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Comparison of Plastic Component for Automotive Filter Using Life Cycle Assessment

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Abstract— Plastic has become unseparated material in our life due to its properties have many advantages, but this material caused a bad environmental impact during production process. PT. DJBP as a plastic component manufacturer for automotive filter has a big concern for their production impact to environment. This company produced the component with Injection Molding machine. To manage its environmental impact, therefore an assessment has been carried out using Life Cycle Assessment (LCA) method to analyze three different thermoplastic material which was used for fuel filter, air filter, and oil filter. The assessment used a SimaPro program as the tools and the result can be seen on midpoint indicator and endpoint indicator.

Index Terms— Endpoint Indicator, Environmental Impact, Injection Molding, Life Cycle Assessment, Midpoint Indicator.

1 Introduction

The rapid growth of industrial has caused damage impact to human health and environment. According to Achim Steiner, UN Under-Secretary General and Executive Director UNEP on a report Assessing the Environmental Impact of Consumption and Production, United Nations Environmental Programme (UNEP), 2010, production of internationally traded goods, vital to economic growth, account for approximately 30% of global CO_2 emissions. The mining sector accounts for 7% of the world's energy use. Agricultural production accounts for staggering 70% of the global freshwater consumption, 38% of the total alnd use, and 14% of the world's greenhouse emissions [1].

Injection molding process is one of processes that generates financial returns. But this process results in many impacts to the environment [2]. PT. DJBP as one of manufacturer that produce a plastic component for automotive filter using Injection Molding has been demanded to create green production process.

Three different thermoplastics material were analyzed using LCA method to see the environmental impact. The method used was gate-to-gate to analized the impact from transportation process of material from supplier, energy consumption during production process, and transportation process to customer. Each process was inputted into SimaPro program.

2 METHOD

2.1 Life Cycle Assessment (LCA)

Accordance to ISO 14040:2006 and ISO 14044:2006, LCA is a structured, comprehensive and internationally standardized method. It quantifies all relevant emissions and resources depletion issues that are associated with any goods of services ("Products") [3].

The stages to conduct LCA were consist of four stages, goal and scope definition, inventory analysis, impact assessment and interpretation as shown on fig. 1 [4].

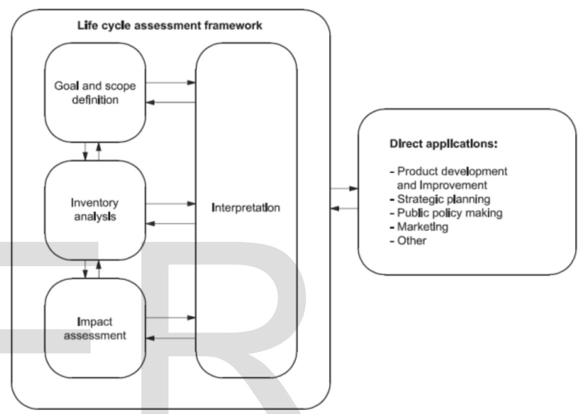

Fig. 1. Stages of Life Cycle Assessment

2.1.1. Goal and Scope Definition

The goal of an LCA should state: the intended application, the reasons for carrying out the study, the intended audience, i.e. to whom the results of the study are intended to be comunicated, and whether the results are intended to be used in comparative assertions intended to be disclosed to the public [4].

The goal of this assessment was to analyze the environmental impact from production process of three different thermoplastic material in PT. DJBP. The impact would cover human health, ecosystems, and resources.

The scope should be sufficiently well defined to ensure that the breadth, depth and detail of the study are compatible and sufficient to address the stated goal. The scope includes the following items: the product system to be studied; the functions of the product system or, in the case of comparative studies, the systems; the functional unit; the system boundary; allocation procedures; impact categories selected and methodology of impact assessment, and subsequent interpretation to be used; data requirements; assumptions; limitations; initial data quality requirements; type of critical review, if any; type and format of the report required for the study [4].

The scope of this assessment was to analyze 1 kg of material. First ranking-product of each material were considered to represent each type of material. The system boundary was gate-to-gate, which mean the only process that being analyzed was from delivery of material from supplier until the finished goods delivered to customer.

2.1.2. Inventory Analysis

The process of conducting an inventory analysis is iterative. As data are collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the data collection procedures so that the goals of the study will still be met. Sometimes, issues may be identified that require revisions to the goal or scope of the study [4].

In this paper, the data was taken from material comsumption and production data in year 2018. These data then inputted to SimaPro program. Eco-invent database on SimaPro ver. 9 faculty was used to represent the process and the material. Due to limitation of the database, therefore some assumption has been taken.

Tabel 1. List of Material and Products

No	Material	1st Ranking Product	Type of Filter	Qty of 1st ranking product/year 2018 (Pcs)
1	LDPE	Cap Dia. 19.5 x T=1.2	Fuel FIlter	26,259
2	PA6 + GF15%	End Cap 04152-31090	Oil Filter	38,231
3	HIPS	End Cap 17801-58040	Air Filter	3,645

Tabel 1 shown a list of material that have been assessed by LCA. LDPE was Low Density Polyethylene, it was a component for fuel filter. PA6 + GF15% was Polyamide reinforced by glass fiber 15%, it was a component for oil filter. HIPS was High Impact Polystyrene, it was a component for air filter.

2.1.3. Impact Assessment

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impact using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts [4].

SimaPro used ReCiPe 2016 to analyze the environmental impact. There were two impact categories on ReCiPe 2016, midpoint indicator and endpoint indicator. Midpoint indicator was more focus on single environmental impact, while endpoint indicator was more focus on human health, ecosystems and resources. Details of impact categories can be seen on fig. 2.

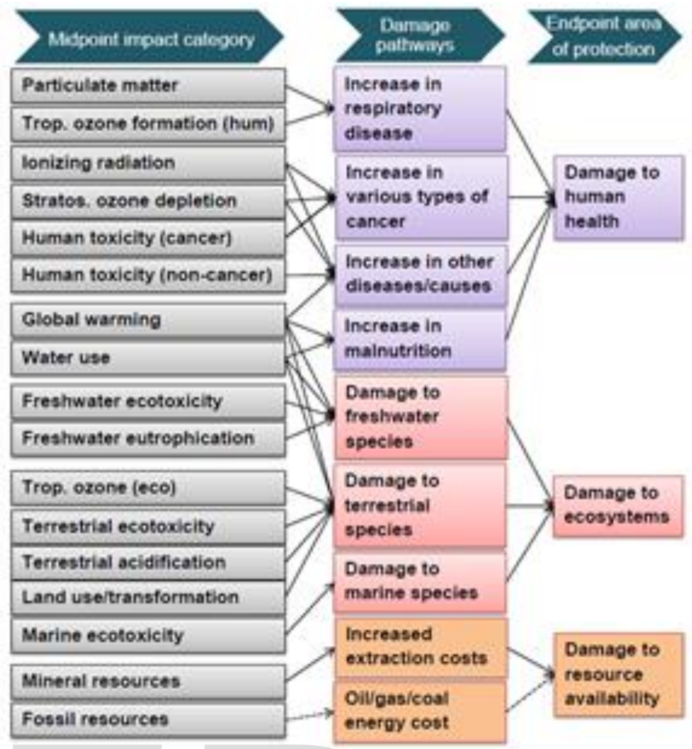

Fig. 2. Impact Category

2.1.4. Interpretation

The interpretation phase should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations [4].

2.2 INJECTION MOLDING

The plastic is the main raw material of products that are processed by injection molding. These materials are fused by heat transfer and solidified when cooled, without changing the chemical properties. The injection molding process is divided into five phases: mold filling, cooling phase, plasticization phase, and injection of the part [5].

There were two types of injection molding machine, vertical and horizontal injection molding. PT. DJBP used horizontal injection molding on production process.

2.3 THERMOPLASTICS

Plastics are a group of materials made up of long molecules, often referred to in scientific terms as macromolecules or more commonly as polymers (translated from Greek as meaning “many-units”. Polymers are formed by joining together many small simple molecules, called monomers, into a long chain. Plastic materials can be divided into two main categories; thermosets and thermoplastics. Thermosets are materials that on heating form a three-dimensional cross-linked network of polymer molecules. The formation of a cross-linked structure is irreversible and thermosets as a result can-

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not be softened again without decomposition occurring. Thermoplastics are characterized by their ability to be repeatedly softened at elevated temperatures and solidified by cooling [6].

2.4 PROCESSED DATA IN SIMAPRO

SimaPro was a computer program that was developed by Pré Consultants B.V. SimaPro had a function to collect, analyze and monitor the LCA data. SimaPro provided a menu to create waste treatment and waste scenario as well.

Three different material have been inputted into SimaPro referred to flow process as shown on fig. 3.

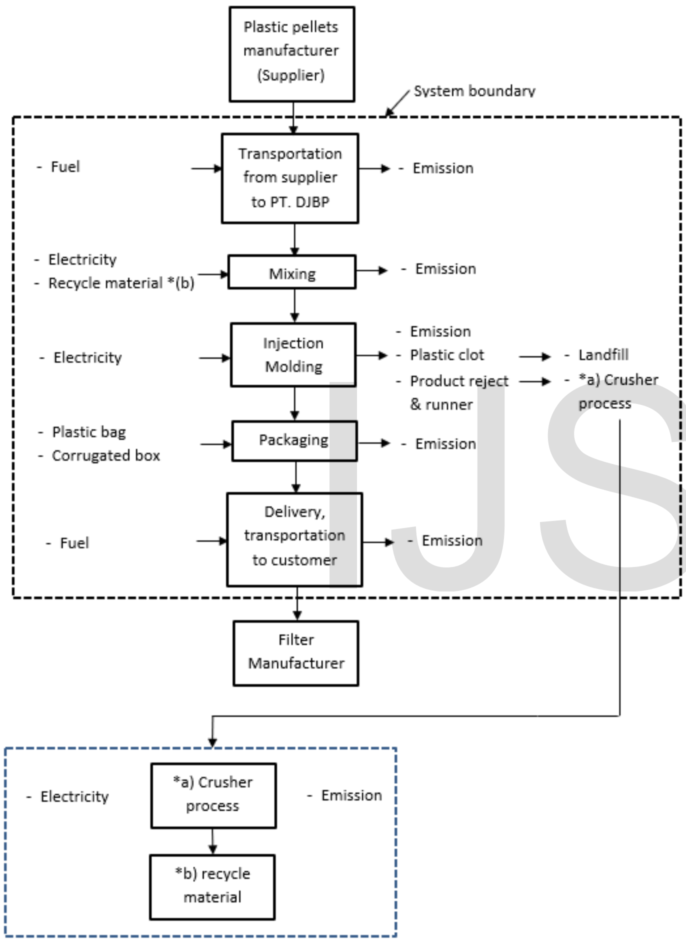

Fig. 3. Production FlowProcess

3 RESULT AND DISCUSSION

The result was consisting of two indicators, mindpoint indicator and endpoint indicator.

3.1 MIDPOINT INDICATOR

Midpoint indicator shown environmental impact per damage category. There were 18 impact categories on midpoint indicator as shown on tabel 2.

Tabel 2. Midpoint Indicator

No	Impact category	Unit	Cap Dia. 19.5 x T=1.2 (LDPE)	End Cap 04152–31090 (PA6+GF15%)	End Cap 17801–58040 (HIPS)
1	Global warming	kg CO2 eq	**151.3077**	121.3284	129.9723
2	Stratospheric ozone depletion	kg CFC11 eq	0.000072	**0.000101**	0.000070
3	Ionizing radiation	kBq Co-60 eq	3.4173	3.3720	**3.9923**
4	Ozone formation, Human health	kg NOx eq	**0.5594**	0.4834	0.5388
5	Fine particulate matter formation	kg PM2.5 eq	**1.0902**	0.3864	0.2791
6	Ozone formation, Terrestrial ecosystems	kg NOx eq	**0.5740**	0.4980	0.5556
7	Terrestrial acidification	kg SO2 eq	**0.5297**	0.4108	0.4374
8	Freshwater eutrophication	kg P eq	**0.0925**	0.0375	0.0309
9	Marine eutrophication	kg N eq	**0.0058**	0.0031	0.0021
10	Terrestrial ecotoxicity	kg 1,4-DCB	564.4144	532.4198	**623.8665**
11	Freshwater ecotoxicity	kg 1,4-DCB	**7.7503**	5.7281	6.2897
12	Marine ecotoxicity	kg 1,4-DCB	**10.8482**	8.1802	9.0363
13	Human carcinogenic toxicity	kg 1,4-DCB	**8.0495**	5.5376	5.7550
14	Human non-carcinogenic toxicity	kg 1,4-DCB	**225.5615**	188.1959	213.8473
15	Land use	m2a crop eq	2.7702	2.7857	**3.3285**
16	Mineral resource scarcity	kg Cu eq	0.3528	0.3468	**0.4098**
17	Fossil resource scarcity	kg oil eq	**46.8528**	38.3282	42.6220
18	Water consumption	m3	**0.5496**	0.5074	0.4870

One-kilogram LDPE produced 151.31 kg CO_2 eq on global warming category. It meant that during production process of 1 kg LDPE will produce 151,30 kg carbon dioxide. This led to an increase global temperature and can caused damage to human health and ecosystems.

Second category was stratospheric ozone depletion with value 0.00010 kg CFC11 eq which was produce from 1 kg PA6 + GF15%. Trichlorofluoromethane-freon 11/R11 (CFC11) caused ozone depletion and cannot protect earth from ultraviolet from the sun. It caused cancer and catharac.

One-kilogram HIPS produced 3.99 kBq Co-60 eq on ionizing radiation category. kBq was kilobecquerel, a unit to measure radiation, while Co-60 was Cobalt-60 isotop radioactive. Ionizing radiation caused health damage such as cancer and damage of DNA.

On ozone formation, human health category, 1 kg LDPE produced 0.5594 kg Nitrogen Oxide (NOx) eq. Photochemical reaction of NOx and Non-Methane Volatile Organic Compounds (NMVOCs) formed the ozone. This ozone caused damage on human health such as asthma and Chronic Obstructive Pulmonary Diseases (COPD).

The other category was fine particulate matter formation which was produced by LDPE 1.0902 kg PM2.5 eq. PM2.5 was a fine particulate matter with a diameter of less than 2,5 µm which was represented a complex mixture of organic and inorganic substances. PM2,5 can be inhaled by human and can caused respiratory damage.

The other category for ozone formation, was terrestrial ecosystems with value 0.57 kg NOx. Beside affected human health, ozone formation also affected ecosystems such as disappearance of plant species.

Terrestrial acidification category had the biggest value from LDPE as well with the amount 0.5297 kg Sulphur Dioxide (SO2) eq. It caused a change in acidity in the soil. The higher the level, it harmed plant species and damaged terrestrial ecosystems.

LDPE also caused biggest impact on freshwater eutrophication and marine eutrophication category with value 0.0925 kg Phosphorus (P) eq and 0.0058 kg Nitrogen (N) eq. The Increased nutrient levels i.e. phosphorus and nitrogen on a body of water caused excessive growth of algae. At the end, it damaged the freshwater and marine ecosystems.

On ecotoxicity category, biggest value for terrestrial ecotoxicity was from HIPS with value 623.8665 kg 1.4-DCB eq. While the biggest value for freshwater and marine ecotoxicity were produced by LDPE with value 7.7503 1.4-DCB eq and 10.8482 1.4-DCB eq. Ecotoxicity that impacted to human health which was human carcinogenic toxicity and human non-carcinogenic toxicity were also produced by LPDE as the biggest value which were 8.0495 1.4-DCB eq and 225.5615 1.4-DCB eq. The toxicity potential was expressed in a refence substance of kg 1,4-dichlorobenzene equivalents. The higher the level of toxicity, it damaged terrestrial ecosystems and caused damage on human health i.e. cancer, other non-cancer desease.

The next category was land use which HIPS produced the biggest value 3.3285 m2a crop eq. This impact was calculated on square meter area that used for agriculture. By producing 1 kg HIPS, it reduced 3.3285 square meter area for agriculture.

On scarcity category, HIPS produced biggest value 0.4098 kg Copper (Cu) eq on mineral resource scarcity category and LDPE on fossil resource scarcity category with the value 46.8528 kg oil eq. It meant by producing 1 kg HIPS it caused mineral resource reduced by 0.4098 kg Copper (Cu) and 1 kg LDPE caused oil resource reduced by 46.8528 kg oil.

On last category; water consumption, 1 kg LDPE consumed 0.5496 m3 during production process of LDPE.

3.2 Endpoint Indicator

On endpoint indicator, there were three indicators of category impact, human health, ecosystems and resources. Tabel 3 shown the endpoint indicator.

Tabel 3. Endpoint Indicator

No	Impact category	Unit	Cap Dia. 19.5 x T=1.2 (LDPE)	End Cap 04152–31090 (PA6+GF15%)	End Cap 17801–58040 (HIPS)
1	Human health	DALY	**0.000906009**	0.000418514	0.00036561
2	Ecosystems	species.yr	**7.16911E-07**	5.58676E-07	5.97557E-07
3	Resources	USD2013	16.38645331	14.99972106	**17.28672049**

On human health category, 1 kg LDPE caused 0.000906009 DALY. DALY was Disability-Adjusted Life Years. It meant the years lost to premature death and expressing the reduced quality of life due to illness in years. By producing this material, it caused 0.000906009 year lost to premature death.

Second category was ecosystems. LDPE also caused the biggest impact on this category by 7.16911E-07 species.yr. This material caused disappearance of local species 7.16911E-07 in a year.

Third category was resources. HIPS caused the biggest impact with value 17.28672049 USD2013. It meant due to resources depletion therefore the cost to extract the resources would be higher as 17.2867 USD2013.

4 Conclussions

Based on the result of midpoint and endpoint indicators, can be concluded that LPDE as a material for fuel filter component has produced the biggest impact on environmental. The second biggest impact was produced by HIPS as a material for air filter component and the third biggest impact was come from PA6 + GF15% as a material for oil filter component.

Based on analysis on SimaPro, the biggest impact was come from transportation process. It because the distance between supplier and factory were too far, therefore need more fuel during consumption. Another cause was come from energy consumption to operate the injection molding machine. The power required for the machine was too big therefore required mo energy to run the machine.

There was some suggestion that can improve the environmental impact, i.e. replacing transportation method to a bigger truck with bigger capacity, use low energy machinery, replacing the material with low environmental impact, and cooperate with automotive filter manufacturer to recycle used-filter components.

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