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Impact of Plastic Waste Recycling on Sustainable Environmental Management in Nigeria

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Abstract
This study examined the impact of plastic waste recycling on sustainable environmental management in Nigeria. Despite the usefulness of plastics for a variety of purposes in our society, plastic waste poses a paramount challenge for environmentalists, governments, socioeconomics, and organisations, as a good number of plastics wastes are disposed of in non-environmentally friendly manner giving rise to polluted oceans, streams and gutters, overextended landfills and ecological damage. Plastic waste management is a menace to our immediate society and the world at large. Nigeria is highly polluted with plastic waste with Lagos state depositing about 450,000 metric tonnes of plastic waste yearly into the ocean. The challenge of plastic waste pollution is now a worldwide concern, which was why the 2018 Earth Day and World Environment Day were both interested in tackling plastic waste pollution. However, plastic recycling is vital to improving the environment and promoting waste management solutions. In spite of the importance of plastic recycling, effective, sufficient and satisfactory plastic waste gathering and recycling systems for sustainable environmental management are absent in most Nigerian cities. Due to this, cast off plastic always find their way into the environment, affecting the health of both aquatic and land animal including humans, and cause climate change. This paper therefore examined the impact of plastic recycling on sustainable environmental management in Nigeria. Specifically, it explored how mechanical and chemical recycling (the two sub independent variables) impact sustainable environmental management in Nigeria. Circular economy and waste hierarchy theories were adopted to support the study. The paper adopted the correlational research design. simple random sampling techniques were adopted by the study to select two (200) workers of plastic recycling companies such as Rida National Plastics and Alkem Nigeria Limited both located in Lagos, Chanja Datti located in Abuja and Shongai packaging industry LTD located in Ogun State which do both mechanical and chemical recycling and twenty (20) management staff was selected each for the study.

Introduction

Plastic waste pollution has become a real monstrosity in Nigeria. The urban centres are littered with single-use plastics and other plastic products; the rural areas are also burdened with plastic waste. This constitutes an eyesore on the landscape, degrades the environment, and clogs the drainage. It is challenging. Reminding Nigeria of the impact of plastic pollution afresh, the United States Agency for International Development said recently that Nigeria, Africa's most populous country is the ninth-highest contributor to plastic pollution globally. The country contributes 2.5 million tonnes of plastic waste annually while 88 per cent is not recycled. This is colossal (Punch Editorial Board, 2024). Several types of plastic waste exist, and the most common ones in Nigerian waste streams are polyethylene and Polyethylene terephthalate (PET) (Awoyera and Adesina, 2020).

Sustainable waste management is one of the greatest problems for Nigerian socio-economists and environmentalists and one major factor which births this challenge is higher population density (Wonah, Ngaji,& Udayi,2022). Despite Nigeria's population density, there is a need for the government to develop a sustainable waste management plan. According to Ezetu (2023), sustainability is a term that has become popular in recent times. Sustainability is a multidimensional concept that involves conscious management and utilization of resources to maximize efficiency, limit waste, and ensure continuous availability for development. Sustainable environmental management thus involves the conscious and effective application of a wide range of environmental resources including fossil fuels, precious metals, minerals, biodiversity, habitats and ecosystems, for productive purposes, ensuring minimal damage to their source (the environment), and actively managing them for the benefit of humanity and generations to come (Ezetu, 2023). Sustainable environmental management in Nigeria, in connection to plastic recycling, denotes the effective handling and repurposing of plastic waste to minimize environmental impact and promote resource efficiency. It covers waste reduction, recycling infrastructure, economic incentives, public awareness and education, legislation and policies, innovation and Technology, partnership and collaboration, and environmental and social benefits.

According to the Mismanaged Waste Index 2024 by the World Population Review(Cited in Punch Editorial Board, 2024), Nigeria's plastic waste status is "very high." The country is credited with 4.5 percent of the global plastic consumption rate. It imports 960,000 tonnes of plastics, produces 935,800 tonnes, and releases 27,685 tonnes of plastic waste into its waterways. It shares the damaging profile with India (7.4 million tonnes), Thailand (3.4MT), Iran (1.3MT), Kazakhstan (1.2MT), United Arab Emirates (1.1MT), and South Africa (1.0MT). USAID's Mission Director to Nigeria, Jones cited in Punch Editorial Board (2024), lamented that the excess plastic waste threatens the ecosystem, marine life, and public health. The source advised that recycling would help reduce demand for new raw materials for plastic production, limit the energy-intensive process of producing plastics by 90 percent, and reduce greenhouse emissions by 25 percent. Jones explained that the recycling value chain, from collection, sorting, aggregating, processing, and manufacturing could provide jobs and sustainable income for residents. Nigeria's plastic waste outlook is disturbing. Due to rapid urbanisation and high rural-urban migration, cities like Lagos, Port Harcourt, and Abuja are strewn with plastics, including sachet water nylons,

plastic bags, and Styrofoam food packaging. This culture has crept into national life due to the convenience and affordability of plastic packages. In addition, SMEs and local and multinational companies across the manufacturing spectrum use plastic containers to package their products. The menace is compounded by improper waste disposal systems. Most states lack seamless and efficient waste disposal structures; many citizens are nonchalant; uncooperative, or unaware of a sustainable waste disposal culture. Many Nigerians dump their refuse in open spaces, flowing gutters, streams or by burning. This results in flooding in the rainy season and contaminated water sources. Burning engenders a toxic atmosphere, respiratory illnesses, and skin diseases.

In rural areas, plastic contamination takes a toll on the agricultural verve of farmers and fishermen. While Nigeria's food security is threatened, its tourism potential is also sabotaged by plastic waste. Microplastics lead to the disruption of life cycles, early death, and extinction of marine life, and farmers may begin to experience rapid soil degradation. Health experts posit that plastic waste could lead to serious health issues such as endocrine disruption, weight gain, insulin resistance, infertility, and cancer. Microplastics in the body could lead to inflammation, genotoxicity, oxidative stress, and apoptosis. It may also lead to necrosis, cardiovascular diseases, inflammatory bowel disease, diabetes, rheumatoid arthritis, stroke, and auto-immune conditions. The UN states that plastic waste takes 20 to 500 years to decompose into microplastics. It never totally degrades. It said 8.3 billion tonnes of plastic had been produced in the last 13 years. Out of the 8.3bt, only 12 percent has been incinerated, 9.0 percent recycled and the rest deposited in landfills and waterways.

Plastic pollution poses significant risks to marine ecosystems, wildlife, and human health. Fish can ingest or become entangled in plastic debris, leading to injury, suffocation, and death. Furthermore, plastics can leak harmful chemicals into the environment, threatening water quality and ecosystem health. The Ellen MacArthur Foundation quoted by punch editorial (2024) estimates that by 2050 there could be more plastics than fish (by weight) in the world's oceans if the current trends continue. Also, the Environmental Science & Technology quoted in the above source estimates that there are between 15 to 51 trillion microplastic particles in the world's oceans, weighing between 93,000 to 236,000 metric tonnes. The economic costs associated with plastic pollution are substantial. Again, The Pew Charitable Trusts and SYSTEMIQ in the same source, estimated that the cost of plastic pollution to marine ecosystems could reach $2.5 trillion by 2050. To curb this plastic waste menace, Nigeria needs to develop effective recycling systems and techniques for sustainable environmental management.

Literature review

Mechanical recycling and sustainable environmental management in Nigeria

Plastics are elements formulated from artificial organic polymers, with an end product of weightless, tough, and affordable substance that can be transformed from one form to another for several purposes ranging from packaging materials (usually disposable), household utensils, medical facilities, construction materials, electronic appliances, etc.(Hopewell, Dvorak, Kosior cited in Otitoju, OlawoOtye, Abiola, Ahmed & Okoma, 2023). Awoyera and Adesina (2020) point out that plastics are commonly used in many products of different scales and packaging because

they are cheap, easy to manufacture, versatile, impervious to water, has lightweight, high impact, bacteria and chemical resistance, and ability to be formed into shapes. Moreover, plastic recycling involves a process of collection, sorting, cleaning, and reusing plastic materials (Otitoju, Olawo Otye, Abiola, Ahmed & Okoma, 2023). It is also the process of recovering and reprocessing plastic waste into new products (Chatbot AI).

According to Ikellea, Oliviab, and Ogah (2023), plastic recycling refers to the process of recovering waste or scrap plastic and reprocessing the material into functional and useful products. Plastic recycling is the process of recovering and reprocessing plastic waste into new products. This helps reduce the amount of plastic waste that ends up in landfills and oceans and also conserves natural resources by reducing the need for new plastic production. Rick(2020) asserts that plastic waste recycling reduces the high rate of plastic pollution while putting less pressure on virgin materials to produce brand-new plastic products. Plastic recycling helps reduce the amount of plastic waste that ends up in landfills and oceans and conserves natural resources by reducing the need for new plastic production. Plastic recycling has environmental, pollution control, conservational, economic, and sustainability benefits. In terms of environmental benefits, plastic recycling reduces the amount of plastic waste ending up in landfills, oceans, and the environment, it decreases the need for raw materials and energy required to produce new plastic products helps conserve natural resources, and reduces greenhouse gas emissions.

According to the Federal Republic of Nigeria's National Policy on Plastic Waste Management (2020), mechanical recycling is the most preferred and widely used method of recycling and it recycles polymers used in water and soft drink bottles, it may emit harmful gases due to its old design components and not having provision for pollution control. The process of sorting, cleaning, and separating selected polymers increases the operating cost. The laminated plastics and carry bags remain the challenge for this process. Serranti and Bonifazi (2019) assert that the mechanical recycling of plastic waste involves the physical degradation of the waste by using processes such as grinding and/or shredding . In contrast, mechanical recycling is reported to be somewhat inefficient as a result of the complex nature of plastic waste mixtures, and instead, the majority of plastic wastes are incinerated [Khoo, and Aryan Yadav and Samadder quoted by Awoyera and Adesina, 2020]. But it is clear from the literature that mechanical recycling is still the most used technique for plastic recycling. It is effective and rapid to execute (Awoyera and Adesina, 2020).

Mechanical recycling refers to operations that aim to recover plastics via mechanical processes (grinding, washing, separating, drying, re-granulating and compounding), thus producing recyclates that can be converted into plastics products, substituting virgin plastics. It is also known as material recycling, material recovery or, related to plastics, back-to-plastics recycling. In mechanical recycling, plastic waste (sorted by material type) is milled and washed, passes a flotation separation, and is dried. The plastic flakes are then either used directly to produce new plastic materials or they are processed into granulates beforehand. Mechanical recycling is used for the recovery of pre-consumer (post-industrial) material as well as for post-consumer plastic waste. It is currently the dominating method of recycling post-consumer plastic waste in Europe. For mechanical recycling, only thermoplastic materials are of interest, i.e. polymeric

materials that can be re-melted and re-processed into products via techniques such as injection moulding or extrusion. It is a well-established technology for the material recovery of plastic materials such as polypropylene (PP), polyethylene (PE) or polyethylene terephthalate (PET) (European Bioplastics, 2020).

Titone, Botta, Mistretta and Paolo La Mantia (2023) point out that mechanical recycling of oil-derived polymers is certainly our best option to reduce pollution, save raw materials, and protect ourselves and the environment from the adverse effects of waste disposal. In their 2023 study on "the influence of a biodegradable contaminant on the mechanical recycling of a low-density polyethylene (LDPE) sample", Titone, Botta, Mistretta and Paolo La Mantia found that 2% of the contaminant is able to influence the rheological, shear, and isothermal elongation properties of recycled LDPE, while the results of the mechanical tests showed that after one extrusion cycle, the main tensile properties were not significantly affected by the presence of the contaminant, but after only two cycles of extrusions, some significant reduction in the final properties began to appear. In short, the presence of 2% of a biodegradable co-polyester in a LDPE matrix gives rise to a more pronounced decay of the rheological and mechanical properties

but, after two extrusion steps, both rheological and mechanical properties seem still useful for the production of film.

Schyns and Shaver (2020), in their study on mechanical recycling of packaging plastics: A review, claim that mechanical recycling is an essential tool in an environmentally and economically sustainable economy of plastics, but current mechanical recycling processes are limited by cost, degradation of mechanical properties, and inconsistent quality products. In the same study, Schyns and Sheaver revealed that mechanically recycled plastics have been effectively used as a replacement for wood in furniture, replacement of bitumen in asphalt mixtures in the construction of roads and bridges, production of fabrics, mixed with concrete and mortars for construction purposes, production of Television backseats, as a thickening agent in liquid lubricants, and for multilayered packaging materials. On their part, Babaremu, Adediji, Olumba, Okoya, Akinlabi, and Oyinlola (2024) reveal that mechanical recycling is the earliest and best kind of recycling because it has lower environmental impact, fewer harmful byproducts, less energy used, and greater acceptability of various plastics.

Also, in the aspect of pollution control, plastic recycling reduces plastic pollution, especially in oceans and waterways, and its severe environmental impacts on marine life and ecosystems. It helps divert plastics from ending up in these sensitive environments. It also mitigates the negative effects of plastic waste, such as wildlife entanglement and ingestion. Furthermore, in the area of conservational benefits, plastic recycling preserves the valuable resources used to make them, such as oil and natural gas, it takes less energy to recycle plastic than to produce new plastic from raw materials, and it also reduces the need for disposal through methods like incineration or landfilling. Equally, in terms of economic benefits, plastic recycling creates jobs in the recycling and manufacturing industries. Recycled plastics can be used to make new products, creating economic opportunities. It can also save money for municipalities and waste management companies by reducing disposal costs. Again, in the aspect of sustainability,

plastic recycling is an important part of the circular economy, where materials are reused rather than discarded.

It helps reduce the reliance on virgin plastic production and move towards a more sustainable future. Increased plastic recycling contributes to the overall sustainability of waste management systems. Overall, plastic recycling is crucial for reducing environmental impact, conserving resources, creating economic opportunities, and working towards a more sustainable future. Encouraging and expanding plastic recycling efforts is essential for addressing the global plastic waste management problem (Chatbot AI). Plastic waste can be recycled mechanically, chemically, and hydrothermally. Mechanical recycling of plastics refers to the processing of plastic waste into secondary raw materials or products without significantly changing the chemical structure of the material. In principle, all types of thermoplastics can be mechanically recycled with little or no quality impairment (circulareconomyasia.org). According to Walther (2023), mechanical recycling of plastic waste is a well-established process that involves sorting, grinding, washing, cleaning, and reprocessing plastic waste. Mechanical recycling is a process that involves physically breaking down and reprocessing recyclable materials into new products. Mechanical recycling is widely used for a variety of materials such as plastics, metals, glass, and paper. Mechanical recycling is generally more cost-effective and energy-efficient compared to producing new materials from virgin resources, making it an important part of the circular economy and sustainable waste management (Chatbot AI).

Chemical recycling and sustainable environmental management in Nigeria

Chemical recycling is the process of converting polymeric waste by changing its chemical structure and turning it back into substances that can be used as raw materials for the manufacturing of plastics or other products. There are different chemical recycling technologies, e.g. pyrolysis, gasification, hydro-cracking and depolymerization (Plastic Europe, 2024).Chemical recycling is a process that converts plastic waste back into its original monomers or other useful chemicals. Unlike mechanical recycling, which simply melts and reshapes plastics, chemical recycling breaks down plastics at the molecular level, allowing for the production of high-quality recycled materials. This method can handle a wider variety of plastics, including those that are difficult to recycle mechanically. Chemical recycling is typified into pyrolysis, gasification, depolymerization and solvolysis.

Chemical recycling offers several benefits, such as reducing landfill waste, conserving resources, and decreasing reliance on fossil fuels for new plastic production. However, it also faces challenges, including high energy requirements, economic feasibility, and potential environmental impacts from the processes involved(Chat GPT).Hydrothermal recycling is a type of chemical recycling that uses water at high temperatures and pressures to break down plastic waste into its original monomers or other valuable chemicals. This process, also known as hydrothermal liquefaction or solvolysis, involves subjecting plastic waste to supercritical water (water at temperatures and pressures above its critical point, where it exhibits unique properties) to achieve depolymerization. Hydrothermal recycling is characterized by high efficiency, versatility and low emissions. Hydrothermal recycling holds promise as a sustainable solution for managing plastic waste and contributing to a more circular and environmentally friendly economy.

Environmental management demands stewardship of Earth's natural resources, which have become increasingly degraded and depleted by over exploitative human societies seeking better economic conditions. But this has been to the detriment of the natural environment, resulting in pollution, biodiversity loss, and solid waste accumulation, among other pressing environmental concerns today. Centuries of unregulated extraction of natural resources from the environment has now resulted in a toxic feedback loop that threatens social order, as well as human health and safety on the only livable planet we know. The unsustainable use of earth's environmental resources over the years led to the establishment of the UN Sustainable Development Goals. Which advocates better management of resources, to ensure sustained economic growth and development for member nations. The SDG's provide a template for sustainable economic development, and resource utilization among other global development objectives for 2030. However, before the adoption of the SDG's in 2015, environmentalists around the world had been advocating for better environmental management practices as regards environmental pollution and solid waste accumulation. The industrial revolution had resulted in increased waste accumulation especially in industrialized cities around Europe. Decades later, industrialization would reach America and Asia, and more recently Africa. Along with its accompanying environmental challenges. Today, while Europe, Asia and America are harnessing technological advancement to tackle their environmental issues, Africa seems to be languishing in environmental pollution, even up to the extent of becoming a dumping ground for waste from other continents. The situation is disheartening. As a result, Nigeria, which is the most populated nation in Africa, is waist-deep in environmental pollution problems, and the volume of municipal waste generated daily around the country is simply overwhelming for waste management and environmental authorities to effectively handle.(Ezetu, 2023).

There are three basic plastic waste management strategies and these are reduce, reuse, and recycling, or simply put " The 3R method. Other strategies include landfill and Incineration. However recycling is one of the most efficient methods of managing plastic waste. Geyer in Abimbola, Adejumobi, Aribisala & Oyeniyi (2023) highlighted the 5 R's (refuse, reduce, reuse, repurpose, and recycle) steps of waste management. The 5 R's are steps that ensure that waste is properly managed, reducing the amount of waste plastics ending at landfills, with recycling as the last action to take in waste management. Refuse deals with rejecting the use of plastic when possible. For instance, plastic packaging bags could be replaced with more biodegradable paper bags, reject the use of disposable plastics for reusable plastics, and rejecting the use of non-recyclable plastics. Plastics can be reduced by avoiding all unnecessary use of plastics. Groceries can be bought in bulk to reduce the use of plastic packaging and take a reusable shopping bag when shopping. Reuse involves the conscientious reuse of plastics. Reusable cutleries, plates, cups, and packaging materials could be used in place of singleuse plastics, which are thrown-away after use. When refusing, reducing, and reusing plastic material seems difficult, and then repurposing comes in handy. Repurposing involves the use of an item meant for a particular purpose for another purpose. For instance, converting plastic bottles into planters and creating bottle pen and pencil holders from plastic bottles. The last 'R' represents recycling of waste plastic. Recycling involves the total conversion of plastic to different products such as fuel, and other chemicals (Abimbola, Adejumobi, Aribisala & Oyeniyi, 2023).

However, the majority of littered plastics come from developing countries, only a small

amount comes from Western countries. This is primarily due to the limited capacity of waste collection systems and low recycling rates. This situation echoes the need for recycling in order to minimize the amount of plastic waste disposed into rivers, oceans and the environments. Thus, the best answer to the problem of how to sustainably manage waste plastic is to recycle it. Ezetu(2023) submitted that without reduce, reuse and recycle options properly looked into, at all levels of government in Nigeria, sustainable waste management will remain a mirage perpetually made unattainable by the huge amounts of municipal solid waste generated daily in cities and towns across Nigeria.

As the world becomes more aware of the environmental damage caused by plastic waste, businesses and individuals alike are looking for sustainable solutions to address the issue. One of the most promising solutions is the chemical recycling of plastic waste, which offers a way to recycle difficult-to-recycle plastics and turn them back into valuable materials. Chemical recycling is a process that breaks down plastics into their chemical building blocks, which can then be used to create new plastics or other materials. Unlike traditional recycling, which involves melting and reforming plastics into lower-quality products, chemical recycling allows for a high-quality recycling of plastics, enabling them to be reused in a variety of applications. One of the main advantages of chemical recycling is that it can recycle a wider range of plastics than traditional recycling. This includes plastics that are contaminated with food or other substances, or that have multiple layers and cannot be separated by traditional recycling methods(Astrum Group, 2023).

In its 2023 study on "Chemical Recycling of Plastic Waste: The Sustainable Solution to Our Plastic Problem" Astrum Group, concluded that chemical recycling of plastic waste offers a promising solution to our plastic problem. By breaking down plastics into their chemical building blocks, chemical recycling allows for a high-quality recycling of plastics that can be reused in a variety of applications. With the potential to reduce plastic waste, create a circular economy, and reduce greenhouse gas emissions, chemical recycling is a sustainable solution that deserves our attention and investment. Also, In their 2024 study titled "Chemical Recycling of Plastic Waste for Sustainable Development", Sadiya, Mahmood and Ibrahim found that the chemical recycling method of plastic waste facilitates the creation of feedstock for a variety of applications, adding alternative fuels and chemical feedstock to petrochemicals.

Equally, Chukwu in his 2023 study on the impact of mechanical and chemical recycling on sustainable environmental management in Abakalike, found that chemical recycling was more effective and efficient than mechanic recycling in terms of its ability to reduce greenhouse gas emission, its encouragement of circular economy, its utilization for the production of high quality materials and its allowance for a second life for difficult-to-recycle plastics. He revealed that chemical recycling expedites the circular economy and supplies innovative approaches for increasing recycling rates, hence it can handle a vast range of plastic waste than traditional mechanical recycling. More so, Jeswani, Krüger ,Russ, Horlacher , Antony, Hann, and Azapagic (2023) in their assessment of the life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery, found that chemical recycling via pyrolysis has a 50% lower climate change impact and life cycle energy use than the energy recovery option. They also revealed that the climate change impact and

energy use of pyrolysis and mechanical recycling of MPW are similar if the quality of the recyclate is taken into account. Furthermore, MPW recycled by pyrolysis has a significantly lower climate change impact (−0.45 vs 1.89 t CO2 eq./t plastic) than the equivalent made from virgin fossil resources.They equally found that pyrolysis has significantly higher other impacts than mechanical recycling, energy recovery and production of virgin plastics. Sensitivity analyses show that some assumptions have notable effects on the results, including the assumed geographical region and its energy mix, carbon conversion efficiency of pyrolysis and recyclate quality. They conclude that these results will be of interest to the chemical, plastics and waste industries, as well as to policy makers.

Again, Montoya (2024) conducted a comprehensive analysis of chemical recycling technologies, focusing on pyrolysis for post-consumer mixed plastic waste (MPW) with the aim of comparing the environmental impacts of circular, chemically recycled plastics-to-plastics systems against conventional, linear fossil-based systems. The study revealed that chemical recycling via pyrolysis has the potential to reduce environmental impacts significantly. When compared to traditional fossil-based systems, this method shows a marked decrease in climate change potential. Key to this is the efficient conversion of MPW into food-grade quality films, which are crucial in packaging applications. The study also found that the environmental benefits of chemical recycling amplify with the use of renewable energy sources and technological advancements in the process. This highlights the importance of continuous innovation and integration with renewable energy for optimal sustainability.

However, in plastic waste management systems, chemical and solvent-based recycling seem suitable for application as a complement to mechanical recycling due to the tendency towards better environmental performance of the latter. Recycling mixed or contaminated waste streams that are unsuitable for mechanical recycling chemically or by means of solvents instead of recovering their energy appears to be potentially environmentally beneficial in most cases. The reduction in system impact achievable may amount up to 40 %. Nonetheless, impact savings over energy recovery may only be minor for certain process configurations, even when making generous assumptions regarding the applicability of chemical recycling given its current marginal utilization. Chemical recycling may for certain configurations even perform worse than energy recovery if WTE energy is able to achieve high benefits by substituting for fossil heat and electricity and WTE efficiencies are high. Consequently, Abimbola, Adejumobi, Aribisala & Oyeniyi (2023) in their study on " The influence of plastic waste management on the environment: A review", reveal that chemical recycling is the most effective recycling process that completely removes waste plastic from the environment.

Statement of the Problem

Over the years, waste management, particularly plastic waste management, has been a serious concern to the government, environmentalists, socioeconomics and the society at large. The Nigeria’s continuous population increase has even made adequate plastic waste management more critical than ever. The challenge of ineffective plastic waste management in Nigeria is perceived to exert detrimental consequence on humans, livestock, aqua-culture and increase pollution and habitat destruction. Despite the Nigerian Federal government's effort through the

establishment of a National Policy on Plastic Waste Management in 2020 and its ban on single-used plastic bags in 2019, the problem of plastic waste management still persists at lamentable rate. However, this problem has been attributed paramountly to inadequate, ineffective or lack of appropriate, adequate and effective recycling industries, plans and strategies by the government at all levels, in spite of the myriad employment opportunities, health and environmental benefits that resides in effective plastic waste recycling. Even the few available recycling companies in the country are privately owned. Therefore, this study seeks to examine the impact of plastic waste recycling on sustainable environmental management in Nigeria.

Purpose of the study

The penultimate purpose of this study is to examine the impact of plastic recycling on sustainable environmental management in Nigeria. Specifically, this study is aimed at examining:

1. The impact of mechanical recycling on sustainable environmental management in Nigeria.

2. The impact of chemical recycling on sustainable environmental management in Nigeria

Statement of hypotheses

The following null hypothesis are formulated to guide this study:

1. There is no significant relationship between mechanical recycling on sustainable environmental management in Nigeria

2. There is no significant relationship between chemical recycling and sustainable environmental management in Nigeria

Research questions:

The following research questions are posed to give focus to this study:

1. To what extent does mechanical recycling relate sustainable environmental management in Nigeria?

2. To what extent does chemical recycling relate to sustainable environmental management in Nigeria?

Methodology

The study adopted the Correlational research design. The population of the study consists of two hundred (200) employees of the four plastic recycling Industries are estimated to be 609 whereas the management staff of the four Industries. Population for the study based on the total number of staff estimate of the four plastic recycling Industries utilized by the study is 651. This study's population comprised all staff members of the four plastic waste recycling companies/ Industries (Rida National Plastics, Alkem Nigeria Limited, Chanja Datti and Shongai packaging Industry LTD) utilized for the study. Rida National Plastic has an extimate of 300 employees and

15 Board of Directors/ Management team members, Alkem Nigeria LTD has a total of 101to 500 employees and twelve (12) key Management personnel, Chanja Datti Ltd boost of sixty five (65) employees and seven (7) management team members and Shongai Packaging Industry LTD has one hundred forty three (143) employees and eight (8) management team members. The selection was done through a simple random sampling technique. The instrument used for the data collection was a questionnaire titled: Impact of Plastic Waste Recycling on Sustainable Environmental Management Questionnaire (IPWRSEMQ) was developed by the researchers and was validated by experts in the Department of Educational Management and Measurement and Evaluation in the Department of Educational Foundations in Faculty of Education, University of Calabar, Calabar. The instrument was divided into two Sections. A and B. Section A sought for respondents' demographic data such as the name of the university, and qualification. Section B consisted of ten (10) items constructed in a four (4) point modified Likert scale ranging from strongly Agree (SA) 4 points, agree (A) 3 points, disagree (D) 2 points, and Strongly Disagree (SD) 1 point. Data collected were subjected to statistical analysis using Pearson Product Moment Correlation Statistical Analysis of Statistical Package for Social Science (SPSS) version 25 was used for data analysis and the results are presented as follows.

Results

Hypothesis 1:

There is no significant relationship between mechanical recycling and sustainable environmental management in Nigeria.

The independent variable in this hypothesis was mechanical recycling; while the dependent variable is sustainable environmental management. Pearson Product Moment Correlation Statistical Analysis was then employed to test this hypothesis. The result of the analysis is presented in Table 1.

TABLE .1

Summary of correlation analysis of the relationship between mechanical recycling and sustainable environmental management (n=200)

Variables	Mean	Std. Dev.	t cal.	p-value
Mechanical recycling	15.82	2.445		
			.723*	.001
Sustainable environmental management	15.79	2.621		

*Significant at .05 level; df= 198 critical- r = .138

The result in Table 1 reveals that the calculated R-value of .723* was found greater than the critical value of .138 when tested at .05 level of significance with 198 degrees of freedom. Therefore, the null hypothesis was rejected while the alternative hypotheses were accepted. This implies that there is a significant relationship between mechanical recycling and sustainable environmental management.

Hypothesis:2

There is no significant relationship between chemical recycling and sustainable environmental management in Nigeria. Pearson Product Moment Correlation Statistical Analysis was employed to test this hypothesis. The result of the analysis is presented in Table 2.

TABLE .2

Summary of correlation analysis of the relationship between chemical recycling and sustainable environmental management (n=200)

Variables	Mean	Std. Dev.	t cal.	p-value
Chemical recycling	15.84	2.496		
			.709*	.001
Sustainable environmental management	15.79	2.621		

*Significant at .05 level; df= 198 critical- r = .138

The result in Table 2 reveals that the calculated R-value of .709* was found greater than the critical value of .138 when tested at .05 level of significance with 198 degrees of freedom. Therefore, the null hypothesis was rejected while the alternative hypotheses were accepted. This implies that there is a significant relationship between chemical recycling and sustainable environmental management.

Discussion of the findings

The result of hypothesis one showed that there is a significant relationship between mechanical recycling and sustainable environmental management. The resulting finding is in agreement with the results of Walther(2023) who viewed mechanical recycling of plastic waste is as a well-established process that involves sorting, grinding, washing, cleaning, and reprocessing plastic waste. Mechanical recycling is a process that involves physically breaking down and reprocessing recyclable materials into new products. Mechanical recycling is widely used for a variety of materials such as plastics, metals, glass, and paper. Mechanical recycling is generally more cost-effective and energy-efficient compared to producing new materials from virgin resources, making it an important part of the circular economy and sustainable waste management (Chatbot AI). Also, the finding is in agreement with Babaremu,Adediji, Olumba, Okoya, Akinlabi, and Oyinlola (2024) whose study revealed that mechanical recycling is the earliest and best kind of recycling because it has lower environmental impact, fewer harmful byproducts, less energy used, and greater acceptability of various plastics.

The result of hypothesis two showed that there is a significant relationship between chemical recycling and sustainable environmental management. The resulting finding is in agreement with the results of Chukwu (2023) whose study on the impact of mechanical and chemical recycling on sustainable environmental management in Abakalike, found that chemical recycling was more effective and efficient than mechanic recycling in terms of its ability to reduce greenhouse gas emission, its encouragement of circular economy, its utilization for the production

of high-quality materials and its allowance for a second life for difficult-to-recycle plastics. He revealed that chemical recycling expedite the circular economy and supplies innovative approaches for increasing recycling rates, hence it can handle a vast range of plastic waste than traditional mechanical recycling.

Also, the finding is in agreement with Jeswani, Krüger,Russ,Horlacher , Antony, Hann, and Azapagic (2023) whose study assesses the life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery, found that chemical recycling via pyrolysis has a 50% lower climate change impact and life cycle energy use than the energy recovery option. They also revealed that the climate change impact and energy use of pyrolysis and mechanical recycling of MPW are similar if the quality of the recyclate is taken into account. Furthermore, MPW recycled by pyrolysis has a significantly lower climate change impact (−0.45 vs 1.89 t CO2 eq./t plastic) than the equivalent made from virgin fossil resources. They equally found that pyrolysis has significantly higher other impacts than mechanical recycling, energy recovery, and production of virgin plastics.

Conclusion

Based on the findings of the data collected and analyzed, the study concluded there is a significant relationship between mechanical recycling and sustainable environmental management. Also, that there is a significant relationship between chemical recycling and sustainable environmental management.

Recommendations

Based on the findings and conclusion of the study, it was recommended that:

i. Mechanical recycling should be use by plastic recycling company in order to sustainable environmental management
ii. Chemical recycling should be use by plastic recycling company in order to sustainable environmental management

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