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Integrated LCA and OPEN LCA-CML baseline analysis on environmental impact associated with the plastic packaging waste management system of Rubavu city Rwanda

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ABSTRACT
Over the past few decades, the life cycle assessment (LCA) has been established as a critical tool for evaluating environmental issues of chemical processes and material cycles. Plastic bottles are the most used materials for packaging beverages and other liquids. In Rubavu, wasted plastic bottles end their lives in Rutagara. This is an open dumpsite that is home to all of the different types of generated waste of Rubavu city, and its management is alarming. This study analyses the impact on the environment associated with the existing plastic bottle waste pathways in Rubavu, Rwanda, from the cradle to the grave perspective until the other process in Nairobi Kenya, as an extended process. Questionnaires, Interviews, Literature: scientific papers, government reports and internet websites were used through this study to get both primary and secondary data. Open LCA CML (baseline) method was applied to analyze the environmental impacts caused by plastic bottles during their management, focusing on its parameters conspicuously: acidification potential, climate change (GWP100), depletion of abiotic resources (elements, ultimate reserves), depletion of abiotic resources (fossil fuels), eutrophication (generic), freshwater aquatic ecotoxicity(FAETP inf), human toxicity (HTP inf), marine aquatic ecotoxicity (MAETP inf), ozone layer depletion (ODP steady-state), photochemical oxidation (high NOx), terrestrial ecotoxicity (TETP inf). Two alternatives to these were also analysed: sanitary landfill, and recycling, described as scenarios 1 and 2. In this framework, the result of LCA shows that the use of landfill was found to have the highest adverse environmental effects, and this process has resulted in high global warming potential due to plastic bottle packaging waste decomposition effects as they release methane and ethylene, which contributes significantly to the greenhouse gases.

Keywords: Life Cycle Assessment (LCA); Plastic; Environmental Impact; Solid Waste Management

INTRODUCTION
Background
Plastic materials are used globally. They are known to be cost-effective polymers that can be thermoformed into other shapes. Their ability to be blown film extruded or extruded into various products has made them very useful globally [1]. Plastic bottles bring many societal benefits; however, if they are not handled well, their use can result in various negative environmental impacts to both the environment and human health. When they are poorly disposed of, they can result in the accumulation of waste in landfills and natural habitats.

They can cause physical problems for wildlife resulting from ingestion, the leaching of chemicals from plastic waste and their potential to transfer chemicals to wildlife and humans. There exist various management practices for plastic bottle waste and some were discussed in this study. These include the waste hierarchy, recycling, pyrolysis, incineration, among others [2]. LCA methodologies make the quantification of used energy and raw materials possible by using the the amount of solid, liquid and gaseous waste generated at each stage of the product's life and it also analyses the potential emissions to the atmosphere when they are being processed.

These emissions can further cause adverse effects on human health and the environment. Unfortunately, there is a delay in the approval from the public for the establishment of any new waste treatment and disposal facilities.

Scope of the study

In this paper, the scope of this study involves tracing plastic bottle waste from their point of waste generation up to landfill or to Nairobi for further processes. Three alternatives in this scenario were analysed: sanitary landfill, incineration and recycling, described as scenarios 1, 2 and 3 respectively.

The scope of this study also analyses and quantifies the sources of plastic bottles waste as generated in Rubavu city as described in

FIGURE *1*. Hence determining their point of generation until any further processes.

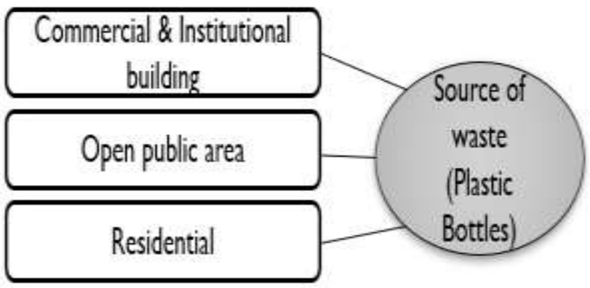
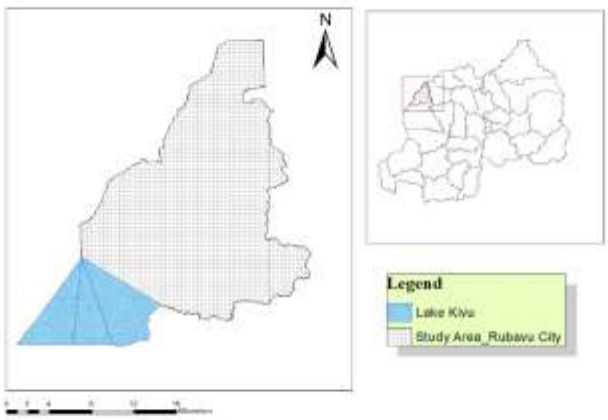


FIGURE 1: Source plastic bottles waste generation of Rubavu City

Case Study and Plastic Waste Generation

Rubavu City is also known as the hub for tourism and industry in Rwanda. It accommodates tourist in areas such as Lake Kivu and the hot springs. Rubavu City also has the highest GDP growth rate among secondary cities, averaging about 11% in the last seven years. Rubavu is situated in the western province with the area under study of 388.3 Km^2, as described in

FIGURE *2*. Rubavu has a population of 426,356 (census MUSA 2020), which generate around 13,450 tons of daily plastics bottles waste with an average rate of 0.03 kg/capita per day. The present study covers all 12 administrative sectors, 80 Cells and the 525 Villages ten



administrative ward cities.

FIGURE 2: Map of the study area

System Boundary and Material Flow Analysis

Plastics represent a low-cost, easily formable, high-modulus, hydrophobic, bio-inert material that finds use in a bewildering range of consumer products. It is often the material preferred. Although some plastic products are an indispensable choice in consumer packaging that accounts for 42% of the global annual resin production [3].

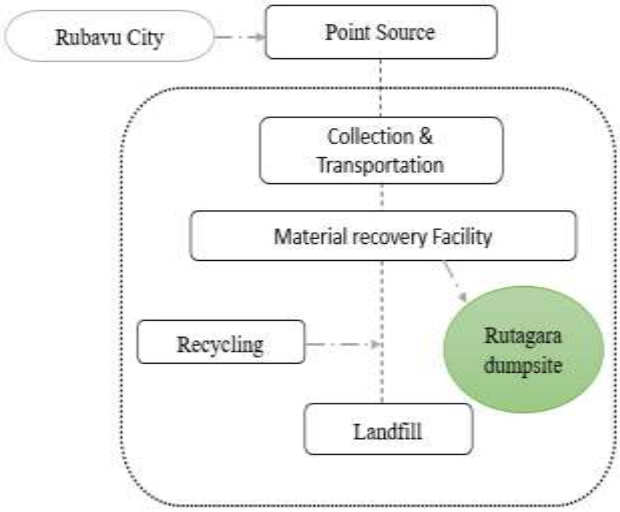


FIGURE 3: System boundary of the study

Following the material flow of this study, it is well indicated that approximately 13,450 tons of bottles are left exposed every year. In this study it was found that 80% of them contain mineral water whereby the rest contain other beverages. These plastics are primarily collected and then sent to the Rutagara open dumpsite.

In this research, primary data and secondary data were used to understand the relevant information about the primary producers of plastic waste in the city. It was found that the producers are local food manufacturing chains such as Inyange Industries, Sulfo Rwanda, Akandi, Amazi ya Huye and Coca Cola companies. All of the 13,450 tons of plastic bottles generated are collected and transported by privately-owned companies, and only 40% of them end their lives in Rutagara dumpsite every year. The remaining 60 % of plastic waste are then exported to Kenya for further processing. As the results of this study, the numbers show that 822 tons are dumped in landfill every year. About 4,610 tons of plastic bottles are discarded in the environment directly after usage per year, and they were described as uncountable [4]. The scenario is described in TABLE 1.

TABLE 1: Description of scenarios used in the present study

Scenario	Description
S1 MRF_LF	36% of recyclables to MRF and 54.4% residual waste to landfill

METHODS

Plastic Waste Generation Sources and Disposal Behavior

Plastic waste is a collection of plastics mixed with other solid waste. Cleaning service agencies collect waste from different sources and transport it to Rutagara dumpsite, which receives 85% of all the waste generated in Rubavu. 52% of plastic waste is collected from public and open places, primarily churches, marriage halls, recreational areas and playgrounds; and an estimated 27% is collected from commercial and institutional buildings like markets, restaurants, shopping malls, medical institutions and prisons; then about 21% is collected from residential buildings including single and large families as described in figure 4. Among the plastic wastes that are generated in Rubavu city, they are collected by the private sanitary companies and be transported to Rutagara dumpsite of which 17% is plastic wastes in general and 7% is waste from plastic bottles.

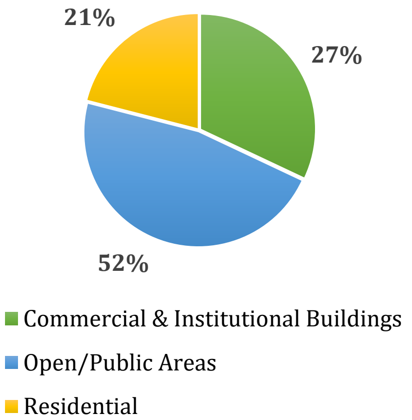


FIGURE 4: Source of plastic waste in Rubavu

Respondents of different ages, social classes, and education level were found to generate different levels of plastic bottle waste and have a different waste disposal behaviour. Plastics bottles are primarily used for packaging mineral water, juices and other liquids across Rwanda. Currently, plastic-packaged beverages are cheap compared to glass and canned packaged drinks. They are also considered to be clean and safe to drink.

Generation behavior versus Disposal behaviour

The Rwandan government has established four social classes to which each and every citizen belongs to, and this social classification takes into consideration different criteria, including people's monthly income, ability to work and their education levels. The level of plastic waste created by the generation of respondents of different age range groups, education level, and the governmental social class is described in FIGURE 4, 5. Showing both the generational behavior.

The primary data collected, indicated that respondents in the range group of 19-45 and 45-70 years old generated 3-4 bottles per day which is the highest daily amount in the studied groups. This is because most of the people found in those two age range groups are workers and earn monthly salaries. Therefore, they can afford to buy bottled beverages considering the hot climate during their working day and they purchase these plastic packaged beverages because they are considered clean and safe for drinking in Rubavu. Respondents who are under eighteen (<18) years old generated 1-2 plastic bottle waste per day while those above 70 years old doesn't often consume plastic bottled beverages. Respondents with secondary, college and higher education level generated 3-4 bottles per day while people with uneducated and primary education level were found to generate less plastic bottle waste at 1-2 per day

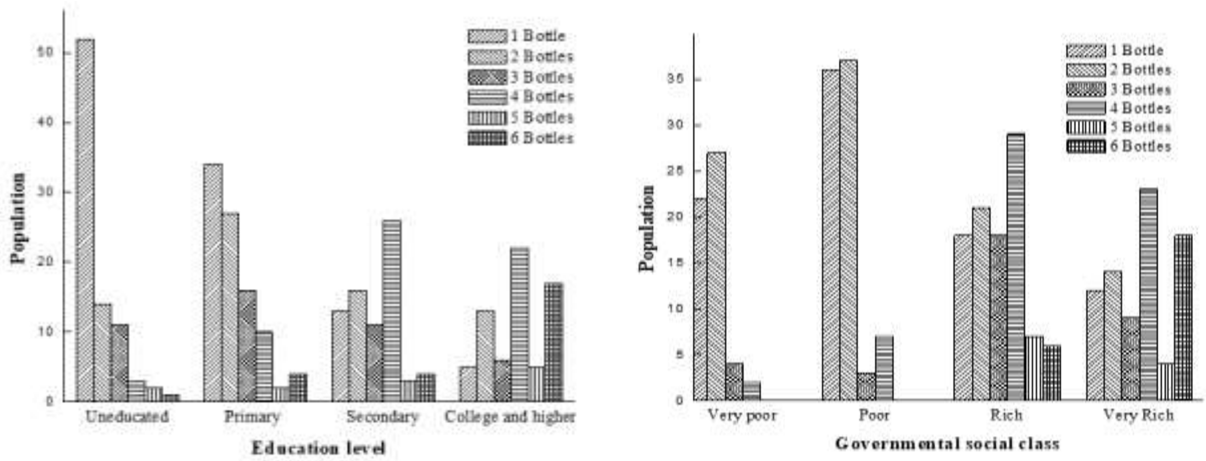


FIGURE 3: General behavior

Four kinds of disposal behavior were set based on the current disposal of plastic waste in Rubavu. In this case people with secondary level, college level and higher education levels were found to dispose of their plastic bottle waste in the nearest dustbin.

Respondents with primary education level were the most likely to reuse their plastic bottles; however, 76% of plastic waste is still discarded after use.

Life Cycle Assessment

LCA is an environmental management tool to evaluate a product, activity or service at all the stages in its life cycle. From the products acquisition of raw materials through processing, manufacturing, distribution, use, possible reuse/recycling and on to final waste management[5]. In this study, LCA's methodology was mainly comprised of its major components including goal and scope definition; inventory analysis; impact assessment and interpretation. LCA accesses the potential impacts of the life cycle of waste (from generation to disposal) and its impact on the environment.

Environmental Impact Analysis

Goal and Scope

As described in **Error! Reference source not found.**, this research aims to analyse the impact on the environment from the existing plastic bottle waste management practices. One scenario that was suggested in (TABLE 1), in regards to the life cycle perspectives is to propose the most suitable plastic waste management option based on minimum emissions for Rubavu city and to make the results of this study available to benefit other secondary cities in Rwanda. The life cycle time or the scope considered is from the cradle to the grave which includes the generation, transportation of waste to treatment facilities (MRF, recycling, landfill) and later final disposal of residues at the landfill as described in the system boundary of **Error! Reference source not found.**.

Inventory Assumptions

The collection and export distance were approximated based on the actual distance and type of roads in Rubavu. Energy used to compress plastic waste; amount of water needed to wash a bottle, methane, ethylene, propylene glycol, toluene, 1, 2, 3-trimethyl Benzene were assumed based on previous research

TABLE 2: Environmental Impacts of landfilling at Rutagara dumpsite

Parameter	Formula /assumptions	Reference
Energy	10MJ/kg of Plastic waste	[6]
Water	0.625L to wash 500ml	[7]
Amount of methane emitted by a plastic bottle in the process of its degradation	0.18kg/kg of Plastic dry waste	[8]
Amount of and ethylene emitted by a plastic bottle in the process of landfilling.	0.45kg/kg of plastic dry waste	[9]
Weight of a bottle	0.0127kg/1 bottle	[10]
ethane, propylene glycol, toluene, 1,2,3-trimethyl Benzene	0.12kg/kg of plastic,0.3 kg/kg of plastic,9.45*Volume of plastic,1.99*Volume of plastic respectively	[11]

Inventory Analysis

The results indicate an average sum of about 13,450 tons of plastic bottles by the year 2020, approximately 4610 tons are collected as waste from different sanitation companies and then taken to the Rutagara dumpsite. The average distance covered during transportation of waste in Rutagara is around 11, 300 km per year using road transportation that have polluting engines. About 7,300 tons of plastic per year is discarded into the environment, and the material flow is explained in FIGURE 7. In this material flow, plastic bottles are generated as waste. Some are reused, some are discarded into the environment by consumers, some are collected, transported, processed and exported, some also end up being dumped with other waste at the Rutagara dumpsite. However, every stage of the plastic waste pathways has different impact levels on the environment.

Plastic waste processes analysis

Pathway 1- Unaccounted for waste is the plastic bottles which are not properly disposed of, i.e. Consumers directly discard them into the environment. If plastic bottles are disposed of this was it can take up to 400 years to decompose [12] and the dangerous and harmful chemicals from the plastic bottles will leak during the process which may lead to health issues such as cancer and other negative environmental impacts.

Pathway 2- Landfilling: Plastic waste is collected together with other waste and transported to the Rutagara dumpsite. In this research, it was found that 60% will be sorted from other waste for further processing. Focusing on the 40% that will be dumped with the other waste at the Rutagara dumpsite.

Pathway 3-Processing: This process, focuses primarily on collection, transportation, sorting and the compressing process. The sorting space requires lighting and the use of electric energy which is approximately 10MJ used per Kg of plastic waste. The sorted plastic bottles are cleaned using approximately 0.625L per 500ml bottle. Compressing the sorted plastic bottle waste is done for 10 hours per month using a 75W compressing machine which runs on fossil diesel.

Emissions from the diesel engine has a high impact on the depletion of abiotic resources (11927.31 MJ worth of fossil energy). Significant values under acidification potential, freshwater aquatic Eco toxicity, ozone layer depletion and terrestrial Eco toxicity. Wastewater used in this process ends in the adjacent natural water resources untreated.

RESULTS AND DISCUSSION

Environmental Impact Analysis

In this study, the CML (baseline) method is used to evaluate the environmental impacts of plastic bottle waste management in Rubavu city using the life-cycle assessment. Based on the current plastic waste management system in Rubavu, three pathways of plastic waste were studied: unaccounted for which is for the plastic waste which is directly discarded in the environment right after use, landfilled is those which is not sorted out from the other waste, and end up dumped at the Rutagara dumpsite, processed-export plastic waste and extended plastic waste management.

Different steps of the existing plastic waste processing system in Rubavu are: collection and transportation, sorting, processing and landfill. They were also analyzed using the CML baseline to determine the level of emission to the environment to describe points where improvement is needed to be made in the system. Plastic waste is transported together with other wastes from the collection sites to Rutagara. To transport this waste trucks (closed and open) are used. These are provided by four collection and transportation companies ACAPE, CPIBO, COCEN. These trucks then need to travel approximately 388.3 Km2 to dispose of the collected waste. In this research, the results show that this process can negatively affect the environment in many ways. The vehicles used while transporting waste from collection sites use diesel which is not a green energy source and can further impact the local environment. The process of the collection and transportation of plastic bottle waste resulted in emitting the highest depletion of abiotic resources -fossil fuel (DAR) and MAETP when compared to other processes due to the long transportation distances using trucks that use diesel as a source of energy. The transportation process consists of a trip to the waste collection sources in all of the cells of Rubavu city and back to the Rutagara dumpsite. While there are efforts being made in the country regarding recycling, there is a lack of experts in the plastic waste management system.

Results from primary data collected has shown that the human resources of these companies do not have much information about the plastic waste varieties, and their toxicity. Waste collection and management companies have also been making tremendous efforts in regard to solid waste in general. However, plastic waste management is still a challenge, plastic waste is not recycled inside of the country, they are sorted out from other waste, washed, compressed and exported to Kenya for further processing. Fresh water is used in this process of washing plastic waste before compressing them and the energy used during compression emits CO_2 in the air.

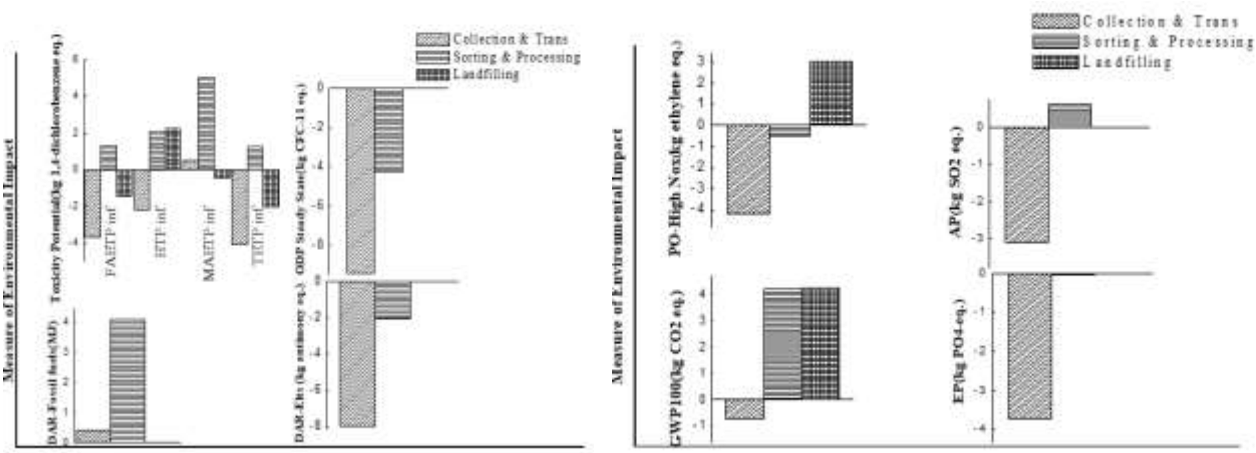


FIGURE 6: Combination results of the impact from waste Mgt process (PO, GWP, AP, EP)

There was a high potential for acidification in the process of sorting and processing the plastic waste compared to other indicators, this is because of the machines used during the compression of the plastic. The machines emit CO_2 during the process, they use diesel as source of energy, and this negatively affects the local environment

Landfilling (Rutagara Dumpsite)

Due to the city of Rubavu lack of sanitary landfill, Rutagara dumpsite is the final destination for all of the different types of unsorted waste generated in Rubavu. Different research had highlighted the high pollution levels of plastic waste when mixed with other waste in an open dumpsite. Also highlighting the high pollution levels produced when plastic waste is being processed. Research has found that their degradation emits methane and ethylene which are one of the leading greenhouse gases [13] This process resulted in a high acidification potential (GWP100) and photochemical oxidation (PO-NOx).

The release of greenhouse gases from aged plastic waste over time indicates that polymers continue to emit gases to the environment for an undetermined period and with time they will decompose into micro plastics [14, 15]. Chemicals released by Plastic waste into the environment, can injure and kill marine life. Moreover, with time it breaks into micro plastics that contaminate water and food supplies. Greenhouse gases are also generated as the plastic degrades. During the process of degradation, methane and ethylene are released. Methane warms the planet at up to 86 times the rate of carbon, while Ethylene is another leading emission [16]. These are some of the many environmental impacts of landfill.

TABLE 3: Environmental Impacts of Landfilling at Rutagara Dumpsite

Impact category	Reference unit	Result
Acidification potential	kg SO2 eq.	0
Climate change - GWP100	kg CO2 eq.	11838
Depletion of abiotic resources - elements, ultimate reserves	kg antimony eq.	0
Depletion of abiotic resources - fossil fuels	MJ	0
Eutrophication – generic	kg PO4--- eq.	0
Freshwater aquatic Eco toxicity - FAETP inf	kg 1,4-dichlorobenzene eq.	0.01185332
Human toxicity - HTP inf	kg 1,4-dichlorobenzene eq.	129.7365372
Marine aquatic Eco toxicity - MAETP inf	kg 1,4-dichlorobenzene eq.	0.112726350
Ozone layer depletion - ODP steady state	kg CFC-11 eq.	0
Photochemical oxidation - high Nox	kg ethylene eq.	11001.277465
Terrestrial Eco toxicity - TETP inf	kg 1,4-dichlorobenzene eq.	0.001181170

LCA impact analysis indicates that the plastic bottle waste that ends up dumped in the Rutagara dumpsite has a relatively high global warming potential (11838 kg CO_2 eq.), as well as a high human toxicity potential (129.736 kg 1,4-dichlorobenzene eq.) and photochemical oxidation (11001.127 kg ethylene eq.).

This makes this end-of-life treatment the worst alternative in the plastic management system in the Rutagara dumpsite. Landfill in Rutagara is not well designed, being more of an open dumpsite. Although freshwater aquatic Eco toxicity, marine aquatic eco toxicity and terrestrial eco toxicity returned low but significant values. This could be due to low leachate flows from the landfill.

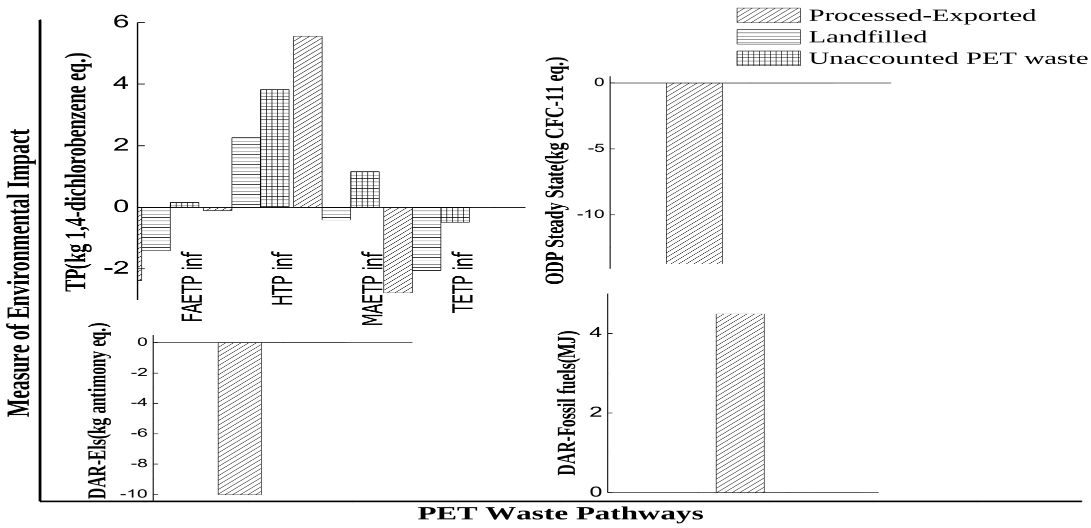


FIGURE 7: Environmental impact associated with plastic pathways (DAR, ODP, FAETP, HTP, MAETP and TETP)

These results show a high negative impact on marine aquatic eco toxicity (108536.47 kg 1,4-dichlorobenzene eq.) and relatively low but significant freshwater aquatic eco toxicity (20.01kg 1,4-dichlorobenzene eq.). The detailed impacts from LCA analysis are listed in (**Error! Reference source not found.**).

TABLE 4: Environmental Impacts of processing

Environmental Impacts of Processing Process		
Impact category	**Reference unit**	**Result**
Acidification potential	kg SO2 eq.	66388366
Climate change - GWP100	kg CO2 eq.	3788.006
Depletion of abiotic resources - elements, ultimate reserves	kg antimony eq.	0.008397158
Depletion of abiotic resources - fossil fuels	MJ	1222031217
Eutrophication - generic	kg PO4--- eq.	0.837736643
Freshwater aquatic ecotoxicity - FAETP inf	kg 1,4-dichlorobenzene eq.	11.1191952
Human toxicity - HTP inf	kg 1,4-dichlorobenzene eq.	100.7726369
Marine aquatic ecotoxicity - MAETP inf	kg 1,4-dichlorobenzene eq.	001736.365
Ozone layer depletion - ODP steady state	kg CFC-11 eq.	3.0662E-01
Photochemical oxidation - high Nox	kg ethylene eq.	0.645337309
Terrestrial ecotoxicity - TETP inf	kg 1,4-dichlorobenzene eq.	12.18811714

In this study, the transportation process components were focused on and this was divided in two parts: 1) Waste collection using 7.5 ton with a payload of 3.3tons, and 2) Exportation of processed plastic waste to Kenya using 40-ton trucks with a payload of 27 tons. In both cases, results of LCA analysis indicate a relatively low but significant impact on the depletion of abiotic resources, ozone layer depletion, photochemical oxidation and terrestrial eco toxicity as detailed in TABLE *5*. The low impact figures could be attributed to the use of modern and well-maintained trucks during transportation.

TABLE 5: Environmental Impacts of plastic waste Transportation

ENVIRONMENTAL IMPACTS OF TRANSPORTATION PROCESS			
Impact category	**Reference unit**	**Transportation during waste collection**	**Transportation during Export**
Acidification potential	kg SO2 eq.	0.004474633	0.001171655
Climate change - GWP100	kg CO2 eq.	0.773363330	0.044633385
Depletion of abiotic resources - elements, ultimate reserves	kg antimony eq.	7.888874E-02	2.9949999E-09
Depletion of abiotic resources - fossil fuels	MJ	1.379980033	0.184774630

Eutrophication – generic	kg PO4--- eq.	0.020003373	4.4553738E-05
Freshwater aquatic ecotoxicity - FAETP inf	kg 1,4-dichlorobenzene eq.	0.002876548	4.4449103E-05
Human toxicity - HTP inf	kg 1,4-dichlorobenzene eq.	0.9993837336	0.001583636
Marine aquatic ecotoxicity - MAETP inf	kg 1,4-dichlorobenzene eq.	2.997444639	0.881792048
Ozone layer depletion - ODP steady state	kg CFC-11 eq.	2.8474749E-10	1.1101883E-11
Photochemical oxidation - high Nox	kg ethylene eq.	2.2774E-02	1.22085E-04
Terrestrial ecotoxicity - TETP inf	kg 1,4-dichlorobenzene eq.	2.22662E-05	1.33733E-05

Impact analysis and discussion

The results of zero in some particular impact categories represent no significant challenge in this area. Those with negative values represent a positive impact. The research in this study emphasizes those with a negative impact on the environment. The sorting process resulted in almost all the impact categories at a higher level compared to other processes. The depletion of natural resources is mainly caused by their use and due to non-renewable energy during the processing at the Rubavu dumpsite. The over-exploitation of some of these resources, or their pollution by human activities, can lead to their shortage and have a significant environmental impact.

This explains the impact criteria such as, water consumption. This process showed eutrophication, freshwater aquatic ecotoxicity and marine aquatic ecotoxicity. These are indicators of the negative impacts on the environment due to the fresh water used in the process of washing plastic bottle packaging waste after being sorted out from other waste. This process releases wastewater that is polluted with different nutrients including carbon compounds whether biodegradable or not.

TABLE 6: General view of the impact categories from all management processes

Impact indicators	Unit/year	Mgt Processes		
		Collection & Transportation	Sorting and processing	landfilled
AP	kg SO2 eq.	0.000847833	4.09685168	0
GWP	kg CO2 eq.	0.186683774	15254.006	17253
Depletion of abiotic resources - elements, ultimate reserves	kg antimony eq.	1.13E-08	0.008397158	0
Depletion of abiotic resources - fossil fuels	MJ	2.605260202	11927.31217	0
Eutrophication – generic	kg PO4--- eq.	1.96E-04	0.950333643	0
Freshwater aquatic ecotoxicity - FAETP inf	kg 1,4-dichlorobenzene eq.	2.08E-04	20.01484952	0.039087174
Human toxicity - HTP inf	kg 1,4-dichlorobenzene eq.	6.80E-03	114.2994944	181.4230227
Marine aquatic ecotoxicity - MAETP inf	kg 1,4-dichlorobenzene eq.	3.28E+00	108536.4706	0.388145664
Ozone layer depletion - ODP steady state	kg CFC-11 eq.	3.76E-10	5.08842E-05	0
Photochemical oxidation - high NOx	kg ethylene eq.	6.14E-05	0.336363349	1033.006839
Terrestrial ecotoxicity - TETP inf	kg 1,4-dichlorobenzene eq.	9.29E-05	18.05770044	0.008833539

The Landfilling process resulted in a high potential to add to global warming due to in the process of plastic bottle packaging waste decomposition as they release methane and ethylene. Ethylene is one of the leading greenhouse gases. Three-time horizons are considered for the calculation of the greenhouse effect: 20 years, 100 years and 500 years. The 100-year horizon is generally used in life cycle analyses. It allows a comparison to the 20-year horizon to consider more expected effects following the increase in the greenhouse effect (climatic variation of the emerged zones). Moreover, when plastic waste degrades, they decompose into small particles known as micro plastic which are known to be harmful to human life and animals when they get in their food chain.

CONCLUSION AND RECOMMENDATION

The LCA was used to assess the current management of the plastic bottle waste management system in Rubavu. Examining the different perspective from all the management processes and the scenarios suggested. GWP, EP, HTP, and POCP indicated that recycling and landfilling were significant contributors to the environment's pollution. Plastic containers are beneficial to society in Rubavu like in the rest of Rwanda and worldwide. However, when this plastic waste is not handled well, it can significantly impact the environment and human health from now and into the future, from the perspective of the three pathways analysed in this research. Results found that the landfill scenario had the highest impact on the environment and caused severe health impacts to humans. The collection and transportation process considered all the round trips and distance of taken for the collection of waste from different collection points and back to the landfill. It also comprises the distance of plastic pellet's exportation to Nairobi, both the complete loaded and non-load return trips.

Due to the types of trucks used in the process of transportation, and considering the distance they cover in a year, the global warming potential impact was found to be significant due to the emission of CO_2 in the air. This means that the management of plastic bottles should be considered as a priority. The Rutagara dumpsite should no longer be considered a long-term solution for the dumping of plastic bottle waste. Other solutions should be examined such as recycling systems.

DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest concerning the research, authorship, and publication of this article.

ACRONYMS

MSW	: Municipal Solid waste
MSWM	: Municipal Solid Waste Management
HDPE	: High-Density Polyethylene
LDPE	: Low-Density Polyethylene
LCA	: Life Cycle Assessment
LCI	: Life cycle Inventory
LCIA	: Life cycle Inventory Analysis
SA	: Stake holder Analysis
SNA	: Social Network Analysis
3Rs	: Reduce, Reuse and Recycle
GWP	: Global Warming Potential
GHG	: Greenhouse gas
AP	: Acidification Potential
POCP	: Photo-smog creation
EP	: Eutrophication potential
DAR-F	: Depletion of abiotic resources-fossil fuel
DAR-E	: Depletion of abiotic resources Elements, ultimate
HTP inf	: Human toxicity
ODP	: Ozone depletion potential
FAETP inf	: Freshwater aquatic Eco toxicity
MAETP inf	: Marine aquatic Eco toxicity
PO	: Photochemical oxidation (high NOx)
TETP inf	: Terrestrial Ecotoxicity

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