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Life Cycle Analysis Study of Plastic Flower Pot Products

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ABSTRACT

Some flower pots are made of plastic materials. Plastic waste is a global environmental issue with varying quantities and types in different countries. One source of plastic pollution is low-durability plastic pots, commonly used for seeding in agriculture, horticulture, and forestry. Waste from these plastic pots is difficult to decompose by soil microbes, thus posing an environmental contamination risk. Life Cycle Analysis (LCA), also known as life cycle assessment, is a method to measure the environmental impacts of products, such as biofuels. In LCA, researchers prepare an inventory of the resources used (e.g., fossil fuels and raw materials) and substances produced (e.g., greenhouse gases, solid waste, and other pollutants) throughout the full life cycle of production, transportation, and use of the product in question. From this inventory, researchers conduct impact assessments that estimate the final effects on human health, ecosystem function, and depletion of natural resources. This study aims to assess the life cycle analysis of plastic flower pot products from their initial material stage to their disposal as waste, in order to gain insights into the potential for minimizing their environmental impact. The results of research where the production of 600 ml plastic flower pot bottles required 28 grams of plastic resin per bottle, as well as energy for the production and transportation processes. Plastic packaging production produces defective products.
Keyword: Injection Molding, Inventory, Life Cycle Analysis

ABSTRAK

Beberapa pot bunga terbuat dari bahan plastik. Sampah plastik adalah masalah lingkungan global dengan jumlah dan jenis yang berbeda di berbagai negara. Salah satu sumber polusi plastik adalah pot plastik berdurasi rendah, yang umumnya digunakan untuk menabur di pertanian, kebun, dan hutan. Limbah dari pot plastik ini sulit terurai oleh mikroba tanah, sehingga menimbulkan risiko kontaminasi lingkungan. Analisis Siklus Hidup (LCA), juga dikenal sebagai penilaian siklus hidup, adalah metode untuk mengukur dampak lingkungan dari produk, seperti biofuel. Dalam LCA, para peneliti mempersiapkan inventaris sumber daya yang digunakan (misalnya, bahan bakar fosil dan bahan baku) dan zat yang dihasilkan (misalnya, gas rumah kaca, limbah padat, dan polutan lainnya) sepanjang siklus hidup penuh produksi, transportasi, dan penggunaan produk tersebut. Dari inventaris ini, para peneliti melakukan penilaian dampak yang memperkirakan efek akhir pada kesehatan manusia, fungsi ekosistem, dan penurunan sumber daya alam. Studi ini bertujuan untuk mengevaluasi analisis siklus hidup produk pot bunga plastik dari tahap bahan awal hingga penghapusan mereka sebagai limbah, untuk mendapatkan wawasan tentang potensi untuk meminimalkan dampak lingkungan mereka. Hasil penelitian menunjukkan bahwa produksi pot bunga plastik 600 ml membutuhkan 28gram resin plastik per pot, serta energi untuk proses produksi dan transportasi. Produksi pot bunga plastik juga menghasilkan produk yang cacat.
Kata Kunci: Analisis Siklus Hidup, Cetakan Injeksi, Inventori

1. Introduction

Achieving the concept of "sustainable development" necessitates the utilization of methods and tools that facilitate the quantification and comparison of the environmental ramifications associated with the provision of goods and services (referred to as "products") to our societies. These products are generated and utilized as a response to a particular need, whether it is genuine or perceived. Every product has a unique "life cycle," which starts with the design and development stage and continues through resource extraction, production (which includes the actual manufacturing or provision of the product as well as the fabrication of materials), use or consumption, and finally, the end of the product's existence through tasks like sorting, collection, recycling, and disposal of waste.

The original "Code of Practice" published by the Society of Environmental Toxicology and Chemistry (SETAC) divided life cycle assessment (LCA) methodologies into four main categories: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and life cycle improvement assessment. Nowadays, plastic makes up a sizable portion of the things in our environment [1]. Practically every object we discover is made of plastic, making it one of the most frequently utilized materials in the world. Injection molding is one of the many methods used in the manufacturing of plastic materials. As stated by [2] injection molding is an important technology used to produce various products. They study the defects and solutions of plastic parts during injection molding because it is difficult to set the process parameters very well which causes many defects such as short-shot, shrinkage, warpage and other defects. The choice of using flower pots depends on the preferences and needs of individual consumers. In the current technological development, creativity and innovation are required to create products, thereby improving the quality of the product in terms of art, function, and strength. Some flower pots are made from plastic materials. Plastic waste is a global environmental problem with varying quantities and types in each country [3]. One source of plastic pollution is low-durability plastic pots that are widely used for seeding, ranging from agricultural and horticultural plants to forestry. Waste from these plastic pots is challenging to decompose by soil microbes, thus posing an environmental contamination risk [4].

By delivering the material via the hopper of the machine to a heated chamber, which softens the material and forces it into the mold with the help of a screw, injection molding is a technique for creating plastic products from powdered thermoplastics.

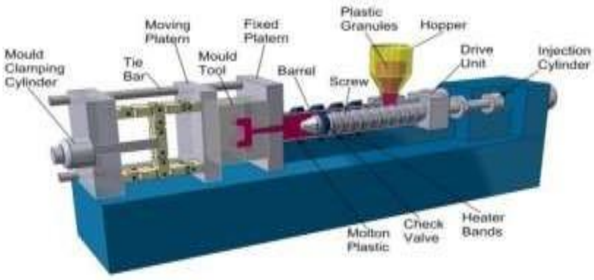

Figure 1. Injection Moulding Machine

Life Cycle Assessment (LCA) in general is approach used to measure impact environment of a product or activity during its cycle product life from raw materials, followed by the production process, use, and ends in waste processing [5]. With increasing international trade, LCA methodology is demanded by various sectors for applied to product and process industries [6]. LCA is methods that can be used to analyze potential environmental impacts caused by an activity whether a product or service with Know the inputs used, energy and sources natural resources [7]. The term life cycle assessment (LCA) refers to a methodological framework used to estimate and evaluate the environmental impacts associated with a product's life cycle. These impacts can include things like climate change, eutrophication, acidification, depletion of resources, water and land use, noise, and the formation of tropospheric ozone (smog)[8]. There are several approaches to LCA, and each has advantages and disadvantages of its own. One of the primary, if not immediately obvious, distinctions is whether the aim of the Life Cycle Assessment (LCA) study is to estimate the net changes in environmental impact resulting from decisions to produce the product, or whether it is to assign responsibility for the environmental impact of a particular product. The first method, referred to as the attributional approach, looks at how human activity affects the environment overall and tries to allocate some of that responsibility to a particular product, which may include the whole supply chain or just certain segments of it. The second method, referred to as the consequential approach, looks at how human activity affects the environment overall and aims to comprehend how it changes as a result of creating and consuming a particular product. Hence, the definition of attributional LCA is arbitrary and depends on the way system boundaries are established, which are usually limited by time, location, or supply chain phases. This is the main application for marketers evaluating different buying choices or engineers looking to increase process efficiency. Adopting life cycle thinking in the context of product policy also suggests that stakeholders are held more accountable for a wider range of environmental interventions over the course of a product's life cycle, realizing that shared responsibility among all stakeholders is the most effective way to achieve overall improvements in a product's environmental performance[9].

During the whole life cycle of the desired product's manufacturing, transportation, and usage, researchers compile an inventory of the resources required (such as fossil fuels and raw materials) and the substances created (such as greenhouse gases, solid waste, and other pollutants). This process is known as life cycle assessment (LCA)[10]. The life cycle of plastic flower pots in Medan consists of three groups: plastic flower pot manufacturers, plastic users (plant producers), and the plastic flower pot recycling network for raw materials for other plastic industries. Currently, these three groups are unidirectional and have not formed a complete cycle. Based on the life cycle inventory analysis of plastic, in the production of 600ml plastic flower pot bottles, 28g of plastic resin is required per bottle, along with energy for the production and transportation processes. The plastic packaging production results in defective products. The recycling process of plastic waste into chips yields a relatively high selling price compared to other materials. These chips are not yet recycled into raw materials for plastic flower pot production but are utilized for plastic products or burned as fuel [11].

Researchers create an impact assessment based on this inventory, estimating the ultimate impacts on ecosystem function, human health, and the depletion of natural resources. LCA is useful in identifying and mitigating the main sources of environmental impact in the product supply chain since it takes the full product life cycle into account. This research aims to examine the life cycle analysis of flower pot products from their initial materials to their disposal as waste, to obtain insights into the potential for minimizing their environmental impact.

2. Methodology

This research focuses on disaster management implemented in the Medan city area. The study takes the form of descriptive research, specifically survey research and direct observation. Descriptive survey research is an investigation aimed at gathering facts from existing phenomena and seeking factual information to ascertain the truth. The collected data consists of two types: primary data and secondary data. Primary data comprises data resulting from direct observation or measurement, such as questionnaires for equipment users, equipment providers, and academics. Secondary data includes information obtained from statistical agencies or previous research. The research is divided into several stages, namely:

1. Analysis of the raw material extraction, production, transportation, use, and disposal recycling processes.

2. Analysis of the use of green energy, both electrical and fuel-based energy.

3. Analysis of product sustainability.

The commencement of the stages of the injection molding process involves the initial introduction of a polymer into a hopper, which is subsequently conveyed to the barrel. The barrel is then heated to an appropriate temperature, allowing the polymer to exhibit fluidity. Subsequently, the molten plastic, resulting from the melting process, is forcefully injected into the mold under elevated pressure. This operation, commonly referred to as injection, is followed by the application of pressure to both the moving and fixed platens of the injection molding machine, with the intention of securing the mold tool in place. After that, the product cools down, which speeds up the solidification process. The two platens split apart to release the mold tool when the product reaches its intended shape. The final result of this process, called mold opening, is the ejection or removal of the molded object from the mold. After then, the entire procedure is performed once again[12]. In [13] Life cycle improvement assessment is now recognized as an integral part of the LCA approach rather than as a stand-alone stage. Furthermore, an introduction to life cycle interpretation has been made. As seen in Figure 2, this step of the LCA process interacts with every other phase.

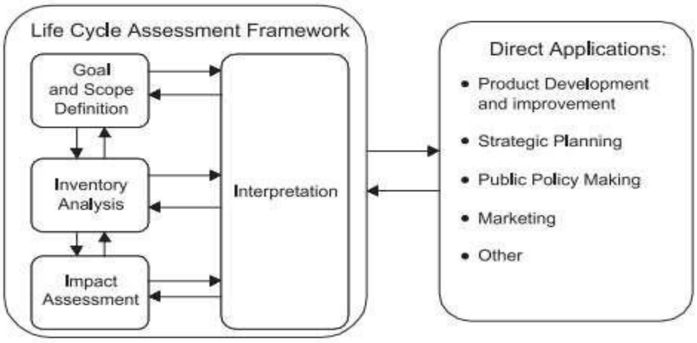

Figure 2. Phases and applications of an LCA (based on ISO 14040, 1997)

Setting goals and scope, or identifying objectives and the extent of the investigation, is the first step in the Life Cycle Assessment (LCA). Prior to the ensuing stages of the LCA, the objectives and parameters of this investigation were established. Finding out the effects that flower pot waste generation and processing have on the environment is the main goal of this study. The definition of limits and the study's scope also serve to reinforce the goal of this investigation. The Life Cycle Inventory (LCI) phase, which is the second stage of the Life Cycle Assessment (LCA), emphasizes the need for a range of raw materials that are used as study inputs. The Life Cycle Impact Assessment (LCIA), also known as the analysis phase, is the third stage of the Life Cycle Assessment (LCA) process. It looks at the kind and extent of the impacts that arise in each category. Further division takes place during this LCIA step, encompassing many analytical phases, including characterization, normalization, and the creation of a single score for the ensuing environmental effect.

3. Result and Discussion

3.1. Inventory Analysis

In this stage, data is collected to support LCA, including raw material and energy requirements, the plastic packaging production process, and the plastic packaging waste recycling process. The life cycle of plastic flower pots begins with the production of plastic flower pots. These plastic flower pots are then used to package plastic flower pot products. Through distributors, the items are made available to customers, who then utilize them, producing packaging debris that might contaminate the environment. Because plastic flower pots cannot be recycled by the environment, pollution may result. There is a bigger chance of environmental degradation the more plastic flower pots that are used to package goods. Thus, action is required to address the waste of plastic flower pots. Plastic flower pots have a long-life cycle because of the numerous parties involved in managing their trash. Three activities make up the life cycle of plastic flower pots: the plastic package recycling network, plastic flower pot manufacturers, and plastic flower pot factories (users).

3.2. Plastic Flower Pot Factory

In summary, the activities of the plastic flower pot factory involve producing plastic flower pots using plastic resin as raw material. The processing and formation of plastic flower pots are done in the form of preforms to be sent to users or other plastic flower pot factories. Plastic flower pots are made through a blow molding process. Based on the mass balance observation in the production of plastic flower pots, out of 1000g of resin, only 25 hot fill preforms and 10 defective ones are produced as waste. The ratio of finished products to defects is 5:2.

During the production process of plastic flower pots, the waste generated mainly consists of solid waste in the form of preforms and plastic flower pots that do not meet the standards. These non-standard preforms and plastic flower pots are sold to industries that require them, such as household products, and are not reused as raw materials for plastic flower pot production. This is due to a decrease in the strength or density of the plastic polymer structure, which can lead to the migration of monomer substances from the plastic material into food.

Quantitative data was challenging to obtain directly from packaging factory and plastic flower pot users, so several literature reviews and interviews were conducted. The plastic flower pot production process is quite lengthy, requiring a significant amount of energy. The energy requirements can be understood from the difference in the melting point between plastic raw materials and silica, resulting in significantly lower energy requirements for plastic packaging production. Plastic processing is done at 120°C, while silica sand is processed at 1500°C. The energy requirements for the production of plastic flower pots amount to 4956 MJ, and out of this, only 445 MJ (9%) comes from renewable energy sources, while the production of other plastic materials requires 9146 MJ (9.7%). The share of renewable energy in the production process of plastic flower pots and other materials is relatively small. The pot manufacturing process using molding injection can be seen in Figure 3.

Figure 3. Initial Stages of Pot Production

Figure 4. Pot Making Using Injection Molding

3.3. Environmental Impact Evaluation

Environmental pollution that occurs during the life cycle of plastic packaging includes contamination by physico-chemical components (air pollution, dust, noise, solid waste, and wastewater) and economic components. Data on air pollution and noise in one of the plastic flower pot production companies can be observed in. Assessing the life cycle impact of the product under study, it was found that the impact value for Table 1.

Table 1. Global Environmental Impact of Plastic Flower Pot Production and Other Materials

Parameter Pollutions	Unit	Year 2003	Year 2008	Environmental Quality Standards	Increase
SO2	Ig/NM3	3,48	29	52000	25,52
NO2	Ig/NM3	1,36	29	56000	27,64
NH3	Ig/NM3	0,58	140	17000	139,42
H2S	Ig/NM3	0,22	4,0	14000	3,78
CO	Ig/NM3	412	3895	29000	3483
TSP (Dust)	Ig/NM3	58,2	60	10000	1,8
Noise	db A	65	85,4	85b	20,4
Production Capacity	Thousand Bottles/Month	6.000	35.000	-	29.000

3.4. Social and Economic Components

In the stage of plastic flower pot production, it is anticipated that job opportunities can be created for the local community, thereby increasing their income. While the increase in community income through labor absorption is not substantial, it is expected to provide job opportunities for the community and encourage the creation of business opportunities for the local population. The life cycle of plastic flower pots involves more labor compared to other types of packaging, leading to an improvement in the welfare of the community due to the plastic flower pot recycling process.

3.5. Production Costs

The life cycle of packaging incurs costs, both for purchasing raw materials and the energy used to support the production and transportation processes. The price of plastic resin ranges from Rp. 12,150 to Rp. 14,400 per kilogram, which is much more expensive compared to other packaging materials, which cost Rp. 2,267 per kilogram. The raw material requirements for producing one unit of packaging in the plastic flower pot production process are 28 grams per unit, with a cost of Rp. 340 to Rp. 403 per unit. In contrast, the production of other packaging materials requires

300 grams per unit, with a cost of Rp. 680 per unit. The energy requirements (Table 1) and energy costs (Table 5) used for the production of other packaging materials are much higher than for plastic flower pots. This is due to the different nature of the raw materials. The production cost for one unit of other packaging materials is Rp. 1,700, whereas for one plastic flower pot, the cost is only Rp. 410 to Rp. 473 per unit. Looking at the costs of raw materials, energy, and transportation in the production process, plastic flower pots are more economical than other packaging materials. The selling price of other packaging materials is much higher than plastic flower pots, at Rp. 2,000 per unit, while plastic flower pots cost Rp. 900 to Rp. 950 per unit. In the waste handling process, the costs for handling plastic flower pot waste are much higher than for other packaging materials, as it involves multiple stages. However, the selling price of plastic flower pot waste is much higher than other packaging materials, at Rp. 3,000 per kilogram, while other packaging waste costs Rp. 1,000 per kilogram. This is due to the better quality of plastic flower pot waste compared to other packaging materials.

The results of the Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) are used to interpret and derive conclusions from the previously determined objectives and scope. When compared to other items, flower pots manufactured from plastic seeds are among the most ecologically friendly ones that were tested. Considering that this kind of substance is biodegradable, or biologically combustible. Every product under investigation has an effect on the environment. Based on the findings of conducted study, different approaches may be devised to optimize material and waste recycling, as well as the use of the most suitable methods for pollution avoidance or reduction.

4. Conclusion

The life cycle of plastic flower pots in Medan consists of three groups: plastic flower pot manufacturers, plastic users (plant producers), and the plastic flower pot recycling network for raw materials for other plastic industries. Currently, these three groups are unidirectional and have not formed a complete cycle. The combination of results from the Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) is used to interpretation, draw conclusions from the goals and scope that have been previously identified. Based on the life cycle inventory analysis of plastic, in the production of 600 ml plastic flower pot bottles, 28 grams of plastic resin is required per bottle, along with energy for the production and transportation processes. The plastic packaging production results in defective products. The recycling process of plastic waste into chips yields a relatively high selling price compared to other materials. These plastic pellets are not yet recycled into raw materials for plastic flower pot production but are utilized for plastic products or burned as fuel.

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