European Journal of Social Sciences Studies
ISSN: 2501-8590
ISSN-L: 2501-8590
Available on-line at: www.oapub.org/soc

DOI: 10.46827/ejsss.v8i5.1475 Volume 8 | Issue 5 | 2023

PLASTIC WASTE RECYCLING AND ITS IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT IN MBARE, HARARE, ZIMBABWE

Rejoice Anna Chuma[1],
Frank Chipfunde[2],
Jemitias Mapira[3i]
[1]Former BSc Honours Student,
Geography and Environmental Science,
Gary Magadzire School of Agriculture,
Engineering and Natural Sciences,
Great Zimbabwe University,
Masvingo City, Zimbabwe
[2]Lecturer,
Agriculture & Engineering,
Great Zimbabwe University,
Masvingo City, Zimbabwe
[3]Geography & Environmental Science,
School of Agriculture, Engineering & Natural Sciences,
Great Zimbabwe University,
Masvingo City, Zimbabwe

Abstract:
This study examines the alternatives for recycling of plastic waste and gives a general overview of the main environmental issues related to plastic disposal. It gives a rundown of the amounts and sorts of plastics in the waste stream and furthermore the primary impacts of recycling on the plastic material itself, the environment and also the national economy. The two main types of recycling are mechanical and chemical recycling. The research also compares the methods of recycling which are already in use and selecting the best in a bid to save the environment from pollution. The study also seeks to discover the challenges and benefits associated with plastic waste recycling. Questionnaires, interviews and observations were used to conduct the study. Data was analysed through hand tallying in the form of tables, graphs and pie charts. From the main findings, there is a lot of plastic waste in Mbare (Harare) because of the shortage of bins and an ineffective waste collection system. However, the plastic waste collection system should be complimented by the Harare city council which should register waste collectors and recyclers for incentives by signing agreement contract terms with them. Mbare has become the most ideal urban area to develop a waste collection centre as plastic waste has become a major problem.

[i] Correspondence: email jmapira@gzu.ac.zw

Keywords: plastic waste, types, challenges, Mbare high-density area, Harare, Zimbabwe

1. Introduction

At the global level, waste has become a huge issue on account of both atmospheric and land contamination. Waste management is acknowledged to be the best approach to resolving difficulties associated with environmental pollution affecting modern societies. The general drive has tended to slant towards reducing, reusing and recycling. Studies show that some 70% of our household waste in Zimbabwe is put in canisters and shipped off to dumpsites. These dumpsites are not genuine landfill destinations and have caused the deterioration of the outward appearance of our metropolitan regions. Waste materials, such as plastics, aluminium jars, paper, glass, batteries and utilized oil are often dumped in peri-urban dump sites even though they can be recycled to produce other useful products.

Plastics are made from limited resources, such as oil. Although it consumes 4% of the world's oil, the supply is very small. Therefore, it is necessary to find ways to reuse and recycle these materials to save these non-renewable resources. The global use of plastics and polymers has increased at an average annual rate of 5%, reaching 227 million tons in 2015, which is worrying because some of them are not biodegradable. Due to this, these materials that have a terrible impact on the environment are often incinerated and discarded, releasing toxic gases into the atmosphere. This has led most countries to comply with laws prohibiting disposal and encouraging recycling. Plastic recycling is a growing industry in the world, lagging behind in less developed countries like Zimbabwe. As garbage and landfills hinder vegetation growth, our major urban areas have deteriorated and, in most cases, are left with an undesirable look. Several organizations in the world have started to recycle plastics, but since there are few locations to recycle materials, personal awareness is very low. There are various ways in which plastics can be recycled. They are divided into three significant classes which are mechanical, thermal and chemical recycling. Mechanical recycling, which is the most well-known type, involves converting used material into new resources without affecting its basic structure.

Thermal recycling is the direct incineration of plastic waste for energy recovery, and chemical recycling is a method of decomposing polymers into other chemicals. These three technologies can be used to reduce the amount of strong plastic waste (PSW) that is deteriorating the outlook of our environment. The existence of various methods is an advantage as it means that we can effectively manage a large amount of waste in various ways as well as selecting suitable ways which are cheap and favourable to our needs. Recycling in the plastics industry takes place within assembly organizations, which are a feature of standard creation measures. For example, in expulsion generally where material restrictions and contamination allow, in-house crap will be reprocessed with original materials to increase the performance of the final materials. Plastic waste from commercial and postal customers goes to landfills. Therefore, in the development process

of the plastics industry, public attention and perception have focused on the problem of plastic waste relatively late. This is due to two factors which are that increasing attention is paid to the financial and environmental costs of landfilling and large amounts of plastic waste entering the waste stream. This study will provide a general introduction to the issues affecting plastics recycling materials from end-of-life to disposal and an overview of the main methods of recycling and the environmental problems that come with it.

2. Study area

The study was conducted in Mbare a high-density suburb which is located on the southern side of Harare City about 5 kilometres from the central business district. It consists of Matapi flats and Tagarika where residents live and work in places such as Siyaso, Mupedzanhamo, Mbare Musika and Mbare bus terminus.

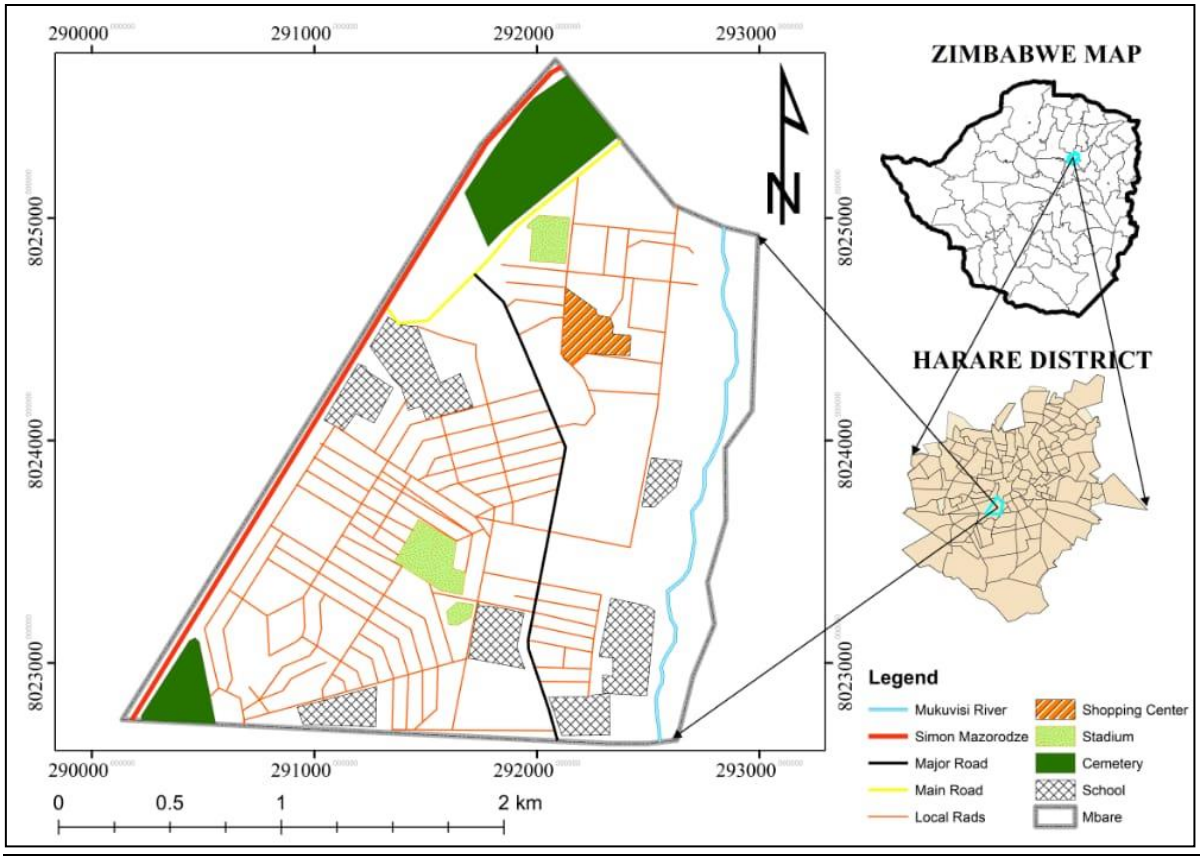

Figure 1: Map of the study area

3. Research methodology

Questionnaires, interviews, observations and documents were used to get necessary information related to the study. Interviews were used to solicit information from some individuals in the field. It relied on asking questions from reliable persons in the field. In addition, questionnaires were also employed to obtain additional information from the

study area. Information from both questionnaires and interviews was combined with that from other sources such as observation was analysed in order to arrive at logical conclusions. Document interrogation carried out at the beginning of the study laid the foundation for the whole study. It involved a survey of the available literature on the area under study. It was followed by a pilot study which exposed the researchers to the actual research context or study area. Information from the various methods noted above was analysed and it contributed to the views that are expressed in this study.

3.1 Types of plastics and their major applications

There are two main types of plastics namely thermoplastics and thermo sets:

A. Thermoplastics

This classification comprises those plastics which become soft when warmed or heated and they can be molded when they are in a plastic state, when cooled they solidify and gain again the state of shape. Thermoplastics are synthesized from plants in large amounts and transformed through chemical processing (Asim and Sultan, 2017). Some common types of thermoplastics include:

- **PS**: It is smooth, clear to dark, inflexible and hard; therefore, it is for the most part used for making containers, cups, tumblers, toys, and electrical equipment for example plugs sockets, switch plates and also circuits.
- **Polyethylene terephthalate (PET)**: due to its properties of being tough, transparent, chemical and heat resistant, it is used in the packaging of mineral water and soft drinks and is also used for making food containers.
- **High-density polyethylene (HDPE)**: This has a good processing ability, good chemical resistance, high melting point of about (130–1350 degrees Celsius) as noted by Gupta (2017) and has water vapor barrier properties; it is therefore used for making water bottles, containers, pipes, carrier bags and storage bins.
- **Low-density polyethylene (LDPE)**: because it has an easy processing ability, low density, low softening and melting point, stretch resistance and good chemical resistance. It is used for making items like carrier bags, milk packaging, wire and link protection and heavy-duty bags.
- **PVC**: This one is versatile, durable and fire resistant and is used for packaging, medical and agricultural equipment, making cables and wires, footwear, furniture, sheets and bottles for water and shampoo.
- **Polypropylene (PP)**: It has a high melting point, low density, good processing ability and good chemical resistance. Therefore, it is best used for making products like bottles, toys, pipes, fans, sheets, straws, films, furniture and also hair dryers to mention a few.

B. Thermo sets

These are non-recyclable materials which when set once, cannot be remolded or changed (Siddiqui et al., 2013) even with the application of heat. Examples are polyurethanes, phenol, melamine, epoxy, urea formaldehyde and unsaturated polyester.

4. The concept of recycling

Solid waste management revolves around the three R's which are **reduce**, **reuse** and **recycle** (Palmera et al., 2020). They prioritize prevention, reduction, reuse and recycling of solid waste, which cuts down on waste disposal thereby conserving the environment (Jerrie, 2018). Effective recycling of solid waste depends on a proper understanding of what is involved, hence the need to correctly define the key concepts such as recycling. Recycling is the reprocessing of recovered materials at the end of product life, returning them to the supply chain (Ernest et al., 2019). This is not the same as waste reuse, which refers to using a waste product without further transformation and without changing its shape or original nature (Ernest et al., 2019). While the reuse of waste is preferable to recycling, it is not always possible as this depends on the original quality of the waste. In urban areas, recyclable waste includes plastics, aluminium, tin, lead, copper, steel, zinc, gold, tyres, textiles, glass and paper (South, 2018). While most of solid waste is recyclable, only a limited proportion can be recycled (Morgan, 2009).

The waste recycling process has three critical stages, namely selection, segregation and extrusion (Pappa et al., 2001). During selection, recyclers select recyclable waste such as plastic and scrap. Segregation involves characterising and separating waste and processing it into pre-consumer waste that is directly recycled and post-consumer waste that is washed, shredded, agglomerated and extruded (Pappa et al., 2001). Separation techniques include sorting waste based on material properties and visual-based techniques (Helonde et al., 2019). Extrusion involves heating material into strands, which are then quenched by water-cooling (Helonde et al., 2019). After the strands are cooled, they are granulated into pellets (Helonde et al., 2019). There are many types of wastes that can be successfully recycled such as paper, steel (tin) and glass. This study focuses on beverage and strong packaging plastic waste recycling.

4.1 Methods and ways of recycling

The recycling of plastic waste essentially means transforming the plastic waste into a significant use as opposed to becoming an issue to the environment. In order to solve the problem of plastic waste there is a need to come up with effective and efficient methods of recycling plastics as a way to save the environment from pollution and also create employment in so doing. There are two techniques of recycling plastics namely, mechanical recycling and chemical recycling/feedstock recycling (Goodship, 2007).

4.2 Mechanical recycling

Mechanical recycling refers to the material reprocessing of waste plastics by physical means into plastics products (Dodbiba et al., 2005). The process involves collection, washing, drying, grinding, extrusion and manufacturing into specific products (Dodbiba et al., 2005). Sorted plastics are cleaned and processed directly into end products or into flakes or pellets of consistent quality acceptable to manufacturers (Goodship, 2007). Pellets are made by melting the dry plastic flakes and then extruding them into thin strands that are chopped into small uniform pieces that are ready for manufacturing into a new product (Goodship, 2007). During the grinding or melting phases, the reprocessed material may be blended with virgin polymer or compounded with additives (Goodship, 2007). Mechanical recycling is the preferred recovery route for homogeneous and relatively clean plastics waste streams, provided end markets exist for the resultant recycles (Baillie, 2005). This technique is also well suited for developing countries since it is less cost-intensive compared to the others (Dodbiba et al., 2005). This method is also used for all types of plastic waste materials.

4.3 Chemical/Feedstock recycling

Chemical recycling implies a change of the chemical structure in a way that the resulting chemical structure can be used to produce the original material (Tucker, 2002). Plastic polymers are depolymerised into monomers or feedstock that is used in the production of new plastics (La Mantia, 2002). The separation methods of chemical recycling include pyrolysis, hydrogenation and gasification (Hamerton, 2003). Pyrolysis is a process where polymers decomposition is induced anaerobically by heat and transforms recyclable plastics waste into synthetic crude oil for further refining into diesel fuel, heating or waxes (Chanda et al., 2016). The gasification process converts polymers into a mixture of hydrogen and carbon monoxide and converts plastic waste into synthetic waste (Joseph, 2005). The synthetic gas can be used for electric power generation or converted into fuel or chemical feedstocks, such as ethanol and methanol, some of which can also be used to make new plastics that go into consumer products (Joseph, 2005). Many products are derived from plastic recycling including plastic bricks of various sizes and shapes using plastic bottles, incinerator/fire, firewood, labour, tar, sand soil, water for washing bottles, washing agents (Helonde et al., 2019).

4.4 Separation methods of chemical recycling

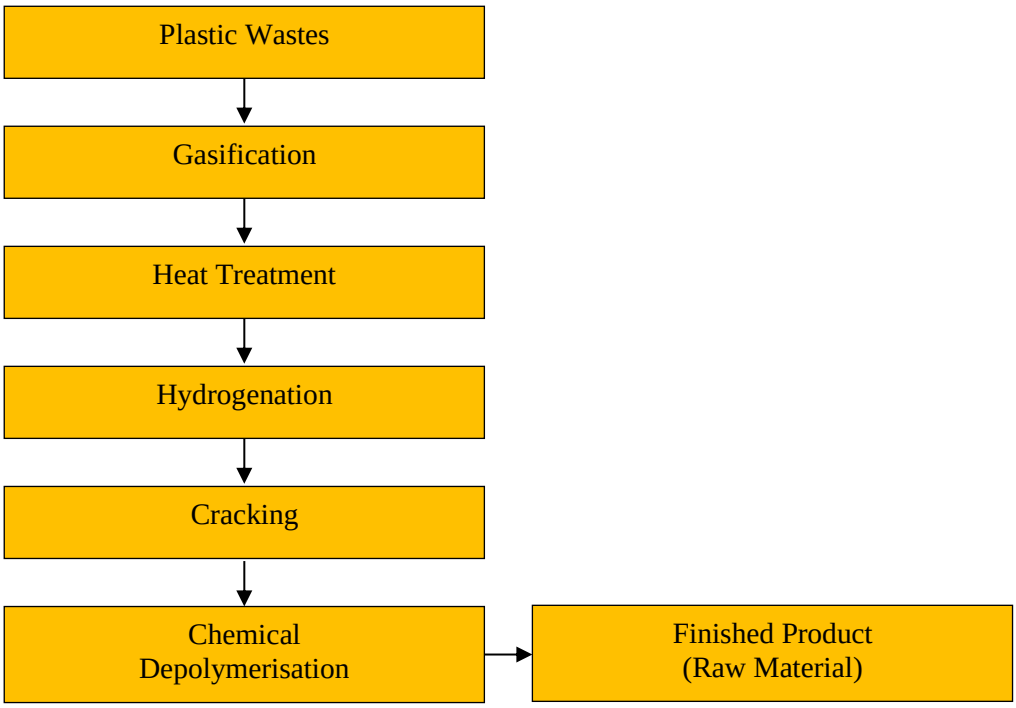

Figure 2: Feedstock recycling processes

4.5 Benefits and challenges associated with plastic waste recycling

Plastic waste recycling contributes to increased incomes from selling the by-products. It can also be a source of foreign currency and employment creation and contributes to improved livelihoods and increased Gross Domestic Product (GDP). Recycling of plastics has also environmental benefits. It can save space at designated landfills and dumpsites by reducing the amount of waste deposited into the environment. Recycling of plastics protect the environment in a considerable way. It saves space at designated landfills and dumpsites by reducing the amount of waste deposited into the environment. Again, recycling of plastic waste will help to keep the water bodies clean, since the wastes in the landfills can leach dangerous chemicals into both surface and underground water. Every society needs to be cleaner and healthier to live in. Plastic wastes litter the streets and choke gutters which in turn create breeding grounds for mosquitoes and flies, causing malaria and cholera to the people. Therefore, recycling of plastic wastes will contribute to reducing or preventing the diseases associated with plastic wastes. A society with healthy people will contribute to better development; since the people would be able to go on to do their work without any problems.

4.6 Challenges associated with plastic waste recycling

Apart from the benefits, plastic waste recycling has its limitations as well. The incineration process emits greenhouse gasses into the environment (Spellman, 2016). This becomes a major problem as it causes global warming leading to climate change.

Sometimes it often costs more to recycle waste than to simply bury it in a landfill (Emsley et al, 2007). Recycling benefits, however, far outweigh its drawbacks.

4.7 Products made from recycled plastics

Many products are made from recycled beverage and strong packaging plastic waste which include: door mats, hats, shoes, bricks, dura walls, litter bins and garden furniture.

Figure 3: Bricks made from recycled PET bottles

Figure 4: Doormat being made from bread packaging plastic waste

4.8 Environmental problems associated with plastic waste

Plastic waste affects the environment negatively. It pollutes the land, water and air.

4.8.1 Land

Plastic wastes litter the land and find their way into gutters and drains. They then block the gutters and drains and cause flooding whenever it rains, because the rainwater cannot get access to flow and the accumulation of the rainwater created by plastic wastes provide breeding places for mosquitoes, which later cause malaria to people. When plastic waste litter farmlands as well, they disturb the crops preventing them from growing also the plastic waste covers the soil preventing air penetration, this kills soil organisms that help to enrich the farmlands.

Figure 5: Plastic litter in Matapi flats (http://ztn.co.zw)

4.8.2 Water

Plastic wastes find their way into water bodies, therefore, polluting the water. The plastics then float on the surface of water bodies thus preventing direct sunlight for water organisms. Biodiversity is destroyed by plastic waste that finds its way into water bodies as they mistakenly eat plastics as food. Since plastics are indigestive materials, they cause pain and this leads to death. After the animal decays, the ingested plastics are freed back into the environment again and continue to cause environmental problems.

4.8.3 Air

Plastic wastes are non-degradable substances that are made of toxic chemicals which pollute the air. Poisonous substances such as toxins are released into the air when plastic wastes are burned. These cause respiratory problems and cancer when they are inhaled. The burning of plastic waste has also an impact on climate change as it releases carbon monoxide into the atmosphere.

Figure 6: Burning of plastic waste (http://climatecentral.org)

4.9 Plastic waste from residential areas

4.9.1 Matapi flats

The average total plastic waste per household per week in Matapi flats, based on waste collected from 40 households was 40,5kg. The amount of plastic waste per household per week was relatively uniform across the 40 households. However, there was a slight variation and it was due to two factors which are:

- There were different numbers of household sizes across the 40 households. The average number of people per household was five. Some flats were occupied by one family, others by two families while others are home to three families with up to seven people per family. As can be expected large families generate more plastic waste than small families.
- The other reason was that there were high-income earners who reside in Matapi flats and these generate more waste than the average household.

This shows that all plastic waste can be put to good use by recycling using both mechanical and feedstock methods to create a friendly and clean environment.

4.9.2 Matagarika flats

On average the total plastic waste generated per household per week in Matagarika flats, based on waste collected from 40 households was 38,2kg. The amount of plastic waste was the same although slightly different because some households occupy many people whilst others occupy less people. The families which occupied many people had as many as 6 people on average whilst those families which occupied less people had as many as 4 people on average.

4.9.3 Matererini flats

The average total waste per household per week in Matererini flats, based on waste collected from 40 households was 38kg. The amount of plastic waste per household per week was relatively uniform across all 40 households. Just like in the case of Matapi and Matagarika. The differences were due to the number of people residing in each flat and the income levels, therefore all this waste can be used to make bricks, chairs, mats, tables and toilets can also be made using plastic waste bottles, for example, those toilets being made in Marondera. This saves the environment from pollution.

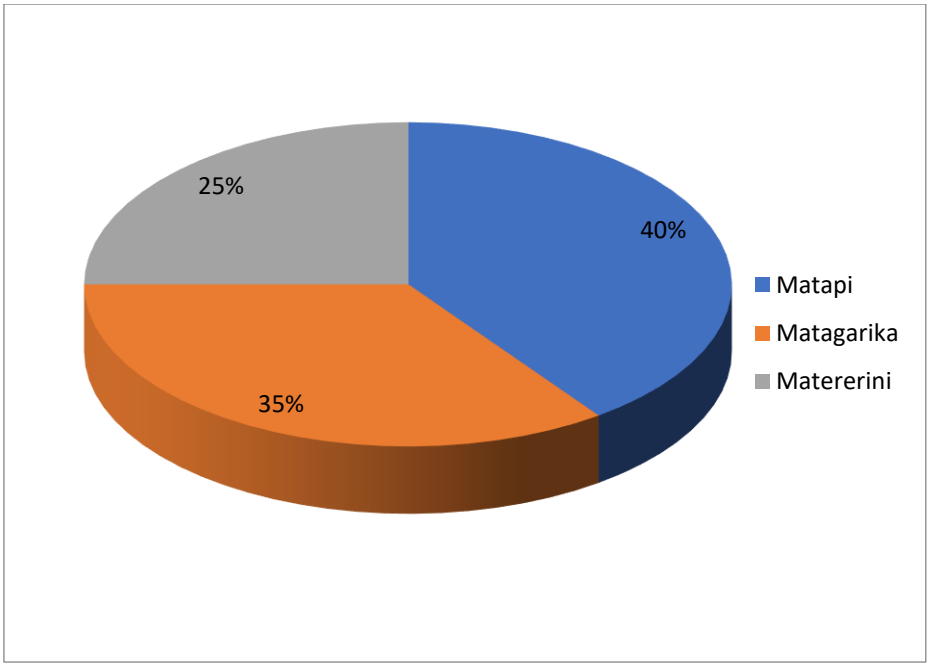

Figure 7: Composition of household plastic waste by weight in residential areas

Table 2: Amount and composition of household plastic waste per annum in residential flats in Mbare

Name of the residential area	Plastic waste (kg)
Matapi	1 944
Matagarika	1 833.6
Matererini	1 824
Total	5 601.6

4.10 Plastic waste from business centres

4.10.1 Siyaso

The total plastic waste in Siyaso was computed by multiplying the weekly average waste by 48 weeks in a year by the total number of small markets in Mbare. The total plastic waste per week in Mupedzanhamo based on waste collected from 40 vending areas was 62,3kg. The total composition of waste differed depending on the number of vendors at an area in Siyaso. Another area occupied a few vendors whilst another occupied many vendors. Plastic waste was the most dominant waste and they were many dumpsites near the vending areas.

4.10.2 Mupedzanhamo

In Mupedzanhamo vendors are mostly into selling clothes i.e. old cloth bales, so the plastic waste is usually less than that found in Siyaso, Mbare musika and Mbare bus terminus although there are some small shops found there. The total plastic waste in Mupedzanhamo per week based on waste collected from 40 vending areas was 60kg. The total waste differed from each market depending on how crowded the vendors will be at one place. Most of the markets were very close to each other with little or no demarcation left between them.

4.10.3 Mbare musika

Mbare musika is a market with vendors who are into selling vegetables and fruits so the plastic waste is more. The total plastic waste in Mbare musika per week based on waste collected from 40 vending areas was 65kg. The amount of plastic waste per vending area per week was relatively uniform across all 40 vending areas. However, the difference was due to the type of packaging used by the vendors to wrap their vegetables. Another difference was due to how the vendors were distributed at a certain point and the many travellers and customers. Some areas occupied fewer vendors whilst some areas occupied many vendors and this contributed to the amount of plastic waste that was found. There were also many dumping sites in Mbare musika which created an environmental eyesore.

4.10.4 Mbare bus terminus

There is the old Mbare bus terminus where buses to Manicaland rank and the other rank where buses to Masvingo, Bulawayo, Gweru, Kwekwe, Kadoma etc rank. The total plastic waste in Mbare musika bus terminus was 62,4kg. Most of this plastic waste was from travellers, customers and also vendors who are found in and around the terminus.

4.10.5 OK Mbare supermarket

Most of the plastic waste found around OK supermarket was from vendors with their markets very close to the supermarket as well as from customers who eat and throw their litter everywhere. The daily average total waste generated amount around OK supermarket was 1.4kg. There are also many small dumpsites around and in front of OK supermarket

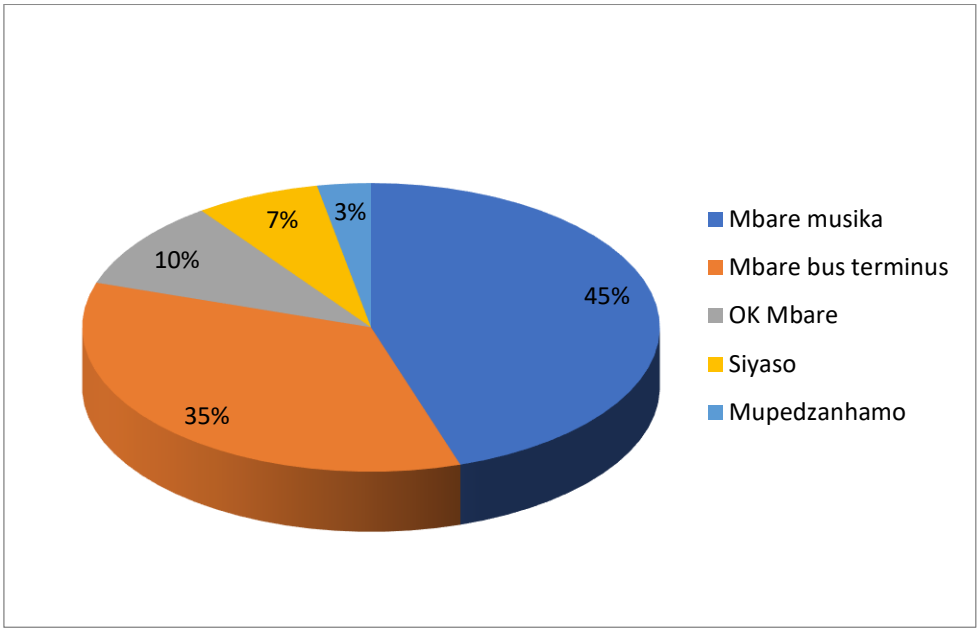

Figure 8: Composition of plastic waste by weight in business centres

Table 3: Amounts and composition of plastic waste per annum in business centres in Mbare

Name of the business centre	Plastic waste (kg)
Siyaso	2 990.4
Mupedzanhamo	2 880
Mbare musika	3 120
Mbare bus terminus	2 995.2
OK supermarket	67.2
Total	12 052.8

5. Results and Discussion

5.1 Collection of plastic waste

The recycling companies are in need of plastic waste from those many dumpsites in Mbare. Local people from poor backgrounds move from street to street, area to area and undesignated dumpsites in Mbare scavenging local small shops, markets and bins to sell the plastic waste to recyclers for a certain amount of money per kilogram. However, some of the people who pick these papers complain because of the amount of money they receive when they sell plastic waste which is one of the reasons why there is still a lot of plastic waste in Mbare. Therefore, the recyclers should increase the amount which they pay the plastic waste collectors so that they are motivated to do so. In order to improve waste collection more waste bins should be available as well as skip bins and in doing so collection becomes much easier.

5.2 Sorting

After collecting the plastic waste from the various collections points and brought to the recycling site, the next action is sorting. The plastic wastes are put on conveyor and here the plastics are separated from other wastes such as metals, wood. And plastic wastes are

sorted into different types of plastic by using recycling code for plastics, for instance, code 3 for PVC (polyvinyl chloride). Sorting of plastic waste can be done in either manual sorting or mechanical sorting. In manual sorting, it involves the use of hands to separate the plastics waste into different plastics or separate the metals, wood etc from the plastics in the case of mixed waste recycling.

5.3 Recyclable plastic waste using chemical and mechanical methods

Residential households generate the most recyclable plastics followed by business centres like Siyaso, Mupedzanhamo, Mbare musika, OK supermarket and lastly Mbare bus terminus. Business centres generated mostly a mixture of plastics and aluminium cans than residential flats which mostly generated plastic waste. This is related to the fact that business centres occupy a lot of people during the day i.e., travellers, customers and the business owners themselves. Disposal of plastic waste everywhere in both residential areas and business centres is however generally greater. This is because there are a few or no household bins as well as skip bins respectively, which makes it very difficult to manage the plastic waste and thus the never-ending dumping sites. There are also so many tuck shops found in Mbare and these release a greater amount of plastic waste. Most of the waste is recyclable and this makes it easier for the recyclers as they will not have to go through the process of too much sorting

5.4 Production and marketing of products generated from plastic waste

The main products that are recycled from plastics are bricks, sandals, mats, hats and also chairs to mention a few. There are many plastic recyclers found within and outside Mbare. Some are now involved in the recycling of these plastics to produce bricks. In order to produce 1000 bricks, at least 200kg of plastics are required and 200 litres of water and they sell each brick at USD0.22.

The production of bricks is however quite low because brick making is labour-intensive, and requires more inputs such as water and pit sand. Recyclers cannot afford to buy more from plastic sellers and pay heavy water bills. It also requires a spacious area for operations. One team according to research operate and sells from home, which also limits their exposure to commercial markets as they cannot access industrial land. This adds to the costs of hiring transportation to move around with loads of bricks and marketing them.

However, given that there are very few businesses which operate in recycling, it should be noted that the research enabled an overview that chemical and mechanical recycling methods should be applied more in Mbare as a way to reduce environmental pollution, as the problem of dumpsites in Mbare is a very serious one.

Figure 9: Bricks from plastic waste

5.5 Total waste

Total plastic waste generated and disposed of in business centres, small shops and vending markets is more than that of residential flats. This is because where business is carried out more waste is generated. The vending markets are tightly packed with little or no demarcation at all and there is a very intense flow of customers and travellers. The total plastic waste produced in business centres as well as OK supermarket is more than that of residential flats as a result of accessibility to everyone that is the customers and travellers. Mbare musika market, Siyaso and Mupedzanhamo are most preferred by everyone because of their cheaper prices as compared to the prices in the Harare CBD. There are also some people who cook different types of food for sale to vendors and other people in general, for example, sadza, meat, rice and potato chips. This produces a significant amount of plastic waste. Residential flats dispose of less plastic waste than business centres because of the low flow of movement from people as well as fewer tuck shops.

Table 4: Plastic waste generated per year across residential areas and business centres in Mbare

Source	**Plastic waste(kg)**
Residential	5 601.6
Mupedzanhamo	2 880
Mbare Musika	3 120
Mbare bus terminus	2 995.2
Siyaso	2 990.4
OK supermarket	67.2
Total	17 654.4

5.6 Waste collection system

The waste recycling system in Mbare should ideally be made up of the following components:

- A waste collection system that harnesses raw materials for recycling;
- Identification, enhancement and development of recycled products to derive maximum benefit and value from waste recycling;
- The business model that can be the most beneficial, and
- Evaluation criteria of the proposed design to determine if it is fit for the purpose.

6. Identification, enhancement and development of recyclable products

It is important to identify the type of recyclable products that can be made from plastic waste. In Mbare the products which were made from recyclable waste were bricks, sandals, mats and hats. It is also necessary to estimate the total amount of products that can be produced from plastic waste as well as identifying the challenges of recycling. The estimation is also important for determining the financial and environmental benefits, which are related to the revenue of the recyclers and Mbare on its own. The possibility of improving and diversifying the products that are made from recycling must also be assessed. This may indicate that the current products are not the most appealing from a financial and environmental point of view.

6.1 Business model

Currently, waste recycling in Mbare is a low-level economic activity, mostly undertaken by scavengers. Given the waste management challenges in Mbare and the financial and environmental benefits that can accrue from serious recycling, it is important to apply more plastic waste recycling methods and upgrade waste recycling. This depends on a good waste management strategy and an appropriate business model. Ideally, this should involve the Harare City Council by formalising waste collection systems and waste recycling practices. The Harare city council should have a way of involving the scavengers and recyclers who are currently involved and those interested in the business of recycling. There is also a need for the involvement of the private sector to provide labour, transportation, market and financial services. Introducing the mechanical recycling method can result in income generation, solid waste management, cost reduction and employment creation.

6.2 Evaluation criteria

The proposed design must be evaluated in relation to its prospects of success. In this study, it is justifiable to say that the mechanical recycling method is the most suitable for Mbare. The mechanical recycling method involves the collection, washing, drying, grinding, extrusion and manufacturing into specific products. Here the plastics are melted, therefore this technique is well suited for an area like Mbare since it is less cost-

intensive as compared to chemical or feedstock recycling. This method is also used for all types of plastic waste materials and therefore easier to apply.

7. Conclusions

This study was conducted in Mbare to find out the methods of recycling that can be applied to save the environment from pollution, which is a challenge in many urban areas in Zimbabwe. This was achieved by characterising the quantity and types of total and recyclable waste, and documenting the waste recyclable practices that are chemical and mechanical recycling methods focusing on plastics. A set of quantitative and qualitative methods was used. A quick field observation study was carried out to identify the current environmental degradation status as a result of plastic and illegal dumping. On this basis, recommendations were described in terms of technical aspects that still need to be undertaken and how this can be applied practically. This is discussed in the context of the limitations of the study. During this study, a number of challenges were faced. The study took place during the COVID-19 era and therefore there was limited personal time with the supervisor and the pandemic on its own restricted much movement everywhere.

Therefore, there was limited time to carry out the research on the study site and the local recyclers could not be frequently found. Data was therefore collected over a period of three weeks, which was not enough time to gather all the necessary information. Some respondents were also incompetent during the research and some did not have enough information related to plastic waste. There was also not enough money to print the questionnaires needed for the study therefore the questionnaires were limited. The total plastic waste was weighed from residential flats and business centres on a weekly and daily basis interval. The total plastic waste generated was 17654.4kg. The study focused mainly on plastic waste although some traces of aluminium waste were also found. There is so much plastic waste in Mbare because there are not enough bins and the waste collection system is ineffective.

The characteristics of the plastic waste were as follows:

- Most of the plastics were polyethylene terephthalate (PET) usually used to make fluid bottles and food containers, high-density polyethylene (HDPE) used for making carrier bags, low-density polyethylene (LDPE) used for making carrier bags and also milk packaging and polyvinyl chloride (PVC).
- Business centres generated most of the plastic waste by approximately 30% more than residential flats because these areas receive a very high flow of customers and travellers and
- Most of the plastic waste was found on surrounding dumpsites and some were scattered everywhere on the ground.

7.1 Design aspects

A system for collecting and recycling waste was designed and this included:

- A waste collection system that harnesses raw materials for the recycling
- Identification, enhancement and development of recycled products to derive maximum benefit and value from waste recycling
- The business model that can be the most beneficial
- Evaluation criteria of the proposed design to determine if it is fit for the purpose.

7.2 Environmental evaluation

Applying plastic waste recycling methods has a major impact on waste reduction, waste management costs reduction because they dominate the total waste generated. Many bricks, mats, bins, sandals, buckets, hats, chairs, tables, bangles and so on can be made in order to make use of the plastic waste in Mbare and, therefore, saving the environment from pollution. This not only reduces waste but improves the livelihoods of contracted waste collectors, recyclers and the community at large. Approximately USD70 per week revenue is collected from plastic recycling by plastic waste collectors. There will be many products made from plastic waste locally instead of us having to import those products from other countries. It also reduces dependency syndrome.

7.3 Recommendations

The waste collection system should separate recyclable waste from non-recyclable waste. The City Council should put in place a sound business model for plastic waste recycling. The plastic waste collection should be complemented by the City Council putting in place a sound business model for waste recycling. The City Council will be responsible for registering waste collectors and recyclers for incentives by signing agreement contacts of terms. The city will need to determine the appropriate number of cooperatives as well as provide land for waste collection and recycling sites. The City Council can also enter into joint ventures with the private sector players. It can approach commercial banks for financing. Waste recycling should be formalised by contracts through a Memorandum of Understanding (MOU). The system design has several environmental, social and economic benefits.

Waste recyclers and collectors benefit from incentives, people benefit from a clean and safe environment and councils benefit from reduced waste management costs. From the data collected in Mbare, the recycling methods can easily be applied. The local recyclers already with a brief explanation during the field observation survey showed interest in these methods of recycling and are willing to work together with the local authorities and private stakeholders. Recyclers should partake in product diversification and venture into making different new products.

Conflict of Interest Statement

The authors declare no conflicts of interest.

About the Authors

Rejoice Anna Chuma is a former BSc Honours student in Geography and Environmental Science at the Gary Magadzire School of Agriculture, Engineering and Natural Sciences at Great Zimbabwe University, Masvingo City, Zimbabwe.

Frank Chipfunde is a lecturer in Agricultural Engineering at Great Zimbabwe University, Masvingo City, Zimbabwe.

Jemitias Mapira is an associate professor in Geography and Environmental Science at Great Zimbabwe University, Masvingo City, Zimbabwe.

References

Vijay Kumar Thakur, Manju Kumari Thakur and Asokan Pappu (2017). Hybrid polymer composite materials, Volume 2, Retrieved from https://www.sciencedirect.com/book/9780081007853/hybrid-polymer-composite-materials

Thamae, T., Marien, R., Chong, L. et al. Developing and characterizing new materials based on waste plastic and agro-fibre. J Mater Sci 43, 4057–4068 (2008). https://doi.org/10.1007/s10853-008-2495-3

Chanda et al. (2016). Plastics Fabrication and Recycling, 1st Edition, Page 216 and Technology Handbook, 4th Edition, Page 896.

Dodbiba et al. (2005). Progress in separating plastic materials for recycling. Physical separation in science and Engineering, 1910, 165-182.

Emsley et al. (2007). Sustainability of bio-based plastics: general comparative analysis and recommendations for improvement. Journal of Cleaner Production. Volume 23, pages 47-56.

Samuel Asumadu Sarkodie, Vladimir Strezov, Haftom Weldekidan, Ernest Frimpong Asamoah, Phebe Asantewaa Owusu, Israel Nutifafa Yawo Doyi (2019). Environmental sustainability assessment using dynamic Autoregressive-Distributed Lag simulations—Nexus between greenhouse gas emissions, biomass energy, food and economic growth, *Science of The Total Environment*, Volume 668, 2019, Pages 318-332, https://doi.org/10.1016/j.scitotenv.2019.02.432.

Goodship, V. (2007). *Introduction to plastic recycling*. GBR: Smithers, Rupra.

Gupta, R. K. (2017). Applied plastics engineering handbook, 2nd Edition. Chapter 29: Plastics in Buildings and construction.

Hamerton, I. (2003). An automated in-situ polymerisation procedure for multi-functional cyanate ester resins via ring formation. *Polymer* 2021**,** *228*.

Jerie, S. (2018). The role of informal sector solid waste management practices to climate change abatement: A focus on Harare and Mutare, Zimbabwe. Department of Environmental Science and Engineering, Kunming University of Science and Technology, Kunming

Joseph. C. S. (2005). *Concise Polymeric Materials Encyclopedia*: CRC Press, New York

Kidder, L. H. and Fine, M. (1987). Qualitative and quantitative methods: When stories converge. Wiley Online Library.

La Mantia, F. (2002). Handbook of plastic recycling. iSmithers Rapra Publishing Retrieved from https://books.google.ro/books/about/Handbook_of_Plastics_Recycling.html?id=TBrOGJqvgcMC&redir_esc=y

Morgan, S. (2009). *Waste Recycling and use*, Evans Brothers Limited, London.

Palmeira, M. and Musso, F. (2020). 3Rs of Sustainability Values for Retailing Customers as Factors of Influence on Consumer Behavior. In *Handbook of Research on Retailing Techniques for Optimal Consumer Engagement and Experiences* (pp. 421-444). IGI Global.

Pappa G, Giannans C. (2001). The selective dissolution/Precipitate technique for polymer recycling: a pilot for unit application. *Resource Conservation Recycling* 34:33-34.

Siddique et al. (2013). Use of recycled plastics in concrete: A review. *Waste Management*. Pg 28, 1835-1852

South. A. R. (2018). Plastics: Facts and Futures: Moving beyond pollution management towards a circular plastics economy in South Africa. WWF South Africa, Retrieved from https://wwfafrica.awsassets.panda.org/downloads/wwf_plastics_report_final_2nov2020.pdf

Gideon Gywa Deme, David Ewusi-Mensah, Oluwatosin Atinuke Olagbaju, Emmanuel Sunday Okeke, Charles Obinwanne Okoye, Elijah Chibueze Odii, Onome Ejeromedoghene, Eghosa Igun, Joseph Okoro Onyekwere, Olayinka Kehinde Oderinde, Edmond Sanganyado (2022). Macro problems from microplastics: Toward a sustainable policy framework for managing microplastic waste in Africa, Science of The Total Environment, Volume 804, https://doi.org/10.1016/j.scitotenv.2021.150170.

Tucker. A (2002). *Plastic waste: feedstock recycling, chemical recycling and incineration, 13(4).* Rapra Technology, London.