimp production by 250% or 2 million tons per year by 2024 (Bosman et al., 2021). Shrimp production systems primarily involve aquaculture, with shrimp feed being a critical factor (Yudiati et al., 2023). Improper feed management can result in the accumulation of organic waste, leading to reduced shrimp growth and survival rates, as well as inefficient production systems (Jescovitch et al., 2018).

The production process of shrimp feed consists of five stages: raw material separation, mixing, molding, drying, and size sorting (Karlovsky et al., 2016). The production process includes various units, such as the intake unit, fine grinding unit, mixer unit, extruder unit, press unit, post-pellet unit, dryer unit, cooler unit, sieveter unit, and bagging off unit. By producing high-quality feed in large quantities, shrimp production can be increased. This study aims to analyse the environmental impact of shrimp feed production using the Life Cycle Assessment (LCA) method with Microsoft Excel as the tool. The LCA stages include goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and data interpretation. The scope of this environmental impact analysis is gate-to-gate (Josa et al., 2007). The ReCiPe 2016 (H) method with midpoint impact assessment is used for impact category analysis in the LCA study.

The hotspots in the shrimp feed production process are the boiler unit and the wastewater treatment plant (WWTP) unit (Li et al., 2022). The impact category resulting from the boiler unit is 228,127 kgCO_2eq in terms of global warming potential, while the impact resulting from the WWTP unit is 0.000175 kgP eq in terms of freshwater eutrophication impact.

RESEARCH METHODS

LCA is one of the techniques employed in environmental management, such as risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment, applicable in various situations (Standardization, 2006).

- Goal and Scope Definition

The initial stage of this study involves defining the goal and scope.

- Life Cycle Inventory (LCI)

The life cycle inventory (LCI) stage involves inventorying input data, such as raw materials, energy, and water used in each activity, as well as output data, including product data and emissions and waste generated.

- Life Cycle Impact Assessment (LCIA)

The LCIA stage is used to analyse the environmental impacts resulting from a process or product, based on quantitative data collected during the inventory analysis stage.

- Interpretation of Data

The final stage of the life cycle assessment analysis is data interpretation. This stage involves identifying important issues, prioritizing areas that require or can benefit from emission reduction efforts (hotspot analysis), and evaluating the data.

Hotspot analysis focuses on identifying the production system's largest contributors to environmental impact and areas that require environmental improvement efforts (Nguyen et al., 2010). The evaluation of data aims to improve the accuracy and reliability of the LCA study's results. According to ISO 14044 (2017) (Standardization, 2006), data evaluation includes three types of checks: completeness check, consistency check, and sensitivity check.

RESULTS AND DISCUSSION

Goal and Scope Definition

The scope of this LCA analysis is gate to gate, starting from the processing of raw materials for shrimp feed production to the final shrimp feed product within the company's scope. In this study, the functional unit (FU) used is per 1 ton of shrimp feed produced in the year 2021. The data utilized in this research are secondary data, including the types of raw materials, products, energy usage, water usage, and emissions to both air and water, based on actual company data. The scope of the study does not include hazardous waste and non-hazardous waste data.

Life Cycle Inventory (LCI)

The second stage of conducting the LCA analysis involves inventorying input data (raw materials and fuel/electricity) and output data (waste and emissions to air and water) for a product throughout the life cycle of shrimp feed production, focusing on the LCA scope under investigation (Wu et al., 2014). Data collection encompasses specifying all input and output flows of the shrimp feed production process. It is necessary to verify the data by cross-checking with the source, such as records or documents reported by the company under operational conditions in the field, as per the data requirements.

The collected and verified data are then validated through a mass balance. When creating a mass balance for each process unit, it is recommended to adhere to the law of mass conservation and provide useful validation methods for the process unit description. The values obtained in the mass balance are based on the mass balance of raw materials and products for the inputs and outputs of each shrimp feed processing unit.

Life Cycle Impact Assessment (LCIA)

The third stage in conducting a life cycle assessment (LCA) study is the life cycle impact assessment (LCIA) stage, which aims to generate easily understandable and organized information about the impacts on human health, resources, and the environment from the LCI analysis. The method used in this LCA study is the ReCiPe 2016 (H) method, which includes impact categories, indicators, and characterization models. The LCIA stage consists of classification, characterization, and normalization.

Classification

In the classification stage, the inventory data is classified into impact categories based on the ReCiPe2016 (H) method (Feng et al., 2023). The following is the classification of the shrimp feed production process. The use of natural gas and coal as fuel in the boiler unit results in emissions to the air, including CO_2, CH_4, N_2O, SO_X, NO_X, and CH_3. These emissions fall under the midpoint impact categories of global warming, stratospheric ozone depletion, ozone formation – human health, fine particulate matter formation, ozone formation – terrestrial ecosystems, and terrestrial acidification.

Parameters such as BOD_5, COD, NH_3, NO_3, NO_2, Ba, Cu, Zn, which represent wastewater loads, fall under the midpoint impact categories of freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, human non-carcinogenic, and water consumption (Ghosb Dit Ghosn, 2022).

Characterization

All data flows in the LCI are classified into specific impact categories, multiplied by characterization factors, and summed with all relevant interventions, resulting in impact scores within those impact categories. The characterization process for the LCI data of shrimp feed production is performed using the ReCiPe 2016 (H) method in Microsoft Excel tools (Cooney et al., 2021). The equations used to calculate the characterization values per unit in the shrimp feed production process is below:

ISc = ΣI = (CFi x Ei) ……………(1) (Riva et al., 2006)

Where:

ISc = Impact score in a specific impact category

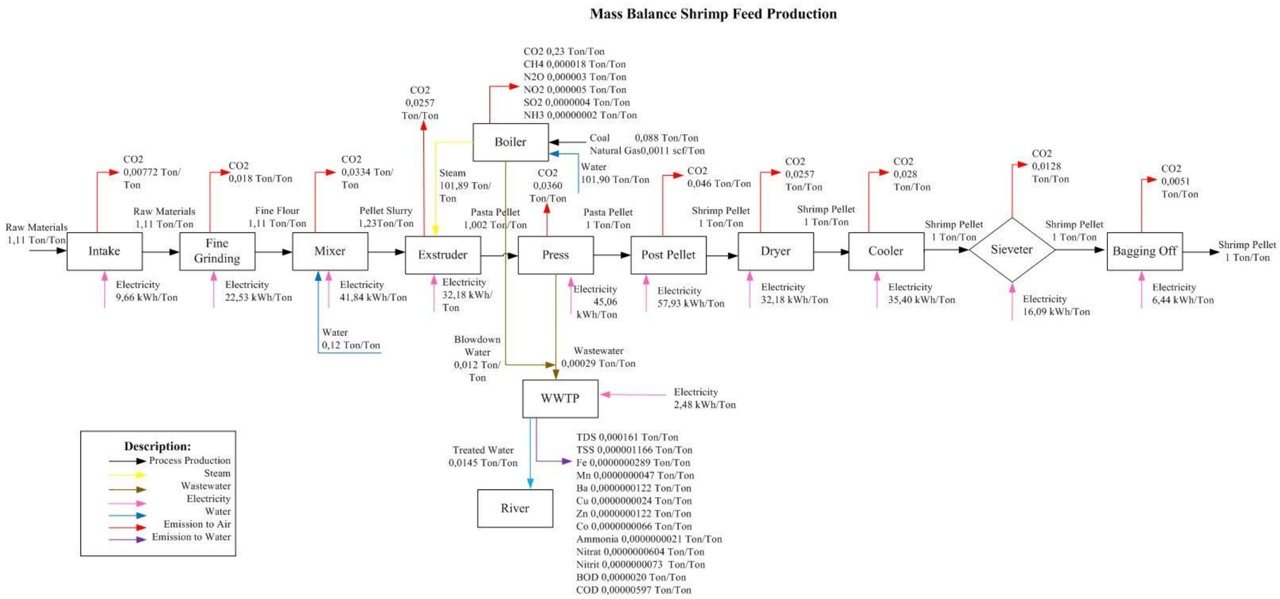

Figure 1. Mass Balance of Shrimp Feed Production

Cfi = Characterization factor

Ei = Elementary flow in a specific intervention

An example calculation of the characterization values for the midpoint impact of the shrimp feed production process is below:

For the boiler unit:

a. Output unit boiler:

Carbon dioxide (CO_2): 0,226743 Ton CO_2/Ton

Methane (CH_4): 0,000018 Ton CH_4/Ton

Dinitrogen monoxide (N_2O): 0,000003 Ton N_2O/ Ton

b. Characterization factor values for global warming (Huijbregts et al., 2017):

Carbon dioxide (CO_2): 1 kgCO_2eq/kg

Methane (CH_4): 34 kgCO_2eq/kg

Dinitrogen monoxide (N_2O): 298 kgCO_2eq/kg

c. Calculation of the characterization value for CO_2 Emissions:

ISc = ΣI = (CFi x Ei)

= 0,226743 Ton CO_2/Ton x 1 kgCO_2eq/kg x 1000 = 226,74 kgCO_2eq

d. Calculation of the characterization value for CH_4 Emissions:

ISc = ΣI = (CFi x Ei)

= 0,000018 Ton CH_4/Ton x 34 kgCO_2eq/kg x 1000 = 0,61kgCO_2eq

e. Calculation of the characterization value for N_2O Emissions:

ISc = ΣI = (CFi x Ei)

= 0,000018 Ton N_2O/ Ton x 34 kgCO_2eq/kg x 1000 = 0,78kgCO_2eq

f. Calculation of the total characterization value for global warming:

Global warming impact of the boiler unit = characterization CO_2 + CH_4 + N_2O

= 226,74 kgCO_2eq + 0,61 kgCO_2eq/kg +0,78 kgCO_2eq/kg = 228,13 kgCO_2eq

Here is a summary of the calculation results for the characterization per impact category in the shrimp feed production process.

Based on Table 1, it is known that the production of 1 ton of shrimp feed results in thirteen (13) midpoint impact categories.

Table 1
Summary of The Calculation Results for the Characterization

Impact Categories	Characterization	Unit
Global warming	469,563434147	kg CO2 eq
Stratospheric ozone depletion	0,000028745	kg CFC11 eq
Ionizing radiation	-	kBq Co-60 eq
Ozone formation, Human health	0,004671777	kg NOx eq
Fine particulate matter formation	0,000647619	kg PM2.5 eq
Ozone formation, Terrestrial ecosystems	0,004671777	kg NOx eq
Terrestrial acidification	0,002166463	kg SO2 eq
Freshwater eutrophication	0,000175486	kg P eq
Marine eutrophication	0,000005212	kg N eq
Terrestrial ecotoxicity	0,000000000	kg 1,4-DCB
Freshwater ecotoxicity	0,002985788	kg 1,4-DCB
Marine ecotoxicity	0,004150852	kg 1,4-DCB
Human carcinogenic toxicity	-	kg 1,4-DCB
Human non-carcinogenic toxicity	0,102548604	kg 1,4-DCB
Land use	-	m^2a crop eq
Mineral resource scarcity	-	kg Cu eq
Fossil resource scarcity	-	kg oil eq
Water consumption	102,023396357	m^3

There are six (6) impact categories generated from the Boiler unit, such as 228,127 kgCO_2eq for global warming impact, 0.0000287 kg CFC11 eq for stratospheric ozone impact, 0.00467 kgNOx eq for ozone formation - human health impact, 0.000647 kg$PM_{2.5}$ eq for fine particulate matter formation impact, 0.00467 kgNOx eq for ozone formation - terrestrial ecosystem impact, and 0.00216 kgSO_2eq for terrestrial acidification impact (Tillman, 2000). Additionally, seven (7) impact categories are generated from the WWTP unit, including 0.000175 kgP eq for freshwater eutrophication impact, 0.00000522 kgN eq for marine eutrophication impact, 0.00000299 kg1,4-DCB eq for freshwater ecotoxicity impact, 0.0000000000000000018277 kg1,4-DCB eq for terrestrial ecotoxicity impact, 0.00415 kg1,4 DCB eq for marine ecotoxicity impact, and 0.102 kg1,4 DCB eq for human non-carcinogenic impact (Morera et al., 2017).

Normalization

The normalization process is a stage where the characterized impact results are divided by the normalization values, aiming to facilitate comparisons between impact categories (Prado et al., 2020).

The following is the equation used in the calculation to obtain the characterization value per unit of shrimp feed production process:

$N = \frac{C}{NF}$ .... (2)(Farahdiba et al., 2023)

Where:

N = *Normalization*

C = *Characterization*

NF = *Normalization Factor*

The following is an example of calculating the midpoint impact normalization of the shrimp feed production process

<u>Unit Boiler:</u>

- Impact on boiler units:

Global warming potential: 228,127 $kgCO_2eq$

- Normalization factor in unit boilers (Huijbregts et al., 2017)

Global warming potential: 7.790

- Calculation of normalization value in unit boilers:

  N *Global warming potential* = $\frac{C}{NF}$

  $= \frac{228{,}127 \text{ kgCO2eq}}{7.790}$ = 0,02855

Table 2
Summary of The Calculation Results for the Normalization

Impact Categories	Normalization Values
Global warming	0,05877
Stratospheric ozone depletion	0,00047901
Ionizing radiation	-
Ozone formation, Human health	0,00022714
Fine particulate matter formation	0,00002533
Ozone formation, Terrestrial ecosystems	0,00026321
Terrestrial acidification	0,00005287
Freshwater eutrophication	0,00027003
Marine eutrophication	0,00000113
Terrestrial ecotoxicity	0,00000000
Freshwater ecotoxicity	0,00011860
Marine ecotoxicity	0,00009555
Human carcinogenic toxicity	-
Human non-carcinogenic toxicity	0,00000328
Land use	-
Mineral resource scarcity	-
Fossil resource scarcity	-

Based on Table 2, it is known that from the production process of 1 ton of shrimp feed, the highest impact values based on normalization values are in the categories of global warming potential (0.05870) and freshwater eutrophication (0.00027).

Interpretation Data

The identification of important issues is the result of reviewing the LCA analysis to determine hotspots, where an analysis is conducted on a production system that has the highest contribution or the largest environmental impact value, and requires environmental improvement efforts. The results of the characterization of the shrimp feed production process, as shown in Figure. 2, it is known that there are two (2) process units that have the largest environmental impacts, the boiler unit and the wastewater treatment plant (WWTP) unit. The boiler unit generates a global warming impact of CO_2 48.29%, CH_4 0.13%, and N_2O 0.17%, stratospheric ozone depletion with a 100% impact, solely due to N_2O emissions (Karunarathna, 2016). The unit has a 100% impact on ozone formation affecting human health, impact on fine particulate matter formation NO_2 79.35%, NH_3 0.77%, and SO_2 19.88%. Additionally, it has a 100% impact on ozone formation affecting terrestrial ecosystems, and contributes to terrestrial acidification NO_2 77.63%, NH_3 1.88%, and SO_2 20.49%. These emissions are primarily caused by the use of energy sources such as coal and natural gas in the boiler unit. On WWTP unit, it has impact on freshwater eutrophication 25.15% BOD_5, 74.85% to COD. It also has impact on marine eutrophication 9.63% NH_3-N, 77.74% NO_3-N, and 12.64% NO_2-N. The unit contributes to terrestrial ecotoxicity 0.89%Ba, 13.20% Cu, and 85.91%Zn. It also has impact on freshwater ecotoxicity 1.14% Ba, 12.95%Cu, and 85.91% Zn. Furthermore, it has impact on marine ecotoxicity 1.2% Ba, 11.1% Cu, and 87.7%Zn. Contributes to human non-carcinogenic toxicity 2.19%Ba, 0.01%Cu, and 97.8% Zn. These emissions are influenced by the discharge of wastewater into the sea based on the wastewater management process in the shrimp feed production.

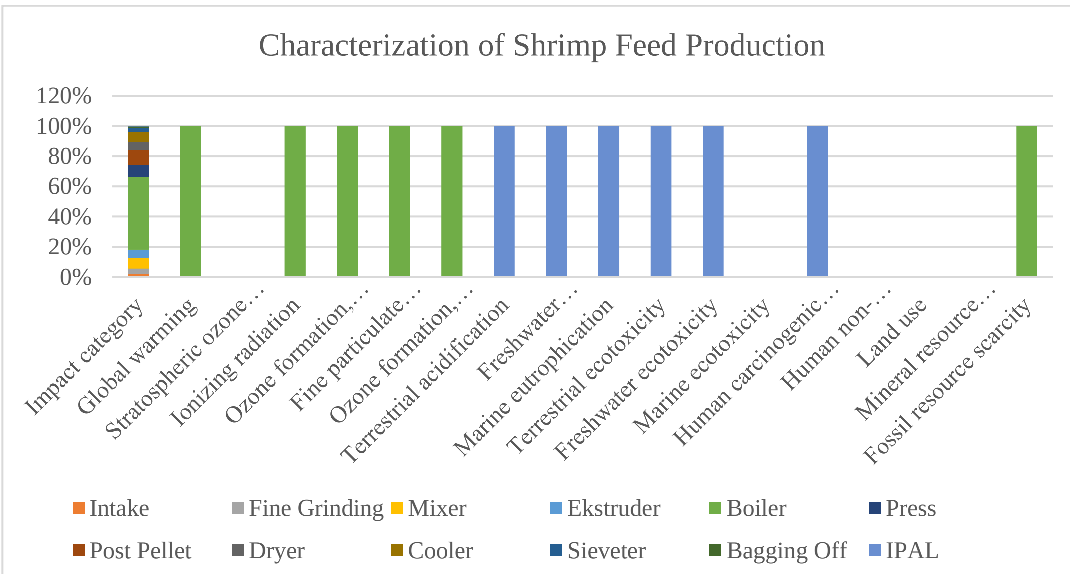

Figure 2. Characterization of Shrimp Feed Production Process

CONCLUSION

The conclusion of this analysis is in the production process of 1 ton of shrimp feed, the most dominant environmental impacts are Global Warming Potential (228,127 $kgCO_2eq$) and Freshwater Eutrophication (0,000175 kgPeq). Therefore, in the shrimp feed production process, the significant contributions come from the Boiler unit and the Wastewater Treatment Plant (WWTP) unit.suggestions provided by the reviewers.

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