LIFE CYCLE ASSESSMENT OF PLASTIC WASTE USING OPENLCA SOFTWARE

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THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF CIVIL ENGINEERING

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ABSTRACT

This study examined the environmental effects of recycling high-density polyethylene (HDPE) ecofurniture using the OpenLCA software package. In this study, life cycle assessment (LCA) was adopted to compare the environmental impact of cradle-to-gate boundary of recycling and manufacturing 1 kg of ecofurniture functional unit. The objective of this study is to compile and develop relevant databases related to the plastic waste ecofurniture, to assess the LCA through OpenLCA in obtaining environmental impact of the waste-to-wealth product generation. Primary data (amount of plastic waste, electricity, emission and water) were gathered in a local recycling centre, EZplast Plastic and data from the European Life Cycle Data database. The CML Baseline impact method, which is readily available in the EcoInvent 37 LCIA database, is employed to determine plastic waste performance in terms of their impact categories. Seven environmental impacts categories were considered, namely climate change, human toxicity, ecotoxicity (terrestrial, fresh water and marine aquatic), acidification, ozone layer depletion, depletion of abiotic resources and photochemical oxidation. According to the life-cycle assessment findings, the consumption of electricity and HDPE during the manufacture of ecofurniture resulted in the greatest amount of environmental loading.

ABSTRAK

PENILAIAN KITARAN HAYAT SISA PLASTIK MENGGUNAKAN PAKEJ PERISIAN OPENLCA

Kajian ini mengkaji kesan alam sekitar kitar semula polietilena berketumpatan tinggi (HDPE) ekofurniture menggunakan pakej perisian OpenLCA. Dalam kajian ini, penilaian kitaran hayat (LCA) telah diterima pakai untuk membandingkan kesan alam sekitar sempadan buaian ke pintu kitar semula dan pembuatan 1 kg unit berfungsi ekoperabot. Objektif kajian ini adalah untuk menyusun dan membangunkan pangkalan data berkaitan yang berkaitan dengan perabot sisa plastik, untuk menilai LCA melalui OpenLCA dalam mendapatkan impak alam sekitar penjanaan produk sisa kepada kekayaan. Data utama (jumlah sisa plastik, elektrik, pelepasan dan air) dikumpulkan di pusat kitar semula tempatan, EZplast Plastic dan data daripada pangkalan data Data Kitaran Hayat Eropah. Kaedah impak CML Baseline, yang tersedia dalam pangkalan data EcoInvent 37 LCIA, digunakan untuk menentukan prestasi sisa plastik dari segi kategori impaknya. Tujuh kategori impak alam sekitar telah dipertimbangkan, iaitu perubahan iklim, ketoksikan manusia, ekotoksisitas (daratan, air tawar dan akuatik marin), pengasidan, penipisan lapisan ozon, penipisan sumber abiotik dan pengoksidaan fotokimia. Menurut penemuan penilaian kitaran hayat, penggunaan elektrik dan HDPE semasa pembuatan ekofurniture menghasilkan jumlah beban alam sekitar yang paling banyak.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ELCD	-	European Life Cycle Data
HDPE	-	High-Density Polyethylene
LCA	-	Life Cycle Analysis
LCC	-	Life Cycle Costing
LCI	-	Life Cycle Inventory
LCIA	-	Life Cycle Impact Assessment
LDPE	-	Low-Density Polyethylene
PE	-	Polyethylene
PET	-	Polyethylene Terephthalate
PP	-	Polypropylene

CHAPTER 1

INTRODUCTION

1.1 Introduction

Plastics are comprised of synthetic organic polymers. They are widely due to their durability, versatility, lightweightness and manufacturing affordability (Khoo, 2017). Plastic is vital because of its lightness, malleability, and flexibility, as well as its resistance to microbial attack and other types of natural degradation (Tamburini et al., 2021). Although the first plastics were created in the 1860s, it was not until 1940s that the manufacturing of plastics became one of the global sectors with the quickest growth rates (H. L. Chen et al., 2020). Recent data suggest a tendency toward increased consumption resulting in waste of plastics. The worldwide plastic output reaching 338 million tonnes in 2019, accelerated 640 % from 1975 (Matthews et al., 2021).

Plastic garbage accounts for a large share of total municipal solid waste globally. Approximately 8,300 million tonnes of plastics were generated between 1950 and 2015, with more than half ended in landfills or pollute the environment. Plastic products are produced and consumed by human beings in massive quantities (H. L. Chen et al., 2020). In addition to that, Malaysia's waste management systems are insufficient to deal with the amount of plastic waste produced. In the country, the primary methods of dealing with plastic waste are landfill disposal and domestic burning. Malaysia is tracking global trends in both overall plastic waste generation and single-use plastic consumption, which has been on an upward trajectory since the 1970s and accounted for 19 %of total waste generated in Malaysia in 2017 (Bataineh, 2020).

The Malaysian plastic industry is divided into seven major sectors which are household, automotive, agriculture, construction, packaging, electronics and other sub-sectors such as plastic furniture and medical devices. Malaysian plastic is most frequently used for packaging, following worldwide trends (H. L. Chen et al., 2020). An estimated 6.30 billion tonnes of plastic garbage were produced between 1950 and 2015. Despite that fact, only 9% of that waste was recycled, leaving more than 80% to build up in landfills or the environment (Liang et al., 2019). Some of the factors that could impact the efficiency of plastic waste recycling are the lack of infrastructure for collecting and processing plastic waste, the requirement for new technology, a complicated recycling process, a poor economic return, a lack of end users, as well as worries about quality and availability.

Furthermore, the cost of virgin plastic production is lower than the cost of recycling, since the cost of crude oil, of which the virgin plastics are made of, is low. Thus, this is where waste-to-wealth agenda comes in line. It aims to identify, develop and deploy technologies to treat waste to generate energy, recycle materials, and extract resources of value (Hossain, M. U., Ng, S. T., Dong, Y., & Amor, 2021). One of the waste-to wealth agendas is by recycling. Recycling can be broadly defined as a waste management practice that involves gathering waste materials and turning them into raw materials that may be used again to create other useful products (Evode et al., 2021).

In order to safeguard the environment and society, it is also referred to as "renewing or reusing." Due to their carbon-based composition and use of additional polymers, plastics are not biodegradable. It includes bottles and other items that can be melted down and used to make furniture made of plastic, such as tables and chairs. The following six steps are used to complete the process are gathering waste plastics, sorting or categorising plastics, washing to eliminate pollutants, shredding and resizing, identifying and separating plastics, and compounding (Evode et al., 2021).

Waste reduction through product recycle has the potential to help with sustainability. It contributes to both environmental and social advantages by reducing waste volume, hazardous substance content in refuse, negative human and environmental consequences, and energy inputs to recycle, treat, and dispose of waste in post-consumption states. The guiding idea for implementing sustainable

waste management was the waste management hierarchy, which places the following measures in descending order of priority: prevention, recycling, recovery, and landfill (Wang et al., 2021).

Life Cycle Assessment, or LCA, is a tool life-cycle system proposed for this project to determine the environmental impact analysis (Amon et al., 2021). There are many software packages that can be utilized to analyse the data input but for this research the OpenLCA shall be used. It is a commonly used and well-known freeware package (open source) that allows the user to compute all of the steps connected with LCA (Iswara et al., 2020). It is a tool used to evaluate applications, alternative plastic materials, and destinations, and, as a result, to identify opportunities for environmental improvement. As an outcome, it can and should be used to assist in communicating sustainability data to public authorities, business and consumers (Gileno & Turci, 2021).

Mechanical recycling yields useful products such as High-Density Polyethylene (HDPE), Low Density Polyethylene (LDPE) and Polyethylene (PE) resins. Mechanical recycling can only be economically viable if these specific types of plastic waste streams are available in sufficient quantities (Khoo, 2017). Mechanical recycling of HDPE with specific identification number two (2) shall be used for this EZplast plastic ecofurniture manufacturing investigated in this study. The aim of the study is to identify the potential environmentally sustainable plastic waste management strategy using the LCA technique.

1.2 Background of the Study

Plastic waste management is one of the most serious environmental issues confronting municipalities worldwide and it is the most serious environmental issue in Malaysia (Bishop et al., 2021). The reason behind conducting this research is because plastics are by far the most frequent recyclable materials in Malaysia, having a significant potential for recycling due to their widespread use and indiscriminate disposal to landfills. It is critical to recognize that not only does bolstering recycling activities lengthen the life of landfills, but it also benefits the economy by opening up a wide variety of profitable commercial enterprises. Despite the fact that most plastics are recyclable and simple to process, there is a lack of recycling awareness among plastic manufacturing companies, and most people are unable to transform their concerns into action (Erkisi-Arici et al., 2021).

Malaysia has an extremely low recycling rate, under 5%, as compared to countries like Singapore (11%), Thailand (14%), Japan (40%), China (13%) and Germany (52.8%). Malaysia has a lot of potential to meet its 22% recycling target by 2025, but not with the current rate of technology advancement. Malaysian recycling has a long way to go, with considerable issues and barriers to overcome before a successful recycling scheme can be implemented (Neo et al., 2021). Other researchers contributed in LCA or LCIA research in most of their regions but not in my specific locality which are the gaps in understanding the areas that have not been addressed in these studies.

1.3 Problem Statement

There is no evaluation of LCA studies applied to plastic ecofurniture and their pre-treatments that includes analyses the LCA methodology employed by each study, comparing assumptions, limitations, and used data, among other components, to the prior research. A review paper on this topic is relevant for policymakers, private-sector decision-makers, researchers and audiences interested in LCA results, as it

answers the question of which methodological elements such as functional units, system limits, required data, impact assessment methods, impacts to be calculated, are recommended to conduct an LCA on them to determine and mitigate the environmental impacts.

Based on the reason of background study above, stated below are some of the issues raised:

1. "What are the types of inventory data is needed to be able to assess LCA in OpenLCA software?"
2. "To what extent does the OpenLCA software can assess the LCA along with the environmental impact categories for the production of plastic waste ecofurniture?"
3. "How would recycling the plastic waste influences the environmental impacts of manufacturing processes and what are the effective strategies to mitigate issues raised if any?"

1.4 Research Objectives

The aims of this study are stated below as based on the reasoning and issues of background description above:

1. To compile databases of processes involved in the plastic ecofurniture for the input and output of LCA in OpenLCA.
2. To assess the life cycle assessment of the manufacture of plastic ecofurniture in the OpenLCA software.
3. To determine the environmental impacts caused by plastic ecofurniture generation through LCIA assessment in OpenLCA.

1.5 Scope of Work

Waste-to-wealth is not a new concept and it is one of the keys to sustainable development. It refers to conversion process of waste to a product that can used for daily purposes. (Khoo, 2017). Unfortunately, most waste has become a second-rate value and expensive due to material recovery processes. Drastic measures on the environment need to be taken immediately and this cannot afford to wait debating on. Recycling, reuse, and energy recovery are all necessary components of an integrated waste management strategy. The project entails processing and developing end materials to create reusable ecoplastic furniture solutions.

An emerging organization in Sabah namely EZplast based in Papar Waste plastics actively collected for recycling by the EZplast company include washing, shredding, drying, and classifying, which are all part of the mechanical recycling process. This process yields granules, pellets, or flakes, which are used in a variety of applications. However, for this organization, it emphasizes more on manufacturing reusable plastic ecofurniture. The scope of this LCA is "cradle to gate," which includes the stage of transporting post-consumer HDPE to the Recycling Unit, as well as the conversion steps in the recycling industry. It includes sorting, cleaning, and grinding of bottles into flakes and processing into finished good as shown in Figure 1.

Figure 1: EZplast Plastic Waste-to-Wealth Product

Table 1 below shows the scope of research work which includes the objectives, scope and items or parameters needed.

Table 1: Scope of Research Work

Research Objectives	Research Scope	Items/Parameters needed
1. To compile databases of processes involved in the plastic waste ecofurniture for the input and output of LCA in OpenLCA.	Obtain fieldwork data from EZplast recycling facilities and online databases to be inserted as inventory of the waste-to-wealth product in OpenLCA software.	1. EZplast Recycling Centre: - Shredding rate - Moulding rate - Machine information - Energy consumption for processes 2. ELCD Database
3. To assess the life cycle assessment of the manufacture of plastic waste ecofurniture in the OpenLCA software.	Utilise OpenLCA software to create flows, processes, systems and project in order to assess the LCA of plastic ecofurniture product using data obtained previously in Objective 1.	1. Functional unit 2. Flows 3. Processes 4. Product System 5. Project
4. To determine the environmental impacts caused by plastic ecofurniture generation through LCIA assessment in OpenLCA.	Obtain the environmental impact results from using the CML baseline method and relate to other research articles for comparison and justification.	1. Climate change 2. Human toxicity 3. Ecotoxicity (terrestrial, fresh water and marine aquatic) 4. Acidification 5. Ozone layer depletion 6. Depletion of abiotic resources 7. Photochemical oxidation

1.6 Significance of Study

The importance of the author's research work and impact on research field includes the contribution to new knowledge, precisely in regionalized LCA. The benefit of study includes understanding the processes that happen in recycling processes. It is also executed to know the ways of recycling. Despite waste management guidelines that have been implemented in stages, more effort is needed to regulate plastic waste management practice in order to prevent potential threats to human health and the environment, as well as to better utilise any potential resources.

Reasons to conduct the study include the need for information on the subject and making it available to those involved in the environmental sustainability of the HDPE chain, namely producers, customers, consumers, collectors, scrap dealers, governments, academics and so on. The end users are primarily companies and entities involved in production, consumption, and recycling of those plastic waste mentioned. The production chains that use these recycled materials as raw materials, in particular the textile industry and packaging manufacturers, require information in order to compose the life cycle assessment of their products. As a conclusion, it aims to inform and motivate decision-makers to take remedial actions to promote their recycling plans.

CHAPTER 2

LITERATURE REVIEW

2.1 Plastic Waste-to-Wealth Agenda

This first section reviews the literature related to plastic waste. In 2013, Moh and Abd Manaf made a concerted effort to create a summary of solid waste recycling in Malaysia at the level of the household, which is the most fundamental unit of a community or country. Most studies focus on a broad picture of the state of solid waste management in Malaysia, even though there is a need to highlight smaller issues such as solid waste recycling and minimization before moving on to the larger picture. Recycling offers a sustainable solution to the country's solid waste management due to rising waste generation in Malaysia's solid waste resources, with household units contributing the majority of this waste, limited space for waste disposal, and other related issues ranging from social to economic concerns.

Through a detailed research of the generation and trade of plastic waste by Liang et al. in 2019, the management and treatment of plastic waste in Asia were analysed regionally. The overall formal treatment and recycling status of plastic waste is less than satisfactory due to the enormous amount of plastic waste that is produced within Asia and the ongoing import of waste from abroad. This is a deficiency that will result in more severe pollution and harm to the environment and human health. Plastic waste imports to Malaysia increased by double and triple in 2017 and 2018 compared to 2016, which is a grave concern. In order to prevent future imbalance of domestic plastic pollution, Malaysia amended its rules in 2018 to tighten management of the imported plastic waste business. Considering the existing plastic

waste scenario, attention needs to be placed on measures to control plastic waste as well as to better recycle plastic waste produced internally.

According to earlier research by Chen et al. published in 2020, recycling plastic garbage uses significantly less energy and has a less negative environmental impact than landfilling or incineration. This is because, regardless of the fact that energy consumption and emissions are necessary for recycling, it enables a reduction in overall fossil fuel use as well as a reduction in overall carbon dioxide emissions. Overall, the societal benefits of recycling, such as improved human health, far outweigh the costs of recycling. The most pressing current challenges for Malaysian plastic waste management systems includes the outlining the plastic waste problem, the plastic waste cycle, description of plastic waste recovery in Malaysia. They made recommendations to address the country's major plastic waste management challenges, which were mainstreaming plastic alternatives and model of plastic waste management based on circular economy. The Malaysian government has stated that turning waste into resources will ensure the effective use of natural resources while lowering pollution in the nation, which is relevant to the waste-to-wealth strategy.

2.2 Life Cycle Assessment

Life Cycle Assessment (LCA) is obtained, based on the International Standards Organization (ISO) documents 14040 and 14044, which provides a comprehensive instrument for evaluating the environmental implications of products and services over their entire life cycle (Sazdovski et al., 2021). Figure 2 below illustrates the typical framework of LCA as standardized in ISO 14040 guidelines, which mainly consist of four distinct stages and used to help a few direct applications. A few issues need to be considered when undertaking an LCA study.