DURBAN UNIVERSITY OF TECHNOLOGY

WASTE MANAGEMENT PRACTICES AMONG MANUFACTURING ORGANISATIONS IN THE ILEMBE MUNICIPAL DISTRICT IN KWAZULU-NATAL

EVERLANE REDDY

JUNE 2024

WASTE MANAGEMENT PRACTICES AMONG MANUFACTURING ORGANISATIONS IN THE ILEMBE MUNICIPAL DISTRICT IN KWAZULU-NATAL

Submitted in fulfilment of the requirements for the degree of

Master of Management Sciences

Specialising in

Business Administration

in the

Faculty of Management Sciences

at the Durban University of Technology

EVERLANE REDDY

JUNE 2024

APPROVED FOR SUBMISSION

Supervisor (Affiliation):___ _________ Date: ____8 January 2024_______

DECLARATION

I, Everlane Reddy, the undersigned, hereby certify that this dissertation submitted to the Durban University of Technology is an accurate representation of my own work in both conception and execution, except where acknowledgements indicate otherwise. This dissertation has never been submitted to another institution of higher learning for degree purposes.

E Reddy 8 January 2024

Everlane Reddy Date

Approved for Final Submission

8 January 2024

Professor. R.W.D. Zondo Date

DEDICATION

In memory of the two most inspiring women that I have ever encountered,
my late mum **Saroj Naidoo** and my sister **Elaine Naidoo**.

It is through your endurance; I have learned resilience.
Through your narratives, I have acquired wisdom.
Through your courage, I have gained perseverance
and
through your faith, I still believe.

Thank you for your unconditional love and for the invaluable lessons you have instilled in me.

This one's for you both!

ACKNOWLEDGEMENT

Completing a Master's degree is an enormous undertaking that places one's commitments to family and employer to the ultimate test. I would not have been able to competently accomplish this remarkable achievement without the support of a number of people who contributed to the existence and success of this thesis:

Thank you to my supervisors, **Professor R.W.D. Zondo & Dr S. Chetty,** for sharing this journey with me. This monumental accomplishment would not have been possible without your expertise, mentorship and unwavering support. Your patience, promptness and constructive feedback and suggestions in the preparation and completion of this dissertation are highly appreciated. You have taught me a great deal about academic writing. I will be forever grateful to you!

To my beloved husband, **Allan Reddy**, my rock and my pillar of strength, thank you for your patience as I navigated through the course of this lengthy journey. Your unwavering faith in me and constant support in all of my endeavours have enabled me to achieve this milestone. Thank you for your tolerance during all those late nights or times when I needed to be excused to acquire information or satisfy academic requirements. This prestigious achievement would not have been attainable without your love and encouragement. I cherish and appreciate you immeasurably!

To my first born, **Aliah Chereez Reddy**, you are one of my greatest sources of inspiration. You inspire me to be more and do more. I hope that my academic journey will remind you that anything is possible. If you believe and act in accordance, you will achieve. Thank you for your understanding, constant encouragement and support throughout my academic pursuit. I am so blessed to have you in my life.

To my baby, **Alison Timiqua Reddy**, your tenacity, optimism and the sound of your regular words "You got this mommy", proceeded to empower me as I pursued this extensive journey. Thank you for your boundless encouragement, constant love, heartfelt prayers and unwavering faith in me! I love, appreciate and adore you tremendously!

To all those who participated in this study, thank you for your valuable time and willingness to share your input, not only for the benefit of this study but for an ecologically conscious future

& above all,

I would like to thank The Almighty for making this prestigious achievement possible.
"I can do all things through Christ who strengthens me" Philippians 4:13.
"If God is for us, who can be against us?" Romans 8:31-39.

ABSTRACT

Manufacturing organisations are responsible for depleting an extensive portion of the earth's renewable resources, as well as contributing to air pollution, water contamination and waste generation. Unsustainable waste management practices exacerbate biodiversity loss, contribute to the ramifications of global warming and endanger public health. Therefore, the aim of the present investigation was to explore the nature and extent to which manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal embrace sustainable waste management practices. The empirical investigation has adopted a quantitative research design, with a standardised structured questionnaire that was distributed to all manufacturing organisations within the iLembe Municipal District in KwaZulu-Natal, which consisted of 262 manufacturing organisations in total. Due to the relatively small size, the entire target population was surveyed. According to the results of the study, only 70.23 per cent of participants from the 262 manufacturing organisations participated in this study. The data was evaluated with the aid of statistical software, version 27 of the Statistical Package for the Social Sciences (SPSS). The objectives and questions of this research inquiry were achieved. Upon analysis of the data, it was discovered that the majority of respondents at 61% agreed that their organisations waste is recycled in-house. The second highest number of respondents at 60% stated that their organisation re-uses waste to manufacture other products, while 48% of the respondents stated that their organisation incinerates waste. Another key outcome of the study revealed that chemical waste was the most prevalent type of waste generated in the Municipal District of iLembe in KwaZulu-Natal, which is alarming and can be harmful if toxins such as mercury and lead are not properly disposed of, with certain chemicals consisting of high global warming potentials due to their accumulation and persistence in the environment. In addition, the drivers that influence sustainable waste management practices and the barriers that hamper sustainable waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal were assessed and analysed.

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LIST OF ACRONYMS AND ABBREVIATIONS

CSPS	Circular Smart Production System
EMS	Environmental Management Systems
EPA	Environmental Protection Act
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Inter-governmental Panel on Climate Change
KZN	KwaZulu-Natal
Ph	power of Hydrogen
PRO	Producer Responsibility Organisation
SADC	Strategy at Combating Desertification
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
UNEP	United Nations Environmental Programme
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organisation

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CHAPTER ONE

NATURE AND SCOPE OF THE STUDY

1.1 Introduction

Waste generation in South Africa has been on an upward trajectory. The country generated 121 million tons of waste in 2017 (Department of Environmental Affairs, 2018). These estimates are higher than those documented in 2011, which showed total waste generation at 108 million tons (DEA, 2011). The trend could arise due to increased waste production from the rising population and improved economic wellbeing, which has resulted to unaccounted for waste that is neither grouped as hazardous nor general (Fakoya, 2018).

Operating an organisation in the context of current environmental concerns necessitates a transition away from a management strategy that is merely focused on achieving economic goals. The chronic issues associated with environmental exploitation and contamination, coupled with the constant shrinkage of the available resources from nature makes environmental challenges an extremely crucial corporate imperative. In this context, sustainable business practices, particularly those that are innovative, are gaining traction. These green initiatives allow for the mitigation and/or reduction of environmental pollution whilst simultaneously generating certain measurable benefits for the companies implementing them. In light of the above, this investigation aims to evaluate the use of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District, KwaZulu-Natal (KZN).

1.2 Context of the research

South Africa contends with an acute waste management crisis due to the annual generation of billions of tons of hazardous waste. Only a small percentage of this waste is appropriately administered and disposed of. Manufacturing companies, according to Ndubisi, Zhai, and Lai (2019), contribute significantly to waste generation, greenhouse gas emissions, water contamination, and the depletion of natural resources worldwide. Only a negligible quantity of South Africa's waste is recycled on an annual basis, with majority of the municipal landfills overflowing and pervasive unlawful dumping occurring (Afrika, Oelofse, Strydom, Mvuma, and John, 2018; Department of Forestry, Fisheries, and the Environment, 2018).

Daniel (2020) asserts that since the majority of South Africa's 826 authorized disposal facilities have almost reached their maximum volume, the nation is in danger of drowning in its own waste. According to the South African Waste Information System (SAWIS), "approximately 42 million tons of general waste were produced in South Africa in 2017". Consequently, only 11.7 percent of the waste generated during that time period was recycled (Department of Environmental Affairs, 2018). Moreover, if the total capacity of waste generated can be reduced, there will be fewer instances of illegal dumping (Conserve Energy Future, 2021).

Landfill facilities are considered a major contributor of greenhouse gas (GHG) emissions. It is estimated that South African landfills will emit roughly 43 million cubic meters of methane gas annually, or 595 550 tons of carbon dioxide ($C0_2$), which is toxic and harmful to humans and the environment (Department of Environmental Affairs, 2018). The waste from food, beverage and chemical processing companies causes major environmental issues (Yang, Xu, Yang, Bi, Li, Shen, Ma, Tian, Liu, Song, Sand and Liu, 2018). Moreover, carbon dioxide is emitted into the atmosphere as a greenhouse gas that traps solar radiation when fossil fuels are burned for energy production and heating. As a result, invasive wildfires, droughts, hurricanes, potentially fatal heatwaves, torrential rains and severe storms are all directly caused by human and commercial activity. These catastrophic events will deteriorate unless people and businesses adopt sustainable practices to minimize their effects.

The manufacturing industry is critical to the economic advancement in south Africa. They aim to upsurge productivity and economic growth while simultaneously reducing energy consumption and decreasing environmental impact. As at the second quarter of 2023, the manufacturing industry increased by 2,2% and contributed 0,3% to Gross

Domestic Product (GDP) growth in South Africa (Statistics South Africa, 2023). On the contrary, Khan, Hou, Le and Ali (2021) argue that the pollution instigated by the Industry has damaging consequences for both the ecosystem and the economy as Manufacturing industries are largely responsible for depleting a significant percentage of the world's renewable resources, as well as contributing to pollution and the loss of biodiversity. Nörmann and Maier-Speredelozzi (2016) asserted that the indirect environmental cost of manufacturing encompasses product use and disposal, which are vulnerable to environmental degradation.

Hence, sustainable manufacturing and waste management initiatives can assist in the alleviation of environmental contamination such as modifying manufacturing processes to produce less waste and greenhouse gas emissions; using non-toxic or less-toxic production ingredients; using less energy and water; re-using resources such as wastewater and factory scrap, rather than throwing them away; and reducing packaging or using environmentally friendly packaging materials (Earley, 2016).

Chapter 14 of a book titled Waste Management in South Africa which emphasises that solid waste management (SWM) is a problem in developing countries like the Republic of South Africa (RSA). The authors discuss the drivers and current state of SWM in RSA, as well as alternative approaches to turning solid waste into a resource. The country's SWM strategy plays a role in moving waste up the waste hierarchy toward minimal generation, reuse, and recycling via extended producer responsibility and economic instruments. However, the absence of all-encompassing planning and management has jeopardized the success of these initiatives (Nyika, Onyari, Mishra, and Dinka, 2019) .

According to Godfrey & Oelofse (2017) SWM is underfunded and uncoordinated, placing South Africa two to three decades behind developed countries like Europe. Poor collection services, unlicensed SWM activities, illegal dumping, inadequate waste data management, and non-enforcement of existing waste regulations are among the most pressing issues. Recognising these challenges, the national and municipal governments are advocating for a shift toward waste minimization, reuse, and recycling through the National Waste Management Strategy (NMWS) (Dlamini, S., Simatele, M., & Kubanza, M. 2019). With increased awareness of these challenges, the emphasis will shift from landfill disposal to waste as a resource.

The European Commission (2018) emphasises that the large-scale adoption of sustainable business practices and waste management can mitigate global warming and climate change. They further stated that green manufacturing is an achievable goal that refers to methods of production that generate fewer waste products and therefore emit fewer environmental pollutants. The modification of processes to use fewer resources, for example, establishing strategies to use fewer litres of water in the manufacturing process or producing more resilient products with replaceable parts, are all examples that corresponds with the circular economy. The issue is that while some businesses are willing to adopt sustainable business practices, many are not doing enough to address these environmental challenges.

There are numerous obstacles in the waste management sector that are hampering businesses in South Africa from moving towards a cleaner, greener future (Averda, 2021). Sustainable business practices not only represent a shift in how resources are handled, but also require responsible waste management and post-production recycling (Shroff, 2016). According to Espinoza (2020), hazardous waste like toxic and flammable chemicals, and electronic waste that contains chemicals and substances like mercury, arsenic, cadmium and lead, have enormous impacts on the environment if they are not properly disposed of. The large volumes of hazardous waste released by businesses and industries on a daily basis have a profound effect on human health in addition to the air, soil, water, people and wildlife. Although regulations are in place to govern industries on how to properly dispose of toxic substances, environmental contamination is a growing problem globally. While much emphasis has been placed on the attempts to recycle as a means of reducing the harmful effects of waste on the ecosystem (Afrika, Oelofse, Strydom, Mvuma and John, 2018), according to National Environmental Management Act (1998), in instances where waste generation cannot be entirely prevented, it must be reduced, recycled, re-used or disposed of with caution.

1.3 Awareness of the problem

The Department of Forestry, Fisheries and the Environment (2021) states that businesses are obliged to implement, monitor and evaluate their waste management strategies as it contends that non-sustainable waste management practices intensify the loss of biodiversity, and contribute to climate change and global warming, which in turn contribute to rising sea levels, melting glaciers, changes in the carbon footprint, and result in freshwater scarcity, food security crises and more frequent and severe weather patterns. Emberson (2020) contends that non-sustainable manufacturing and waste management practices compromise the health of the general population by contaminating the air, drinking water, soil, crops, cattle, fish and other resources. Small and medium organisations that produce goods, according to Ndubisi, Zhai and Lai (2019), are also responsible for waste production, contaminated water, air pollution, and the depletion of a significant portion of the world's natural resources.

Consequently, sustainable waste management aims to diminish the volume of renewable resources consumed; re-use and recycle as many natural materials as possible; and significantly reduce wasteful activities for the benefit of the environment and future generations.

1.4 Purpose of the study

Manufacturing businesses have been identified by Ndubisi, Zhai, and Lai (2019) as significant contributors to waste generation, greenhouse gas emissions, water contamination, and the depletion of natural resources on Earth. In South Africa, the majority of municipal landfills are overflowing and there is widespread illegal dumping, indicating that a modest percentage of the country's annually generated waste is recycled (Afrika, Oelofse, Strydom, Mvuma and John, 2018; Department of Forestry, Fisheries and the Environment, 2018). Consequently, increasing pressure is being placed by governments and civil society on organisations to adopt sustainable waste management practices. The South African Department of Environment, Forestry and Fisheries (2020) emphasises that if proactive waste prevention measures are not implemented, the overall volume of waste generated is expected to rise in the coming years, which will require greater waste diversion initiatives to maintain the present level of landfill airspace usage, which has already been identified as unsustainable.

Given the dire consequences of poor waste management in South Africa, the purpose of this study is to identify the various types or groups of waste generated and the disposal methods employed by manufacturing organisations in the iLembe Municipal District of South Africa. In addition, this study explores the factors that influence waste management practices and identifies the barriers to sustainable waste management in the area.

1.5 Significance and objectives of the study

South Africa's Constitution (Act 108 of 1996) states that all individuals possess the right to an environment that is secure and healthy. This legislation is still in effect, and both statutory and non-statutory measures are required to protect and nurture the ecosystem for subsequent generations to come. As a result of the aforementioned, it is vital for organisations to adopt sustainable waste management practices, and it is anticipated that the results from the present investigation will partially contribute to the paucity of research on sustainable waste management practices in South Africa.

1.5.1 Objectives of the present study

This study aims to achieve the following clearly defined objectives:

- to establish the types of waste generated and the waste disposal measures employed by manufacturing organisations in the iLembe Municipal District;
- to investigate the strategies employed by manufacturing organisations in the iLembe municipal district to minimise waste;
- to identify the drivers of sustainable waste management practices amongst manufacturing organisations in the iLembe municipal district; and
- to explore the barriers hampering the implementation of sustainable waste management practices amongst manufacturing organisations in the iLembe municipal district.

Having discussed the waste management issues amongst manufacturing organisations in South Africa (amongst other things) and providing a clear description of the objectives and intent of the study, the subsequent sections provide an outline of the research approaches, preceding the division of chapters.

1.6 Research methodology

The research methodology encompasses the method used and its justification for use in data collection for the purpose of the investigation by expounding upon the research design, the population of interest, the measuring instrument, pilot testing, delimitation, reliability and validity, data analysis, and ethical considerations.

1.7 Division of chapters

The remaining chapters of this study are structured as follows:

Chapter Two critically discusses the relevant literature pertaining to, *inter alia*, global warming and the climate crisis and the implications thereof; business practices that exacerbate climate change thus contributing to global warming; and sustainable waste management practices, more especially amongst manufacturing organisations.

Chapter Three presents the methodology and its justification for use in gathering data for the research study by expounding upon the design of the research study, target population, gauging instrument, delimitation, validity and reliability, data analysis and ethical considerations.

Chapter Four presents, analyses and discusses the results that emerged from the empirical investigation.

Chapter Five summarises the main results that emerged from the examined literature as well as the empirical research, and, *inter alia*, recommends sustainable waste management practices that manufacturing companies in the iLembe Municipal District, KwaZulu-Natal, may adopt.

1.8 Conclusion

This chapter contextualised the waste management practices employed by manufacturing organisations within the Municipal District of iLembe in KwaZulu-Natal and presented an overview of the research. The research problem aims and objectives of the study, critical questions, in addition to the rationale for the study were highlighted and presented in this chapter. Chapter One also outlined the breakdown of the chapters of the study. Key concepts relevant to the study were defined to acquaint the reader with their significance. The subsequent chapter will review the literature related to waste management within the context of the manufacturing industry and will critically discuss the relevant literature pertaining to, *inter alia*, business practices that contribute to environmental degradation and sustainable business practices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter explores the various works of literature on waste management in the context of the manufacturing industry, and critically reviews the relevant literature pertaining to, *inter alia*, the deterioration of global warming attributed to climate change and the implications thereof, business practices that aggravate environmental degradation and climate change, and sustainable business practices.

2.2 The concept of waste

The development of urban areas, population growth and economic development are all major phenomena in modern civilisation that have not only improved human well-being but also increased resource consumption and waste generation (Chen, 2018). According to Chan (2020), waste can accumulate as a result of raw material deficiencies, which eventually end up being treated as scrap and rendered unusable. Moreover, while waste is an inevitable by-product of daily human activity, it is also a consequence of poor manufacturing processes and techniques, and the perpetual generation of waste further contributes to the depletion of vital resources. This is a severe issue, especially in countries that are emerging, such as South Africa, where the potential to manage such waste is constrained. Developing countries generate less waste per capita than countries with a higher level of development, but the ability to control landfills, re-use and recycle waste in an effective and sustainable manner can be extremely difficult (Ahsan, Alamgir, El-Sergany, Shams, Rowshon and Daud, 2014).

Waste is generated in many different forms, namely solid, liquid, gaseous, and is classified based on various sources such as waste materials from industry, agriculture, commerce, demolition and construction, mining and households. It consists of diverse substances with both hazardous and innocuous properties. The state of waste and what it entails is briefly explained below:

- **Solid waste:** refers to various categories of waste created by businesses, industries and domestic activities. This waste can be managed in a number of ways (Leblanc, 2020). Non-recyclable glass, paint residue, oil-contaminated waste, automobile tyres and electrical elements are all examples of industrial solid waste (US Waste and Recycling, 2018);
- **Liquid waste:** is a term used to describe any form of liquid waste classified as hazardous waste that can cause destruction if the pH-value is less than or equal to 2, or greater than or equal to 12.5 (Environmental Hazards Services, 2022). Several industries utilise sodium hydroxide, which has a high pH level, or hydrochloric acid, which has a low pH level, to clean or degrease metal parts. Solvents, cleaning fluids pesticides and certain by-products of manufacturing processes are highly flammable and are all examples of liquid waste (Kanagamani, Geethamani and Narmatha, 2020); and
- **Gaseous waste:** refers to emissions that contain harmful gases like dioxins, along with acid gases like sulphur oxides (SO_X) and nitrous oxides (NO_X) (Dmitrienko, Nyashina and Strizhak, 2018). Gases that are emitted when phosphate rocks are processed with acid, such as hydrogen chloride gases, are extremely acidic and severely corrosive. Zubair and Adrees (2019) emphasised that "volatile organic compounds are considered a common category of hazardous waste because they can be flammable, environmentally hazardous, or even carcinogenic. They also contain solvents with halogens like trichloroethylene and chloroform as well as nonhalogenated light solvents like methanol".

According to Chertow, Krones and Li (2020), as a probable secondary resource base, industrial waste that is not hazardous has not received the same amount of interest. Non-hazardous waste from industry forms a substantial waste flow by volume and consists of by-products generated by manufacturing processes that do not gravely endanger humans or the environment, such as specific waste from pulp and paper, foundry sand, or non-hazardous inorganic chemical wastes. Hazardous waste management has gained much scrutiny over the years and is critical for maintaining a healthy environment. It necessitates a high level of monitoring and management since humans interact with it daily. According to the World Health Organisation (2023), a simple action like burning hazardous waste has been discovered to release dioxins, which are amongst the most hazardous substances known. Excessive human exposure to high levels of dioxins for only a limited amount of time may result in skin lesions as well as altered liver function.

Prolonged exposure has been associated with immune system disorders, amongst other things. Hazardous waste is mainly generated by industries that manufacture chemicals, petroleum and coal products, pesticides, fertilizers, iron and steel, and waste treatment and disposal (The World Counts, 2022). According to the Department of Health, State Government of Victoria, Australia (2021), hazardous waste refers to any substance or item that may endanger public health or the environment and thus necessitates careful handling and treatment. According to the Environmental Hazards Services (2022), in order to determine how to handle produced waste appropriately, it is imperative that one can identify which categories hazardous waste belongs to. The identification of hazardous waste is based on the characteristics that it exhibits, as listed below:

- *Ignitability*: refers to waste that is combustible and that has the potential to start a fire. Examples of this include liquids that have points of contention lower than 60°C or 140°F, as well as non-liquids that have the potential to ignite under specific circumstances, and gases that have been compressed.
- *Corrosivity*: According to Environmental Hazards Services (2022), this is a term for “waste (typically acids and bases) that can rust and decompose and has the ability to melt through steel materials. Examples of these include aqueous wastes with an acidity level equal to or less than 2 pH (power of Hydrogen) or equal to or greater than 12.5 pH”.
- *Reactivity*: refers to waste that is precarious and hazardous under typical conditions. This includes waste that has the potential to detonate and emit greenhouse gases.
- *Toxicity*: is a term used to describe waste that, when ingested or absorbed, is fatal. Batteries containing lithium-sulphur and other substances that are toxic if consumed are examples of these.

The generation of waste remains a major source of concern internationally, whether it was intended for trade, used for recycling, to be repaired, or purified using a process other than the one that created the product (Chandler, Eighmy, Hjelmar, Kosson, Sawell, Vehlow and Sloot, 1997). Industrial production and distribution systems are being placed under pressure due to the intensifying demand for goods, which negatively affects both the ecosystem and society. As a result of increased pollution and environmental disasters caused by factory operations, academics and business professionals are being compelled to focus more on sustainable production methods and utilisation issues (Rajeev *et al*., 2017).

2.3 Legislation, policies and declarations governing waste management in South Africa

In South Africa, there are more than one legal definitions of waste (Oelofse and Godfrey, 2008). This not only complicates the classification of materials as waste, but also causes discord among industry and government officials dealing with waste management issues. This hinders the successful implementation of the waste hierarchy, which aims to divert waste away from landfills by encouraging sustainable waste recycling and re-use. According to the National Environmental Management Waste Act (NEMWA), waste refers to any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act (Government Gazette, 2014). The phrase waste management also refers to the regulations and systems that govern waste management. This includes disposal, recycling, and re-use, among other things. While there are different definitions of what is waste, for the purpose of this study an all-encompassing definition of waste was adopted to promote environmental protection through the application of the precautionary principles. This study considers all types of waste generated through manufacturing processes.

According to Jeyabharathi, Thava, Idas, and Sangeetha (2021), when waste generation increases in volume, it results in challenges associated with finding new disposal sites; proper waste disposal techniques, collection, and management methods are required. Numerous regulations have been enacted in response to concerns about the need to efficiently manage waste flow and its acceleration. Moreover, the United Nations Environment Programme (2022) stated that “one of the greatest global challenges is to integrate environmental sustainability with economic growth and welfare by decoupling environmental degradation from economic growth and doing more with less”. In 2015, the 2030 Agenda for Sustainable Development was established with the objective of achieving the Sustainable Development Goals (SDGs) set forth by all UN Member States (United Nations, 2015). The Sustainable Development Goals (SDGs) comprise seventeen objectives that are centered around three main objectives: eradicating poverty; safeguarding the environment and planet; and enhancing the social and economic well-being of the global population. Although all the SDGs are important, the National Waste Management Strategy (2020) is unambiguously reactive to Sustainable Development Goal 12 on Responsible Consumption and Production (Department of Environment, Forestry and Fisheries, 2021). SDG 12 enacts waste-reduction initiatives, promoting recycling and re-use. It also enhances public awareness initiatives and encourages sustainable production and consumption patterns (United Nations Environment Programme, 2022). The failure to achieve sustainable development goals could pose an adverse effect on the environment and exacerbate issues such as hunger and poverty. Furthermore, there may be negative effects on well-being and economic growth.

According to Pandey (2019), prior restrictions prohibited potentially hazardous waste in liquid form with calorific values greater than 20 megajoules per kilogram (MJ/kg) from being disposed of in landfills. As specified in the Waste Act of South Africa, the prohibitions were aimed at accomplishing secure landfill activities, waste recycling and environmental preservation (waste hierarchy). An example of a regulation designed to protect the environment is the KwaZulu-Natal Policy for the effective disposition of Pharmaceutical waste (Department of Health, KwaZulu-Natal, 2016):

- all disposal and subsequent destruction of chemical or pharmaceutical waste must be in compliance with applicable provincial laws and local municipal ordinances. Any individual who is accountable for the disposal of pharmaceutical waste may be requested to demonstrate that the method used was constitutional;

- if the Director General of Health provided legal authorization, the individual in question must present a certificate of destruction and, in the instance of a South African Police Services (SAPC) officer, a reference number for the case. This documentation must be retained for a period of 5 years;
- all forms of pharmaceutical medication and prescribed drugs must be discarded of in an acceptable manner that does not encourage recovery or accessibility; and
- all quantities destroyed must be declared by the individual accountable for the destruction. On the day of destruction, an appropriate form or register must be completed, with reference to the obliteration certificate or case number.

The objectives of the South African National Environmental Management Waste Act no. 59 of 2008 are as follows:

- "to reform the law regulating waste management to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation, and for securing ecologically sustainable development;
- to provide for institutional arrangements and planning matters;
- to provide for national norms and standards for regulating the management of waste by all spheres of government;
- to provide for specific waste management measures;
- to provide for the licensing and control of waste management activities;
- to provide for the remediation of contaminated land; and
- to provide for compliance and enforcement".

Policies aim to move waste up the waste management hierarchy toward re-use, recycling and reduction (Godfrey and Oelofse, 2017). Section 18 of the National Environmental Waste Act (2008) emphasizes the need for manufacturing organisations to accept accountability for where their goods end up. According to mandatory guidelines pertaining to the extended producer responsibility (EPR) framework, manufacturers are accountable for the goods and packaging they produce throughout the duration of the product's existence. The National Environmental Waste Act 18 (2008) requires producers to implement the Extended Producer Responsibility measures listed below:

(a) “establish and implement an extended producer responsibility scheme or join another scheme;

(b) be fully accountable for the performance of the extended producer responsibility scheme;

(c) finance the extended producer responsibility scheme;

(d) develop and maintain a system to collect the extended producer responsibility fees;

(e) conduct internal audits and make these audit reports available to the Department upon request;

(f) make the internal biannual audit reports available to the external auditor;

(g) appoint an independent financial auditor for each year;

(i) audit the financial records;

(ii) include the internal bi-annual audit results in the annual audit report; and

(iii) submit this audit report to the Department within 30 days after completion of the audit report;

(h) develop and maintain a register of its members;

(i) develop and manage the data collection system;

(j) collate and submit the aggregated data to the South African Waste Information System as required in Regulation 8 of these Regulations;

(k) conduct a life-cycle assessment in relation to the product, in accordance with the relevant South African Bureau of Standards or International Organisation for Standardization standards (14040 and 14044);

(l) through the life-cycle assessment factor changes in the design, composition or production process of a product that will result in:

(i) reduction in the consumption of natural resources;

(ii) design of more environmentally friendly products;

(iii) waste prevention;

(iv) reduction of the volume of the resulting post-consumer waste stream; and

(v) reduction of toxicity of the resulting post-consumer waste stream;

(m) tender and contract for the collection, recycling and recovery of waste;
(n) document collection, sorting, recycling and recovery of waste;
(o) control all services that have been awarded to service providers in particular, these services include the fulfilment of collection and recycling by waste management companies;
(p) establish new infrastructure to promote the effective implementation of the extended producer responsibility scheme;
(q) utilise existing infrastructure for waste management where feasible;
(r) utilise new and existing infrastructure across schemes and for multiple waste streams in a collaborative manner where feasible;
(s) promote small businesses;
(t) develop a broad-based black economic empowerment (BBBEE) transformation charter within the waste sector of the products identified in the Notice published in terms of section;
(u) implement transformation within all levels of the value-chain, including transformation targets with BBBEE charter time-frames;
(v) develop and establish secondary markets for recyclable materials;
(w) implement mandatory take back of all their products at the end of its life; and
(x) implement environmental labels and declaration for the identified products in accordance with SANS 14021, SANS 14024 and SANS 14024."

The ERP scheme applies to a wide range of products, including various light bulbs, solar panels, single-use items, vinyl-based materials, metallic items, glass packaging, automobile lights, toys, TV and computer screens, and an array of domestic appliances, electronic equipment packaging, plastic, paper and lighting (Department of Forestry, Fisheries and the Environment, 2021).

The Environmental Protection Act (EPA) of 1990 obliges local government agencies to collect waste responsibly and addresses issues related to waste on land. It illustrates all aspects of waste management. Businesses have a responsibility to dispose of waste in a legal manner safely. Under Section 34 of the Environmental Protection Act of 1990, persons who handle waste have an obligation to exercise caution. The obligation of caution should be exercised by anyone who generates, transports, stores, imports, treats or discards controlled waste, or as an agent who exercises authority over such waste and emphasizes the significance of effective waste management by both waste producers and the waste industry (Creamer Media, 2019). According to Kate Stubbs (2020), the business development and marketing director of Interwaste stated that since more waste streams are subject to this ban every year, it is imperative that organisations support the regulation and make the necessary efforts to comply with it. On August 23, municipal laws prohibited the disposal of any liquid waste in landfills, signalling a significant shift in South African waste regulations. The banning of liquid waste from landfills that occurred in August 2019 advocates for alternative and more sustainable waste management systems to be implemented in South Africa (Creamer Media, 2019).

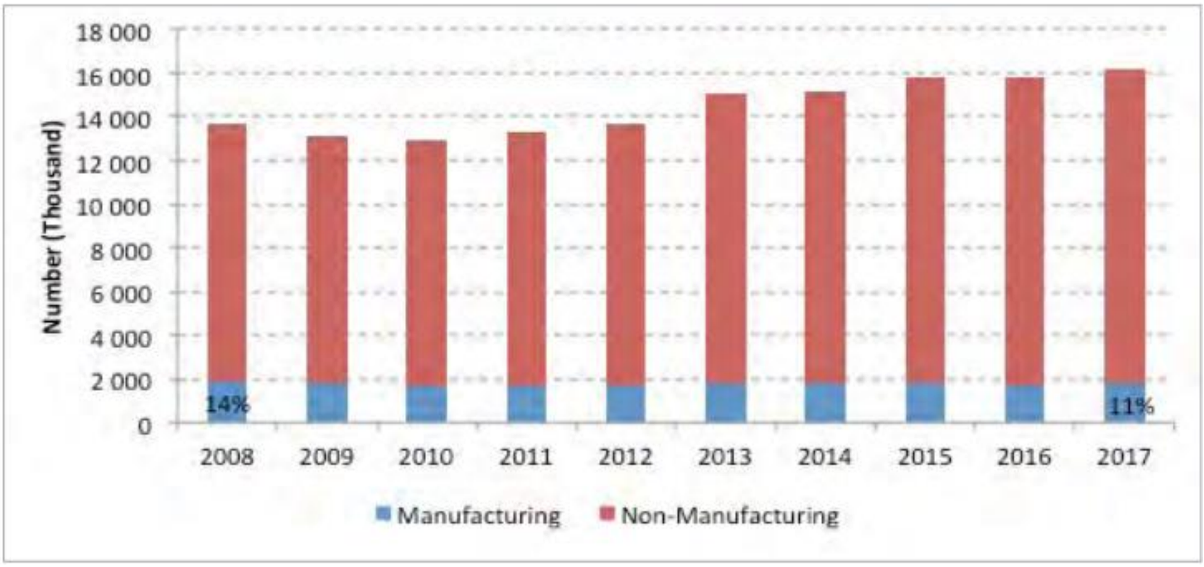
SADC (2019) stated that "in line with the Paris Agreement, sustainable management of the environment for socio-economic development in the region is assured through the implementation of programmes on Climate Change, biodiversity, waste management, sustainable development, the SADC Regional Green Growth Strategy and Action Plan and the Sub-Regional Strategy at Combating Desertification". According to SADC (2012), the increasing frequency of waste generation; the inadequate ability to manage the large volumes of waste; the substantial expenses associated with waste management a shortage of appropriate disposal technology; the scarcity of human resources and machinery; and inadequate enforcement are all understood by SADC as significant contributors to the region's poor waste management. As a consequence of these issues, most SADC countries have frequent unregulated disposal of domestic and industrial waste (SADC 2012). In an effort to tackle these obstacles, the countries that make up SADC have pledged to continue advancing efficient conservation of the environment through pollution control, waste management and education on the environment. This includes education and training on pollution and waste caused by urbanisation and industrialisation, in addition to the implementation of pollution prevention efforts and projects for industrial and residential waste management (SADC 2001).

2.4 The importance of South Africa's manufacturing sector

The Department of Trade and Industry's Director General claims that the South African government has acknowledged the importance of the manufacturing industry in achieving the country's goals for economic development (South African Government News Agency, 2018). Hayes (2022) agrees and states that the capacity to produce goods has a significant impact on a nation's wealth and development. Manufacturing is a vital aspect of industry in South Africa, not only to supply goods for the marketplace, but also to drive the economy.

Unemployment is one of South Africa's most pressing issues. The unemployment rate amongst young South Africans aged 15 to 34 years old was 38.2% in the first quarter of 2018, which suggests that at least one in every three young people in the job market was unemployed, according to the Department of Trade and Industry (2019).

Figure 2.1: The Manufacturing industry's share of total employment in South Africa, 2008-2017



Source: Statistics South Africa, QLFS and own calculations (2017)

Between the period 2009–2017, the manufacturing industry represented approximately 11 per cent of all workers in South Africa, which reduced from 14 per cent in the year 2008, as demonstrated in Figure 2.1. Moreover, although the general level of employment in the economy of South Africa has been rising since 2011, the manufacturing sector's employment share remained consistent at roughly 11 per cent for the eight years leading up to 2017 (The Department of Trade and Industry, 2019).

In the fourth quarter of 2021, nearly 1316 million people in South Africa were employed by the manufacturing industry of South Africa. The sector consisted of the fourth highest number of employees, following the Community and social services sector, the Trade sector and the Finance sector (Galal, 2022). The vast majority of the technical workforce in the manufacturing industry is comprised of artisans, the majority of whom belong to the basic metals sector. Additionally, approximately 24.4 per cent of South African women work in the manufacturing sector in craft and trade positions.

According to Statistics South Africa (2022), in 2020, despite the Coronavirus pandemic that had disrupted the economy, thirteen per cent of the nation's GDP and nearly fifty per cent of its export revenue were generated by the manufacturing sector in South Africa. Basic iron and steel products generated R65.9 billion, that is 9.5 per cent of the total that year, while food production generated R60.7 billion, that is 7 per cent. Nonetheless, the production of automobiles, valued at nearly R165 billion (23.7 per cent), emerged as the mainstay. In 2021, South Africa's economic value for production as a percentage of gross domestic product was estimated at 11.7 per cent (Trading Economics, 2022) and in 2018, the sector contributed approximately 14 per cent to the gross domestic product (Statistics South Africa, 2018). The disadvantages of this are that whilst the manufacturing sector contributes significantly to the GDP, it simultaneously contributes to pollution and hence environmental degradation.

2.4.1 Waste management practices and procedures in South Africa

The term "waste management" describes the guidelines and processes which regulate the management of waste. This encompasses disposal, recycling and re-use (Jee and Shagufta 2010). Jeyabharathi, Thava, Idas and Sangeetha (2021) state that “when waste generation rate increases it leads to issues of finding new disposal places, proper waste disposal, collection and management methods are needed.

Management of waste includes proper collection, segregation and recycling of discarded wastes in an environment friendly manner". Waste management is an approach that encompasses necessary waste management activities, including waste collection, transportation and disposal. Its primary goal is to reduce waste from unusable materials while avoiding potential environmental and health risks (Compactor Management Company, 2022). According to Godfrey, Tawfic Ahmed, Giday Gebremedhin, Katima, Oelofse, Osibanjo, Henning Richter and Yonli (2019), the economic benefit that waste can contribute to the local economy is being overlooked as a result of the manufacturing sector's current waste management practices. Since waste is discarded in landfills and dumpsites, the African economy forfeits a vast number of valuable resources such as metallic substances, minerals, fibre from paper, waste from plastics, and useful polymers from organic waste. According to Stubbs (2020), 90 per cent of the 108 million tons of waste that South Africa generates annually continues to be deposited in landfills and only 10 per cent is recycled. Therefore, the management of waste in South Africa is a huge concern necessitating major consideration. Taking cognisance of these statistics, South Africa's landfills are fast approaching full capacity. These statistics reflect an urgent focus on diversion from landfill, finding alternative uses and revenue streams, and a commitment to adhering to legislative frameworks.

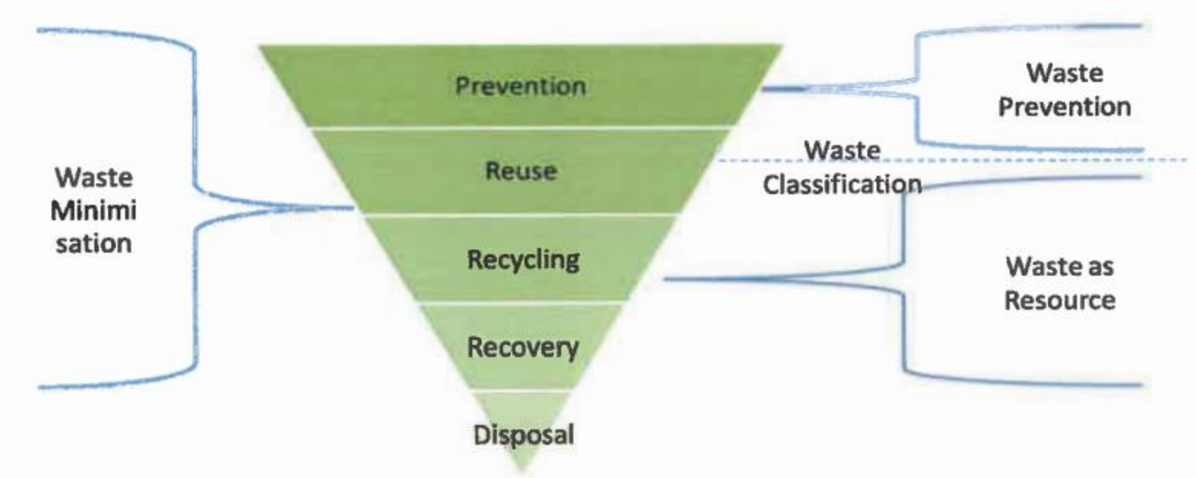
According to Linnenkoper (2019), the waste management industry in South Africa was worth around ZAR 25 billion (EUR 1.4 billion) in 2019. The country recycles more than 70% of used metal beverage cans, whereas glass and plastic packaging are recycled at 42% and 30%, respectively. South Africa transmits approximately 95 million tons of waste to its 826 landfill sites, with under 40 per cent of the materials being recycled. Furthermore, the country generates more than 65 million tons of hazardous waste, only six per cent of which is recycled. According to Creamer Media (2019), during 2017, "regulations state that hazardous liquid waste with high CV exceeding 20 MJ/kg – such as refinery waste, chemical processed paint waste, hydrocarbon contaminated liquids, sludges and chemical solvents – ought to have been progressively banned from landfills". However, in August 2019, a significant modification transpired in South African waste laws when local legislation prohibited the disposal of all liquid waste in landfills. Landfills are overflowing, unlawful dumping is occurring, and a considerable quantity of natural resources used is being squandered (Afrika, Oelofse, Strydom, Mvuma and John, 2018; Department of Forestry, Fisheries and the Environment, 2018). As stated by Ndubisi, Zhai and Lai (2019), manufacturing industries are major emitters of toxic Greenhouse gases, and they also account for the depletion of a significant portion of the world's resources, whilst consuming approximately 61 per cent more energy than non-manufacturing industries. Although the industry promotes economic expansion, there are costs associated with this growth, particularly for the welfare of society and environmental wellbeing.

The following two diagrams illustrate the waste management hierarchy of the Department of Environment, Forestry and Fisheries in South Africa. The hierarchy concentrates on waste minimization, waste prevention and waste as a resource, which are three of the main tenets of South Africa's National Waste Management Strategy (2020). The waste management hierarchy indicates that not all materials and waste streams can be managed by a single waste management strategy in every scenario. The hierarchy prioritizes the environment when ranking the various management philosophies. In the hierarchy, reduction, re-use, recycling and recovery are ranked as crucial elements of sustainable materials management (Environmental Assurance, 2020).

Figure 2. 2: Waste Management Hierarchy of the Department of Environment, Forestry and Fisheries (DEFF, 2020)

Waste Management Hierarchy (DEFF, 2020)

Figure 2. 3: National Waste Management Strategy of South Africa (2020)



Waste management hierarchy. Integrated Waste Management Plan version 2 (2021-2026)

- Waste minimisation opportunities: According to the hierarchy above, recycling needs to be more actively addressed, specifically in terms of waste minimization and promoting waste-to-energy and composting as alternative solutions to discarding organic waste in landfills. Waste-pickers also help reduce waste since they perform the vital first step in gathering re-usable and recyclable materials out of the waste stream and beginning their re-valuation. A segment of the value-chain involves reducing production expenses by minimizing waste or substituting less expensive recovered and recycled materials for virgin ones, or converting waste into capital by means of recycling and re-use.
- The prevention of waste is given priority in the waste management hierarchy as it focusses on product design and packaging, as well as cleaner production methods to prevent and minimise the generation of waste before products and resources are thrown away or become waste. Manufacturers can eliminate the "take-make-use-dispose" linear pattern by adopting circularity during the design phase, but the environmental impacts associated with manufacturing are still decided upon during this phase.
- The application of waste as a resource emphasizes the development of a secondary resource economy through the recovery and recycling of materials and energy from waste. The circular economy has the capacity to substantially decrease the expenditure of raw material across the value-chain and production processes; establish new business opportunities; keep the industry competitive over a prolonged period of time; and shift it toward sustainability. A critical component of waste management hierarchy practices involves giving precedence to recycling waste for the re-use and recovery of materials over the recovery of energy from waste.

There are numerous benefits of properly applying the waste hierarchy. It can help to reduce emissions of greenhouse gases, pollution, consumption of energy, preserve resources, create employment opportunities, and promote sustainable technological advancement (DEA, 2017:27). According to Creamer (2019), effective waste management techniques must contribute to sustainability. Eco-friendly waste management systems prioritise waste management and prevention, encourage energy recycling, and promote the shift from an economic model that is linear to a circular economy (Pulselli and Zuo, 2022). The authors further contend that the scope of waste management must encompass the following aspects:

- Circular economy
- Minimisation of waste
- Recycling, re-use and re-manufacturing
- Generation and characterisation
- Relevance to carbon peak and carbon neutrality
- Treatment solutions (mechanical, biological, chemical, thermal, other)
- Conveyance and transference
- Waste disposal in its final stages
- Environmental and Life-Cycle Assessments
- Systems for accounting and economic analysis
- Governance, policy and regulations
- Education, social and engagement initiatives
- Sustainable development and system-based approach

Poor waste management affects the Triple bottom-line is a social, economic and environmental issue that South Africa and other African countries must address. The quantity of toxic waste has increased significantly in accordance with rising populations and immense industrial development. Thor Chemicals, a United Kingdom (UK) controlled organisation, has been operating in Cato Ridge, South Africa, since the 1970s, when environmental regulations were far laxer than in the UK. The primary operations of Thor Chemicals were to manufacture a paint additive containing mercury that was subsequently banned. They also ran a trade-back program through which they claimed to recover mercury-rich waste from other companies. However, a South African waste management company known as Ground Work interpreted their true intention as illegal dumping. In 2020, tests were conducted on former employees and the results revealed that they were exposed to elevated levels of mercury. Nearly half of the 104 employees at Thor had since passed away. A former employee at Thor Chemicals, Mr. Khanyile, provided details of the perilous working conditions he encountered while working at Thor Chemicals with mercury effluents. South Africa has a severe waste management problem that needs immediate attention as billions of tons of hazardous waste are generated annually. However, just a tiny fraction of this waste is appropriately treated and disposed of. According to Betti, de Boer and Giraud (2022), the cornerstone of eco-sustainability is the commitment to using energy-efficient methods, water conservation, reducing carbon emissions, and proper waste management.

Some of the biggest drivers of waste are urbanisation, population growth, a lack of compliance and general behaviour towards managing waste effectively (Infrastructure News, 2022). Correspondingly, due to the rising volumes of processed commodities, there is an even larger need to regulate waste output in South Africa. The resurgence of recycled resources into local value-chains, which includes fibre, metals, polymers and nutrients, inter alia, has the potential to boost the manufacturing industry's economy while reducing financial strain on imports. Government, business, and civil society must act swiftly to regulate waste by capitalising on the benefits that waste presents as a renewable resource (Godfrey, Ahmed, Gebremedhin, Katima, Oelofse, Osibanjo, Richter and Yonli, 2019).

According to Abdel-Shafy and Mansour (2018), some of the most significant challenges are poor collection and disposal services; unmonitored waste management practices; unconstitutional dumping of waste; inadequate management of information pertaining to waste; and a lack of enforcement of the applicable waste regulations. Taking these concerns into account, the National Waste Management Strategy (NMWS) encourages waste reduction, re-use and recycling (Dlamini *et al*., 2019). Furthermore, as individuals and businesses grow conscious of these challenges, the transition from disposal at landfills to viewing waste as a valuable resource will be emphasized.

According to the results of a survey conducted during November 2018 amongst manufacturing organisations located at the Isithebe Industrial Estate in KwaDukuza, KwaZulu-Natal, the main waste produced was plastics, metal and wood (iLembe Chamber of Commerce and Tourism, 2019). The study also found that in excess of 360 tons of wood waste was generated each month. While some of the waste is provided to the residential neighbourhood, the majority of it is dumped in landfills. There is also a great opportunity for improvement in terms of water harvesting, as many organisations lack water harvesting tanks and machinery. According to one of the respondents, their organisation used approximately 6 million litres of water each month, 60 per cent of which is returned to the malt-producing process and 40 per cent (2.4 million litres) is lost /wasted (iLembe Chamber of Commerce and Tourism, 2019).

In 1996, the International Organisation for Standardisation developed the ISO 14001 Environmental Management System (EMS) standard as a structure for the management of environmental issues (Yin and Schmeidler, 2008). The International Standards Organisation (ISO) 14001 assists organisations in quantifying, monitoring and mitigating their environmental impact. By monitoring the use of energy, waste, and renewable resources, companies can enhance the credibility of their brand, increase their chances of attracting new customers, and find ways to reduce costs (QMS International, 2022). It requires that an organisation be certified by a third-party independent auditing body, thus ensuring that the EMS conforms to the guidelines stated in the ISO 14001 standard (Darnall, 2006). The ISO 14001 standard requires organisations to establish the following (Dwarika, 2015):

- an environmental policy;
- set objectives;
- set targets;
- develop and implementation plan;
- monitor and measure system’s effectiveness;
- correct problems; and
- conduct reviews for continuous improvement.

Dwarika (2015) stated that "the primary purpose of this standard is to progressively manage environmental impacts while ensuring that objectives and targets are met. It assists in inspecting the environmental operations and performance more especially when frequently revised to continuous improvement”. In order to promote continuous improvement, ISO 14001 mandates that the Environment Management System be audited, and that top management regularly evaluate the suitability and efficacy of the EMS (Morrow and Rondinelli, 2002).

According to Gourley (2020), the waste disposal process has a significant human and environmental impact as it wastes human labor and risks exposing workers and communities to hazardous waste materials. While a number of waste management techniques are implemented across the African continent, incineration is the most preferred technique because it can quickly reduce waste by as much as 90 percent and use the heat it generates for boilers and to produce energy (Ansari, Ehrampoush, Farzadkia and Ahmadi, 2019). Ansari *et al*. (2019) and Omwoma, Lalah and Kueppers (2017) state that the residuals and hazardous emissions released by burning these types of waste outside are harmful to the environment.

According to preliminary research, diverting waste from landfills and re-using, recycling and recovering it could strengthen the African economy by an additional US$8 billion per year, whilst also creating significant opportunities for socio-economic development. Moreover, this would address the negative environmental and human health consequences of inadequate waste disposal methods (Oelofse, Nahman and Godfrey, 2018). As a result, waste represents a significant opportunity for the continent if it can be effectively collected and channelled towards re-use, recycling and recovery. The following are some examples of waste management methods:

- **Preventing or minimising the generation of waste:** Frequent use of novel or superfluous products leads to uncontrolled waste generation. Utilising second-hand goods or using existing ones carefully is required due to the growing population as there is a risk that toxic wastes will harm both people and the environment;
- **Recycling:** refers to the conversion of wastes into items that belong to a corresponding category through manufacturing processing;
- **Incineration:** refers to the burning of wastes, aimed at transforming them into raw materials, with the extracted heat being conserved for future energy development. Common by-products include various gases and inert ash;
- **Composting:** refers to the disintegration of organic substances by micro-organisms caused by the accumulation of waste in an excavation for a prolonged period of time. The biological refurbishing vastly improves soil

fertility, and the nutrient-dense compost is frequently used as plant fertilizer, but the process is laborious and requires a considerable area of land;

- **Sanitary Landfill:** refers to a method of discarding waste on land that does not harm the ecosystem or public health. A protective lining is used to prepare the base, which keeps hazardous chemicals out of the water zone and serves as an intermediate layer between the waste and the groundwater. Subsequent to the compacting the layers of waste, an additional layer of sand is applied;
- **Disposal into the Ocean/Sea:** According to the Compactor Management Company (2022), “wastes generally of a radioactive nature are dumped in the oceans far from active human habitats. However, environmentalists are challenging this method, as such an action is believed to spell doom for aquatic life by depriving the ocean waters of their inherent nutrients”; and
- **Plasma Gasification**: As defined by the Compactor Management Company (2022), “plasma gasification is an environment-friendly waste disposal method. It is used to convert commodity recyclables extracted from municipal solid waste in the landfill into energy. The carbon-based materials are exposed to high temperatures and transformed to syngas, a gas that can either be directly combusted or further refined into chemicals and higher-grade fuels”.

Numerous untapped waste management strategies can be used in iLembe, where much more has to be done to reduce natural resource usage and mitigate climate change. The iLembe Chamber of Commerce and Tourism (2019) reported that in the Isithebe Industrial Estate, the local municipality played a limited role in the collection of waste as 29 per cent of the businesses use their own means of removing their waste. This is a potential avenue that informal operators can use through being sponsored by companies as waste collectors or waste-pickers (Profile: iLembe District Municipality, 2020).

According to iLembe Chamber of Commerce and Tourism (2019), the Isithebe Industrial Estate generates a variety of main and secondary waste products that may be used as input material in other businesses, or recycled and re-used. However, from the list of companies that produce secondary waste streams, only two were interested in engaging with informal waste collection strategies and four of them believed that existing or other third-party recyclers could benefit from their waste outputs. This could be a result of security reasons or types of waste, that is, hazardous.

2.5 Greenhouse Gas (GHG) Emissions

Means and Lallanilla (2021) stated that "the phenomenon of global warming and climate change is caused by an increase in greenhouse gases in the earth's atmosphere". To achieve greater sustainability, the conventional corporate model of the manufacturing industry must be completely restructured, with a focus on reducing waste generation and greenhouse gas emissions through carbon-free emissions and recycling techniques (Beier, Niehoff, Ziems and Xue. 2017). The Inter-governmental Panel on Climate Change (IPCC) (2020) stated in their 'special reports' that over the past 150 years, industrial activities have elevated the amount of carbon dioxide in the atmosphere from 280 parts per million to 416 parts per million, and there is a greater than 95 per cent chance that human-generated greenhouse gases, such as methane, carbon dioxide and nitrous oxide, amongst other things, have contributed to much of the observed increase in the earth's temperature. The mitigation of climate change by reducing greenhouse gas (GHG) emissions has become a critical strategy. Significant and sustained reductions in pollution and other greenhouse gas emissions must occur in order to limit climate change and environmental degradation. In particular, international initiatives aim to achieve net-zero emissions of carbon dioxide (CO_2) worldwide by 2050 (IPCC, 2021).

The contribution of global carbon emissions from African countries are relatively miniscule when compared to that of other countries. However, South Africa, Morocco, Algeria, Nigeria, Libya and Egypt account for more than 80% of Africa's emissions (Ayompe, Davis and Egoh, 2020). Saleh (2022) stated that "in 2020, South Africa was ranked the most polluting country in Africa. During that year, it emitted nearly 452 million metric tons of carbon dioxide (CO_2) and Egypt ranked second by approximately 213 million metric tons of CO_2 emissions". Despite its major economic contribution, the manufacturing industry is also a significant emitter of greenhouse gases (GHG), which contributes to climate change. Tongwane and Moeletsi (2021) stated that "road transport produces over 50 million tons of carbon dioxide equivalent (Mt CO_2e) in

South Africa. Motor vehicles are the largest contributor with 45.74 per cent of the road emissions and their contribution is growing daily. Their emissions are currently growing at over 3 per cent per year. Heavy-duty vehicles are the second largest source of emissions. If unmitigated, GHG emissions from road transport are projected to be more than double by 2050". According to the most recent IPCC assessment, negative emissions technologies (NETs) are crucial in limiting the rise in global temperature to two degrees Celsius at reasonable cost. Nevertheless, no reliable, transparent or systematic evaluation of the literature exists during this period for various greenhouse gas removal alternatives (Fuss, Lamb, Callaghan, Hilaire, Creutzig, Amann, Beringer, Garcia, Hartmann, Khanna, Luderer, Nemet, Rogelj, Smith, Vicente, Wilcox, Dominguez and Minx, 2018).

According to the Intergovernmental Panel on Climate Change (IPCC) (2022), also known as the United Nations body for assessing the science related to climate change, all facets of society would need to undergo swift, profound and uncommon changes if global warming were to be limited to 1.5°C. Moreover, maintaining a more environmentally conscious and sustainable society may be closely associated with actively keeping global warming at 1.5°C rather than 2°C, which has distinct advantages for both people and the environment. According to the report, regulating the global temperature rise to 1.5°C would require extremely fast and broad changes in industry, energy and land, amongst others. By 2030, the global net carbon emissions are required to be reduced by approximately 45 per cent from 2010 levels, to ultimately reach "net zero" around 2050. This implies that any additional emissions must be compensated for by eliminating CO_2 from the earth's atmosphere (IPCC, 2022).

National Geographic (2019) stated that "greenhouse gases have far-ranging environmental and health effects that causes climate change by trapping heat, and they also contribute to respiratory disease from smog and air pollution. Extreme weather, food supply disruptions, and increased wildfires are other effects of climate change caused by greenhouse gases". Carbon dioxide, nitrous oxide, methane and various synthetic chemicals are substantial GHGs, and their origins are discussed below (US EPA, 2020):

- **carbon dioxide** is widely considered to be the most significant human-induced greenhouse gas as it emerges naturally as an essential component of the earth's overall carbon cycle. However, human activities have exacerbated atmospheric pressure through the combustible process of fossil fuels and other sources of air pollution;
- **methane** is generated by an array of processes, such as digestion in livestock and agriculture; the mining of coal; generation and distribution of natural gas; the disintegration of landfill waste; and the activities of human beings;
- **nitrous oxide** is emitted into the atmosphere during industrial, agricultural and solid waste combustion processes, in addition to fossil fuel combustion;
- **various synthetic chemicals**, such as chemical solvents, peroxides and sulphur compounds, amongst other synthetic gases, are released into the atmosphere as a consequence of commercial, industrial or household uses; and
- **many other gases** have a reputation for retaining heat in the atmosphere. Water vapor, which naturally exists as a component of the global water cycle, and ozone, which naturally occurs in the stratosphere and is primarily found in the troposphere as a consequence of human activity, are two prominent examples.

De-carbonization levers across the manufacturing sector would include a significant shift to green hydrogen and biomass beyond 2030 in order to substitute natural gas as an energy source and feedstock in several chemical and industrial processes. For example, in South Africa, the manufacture of virgin steel via hydrogen direct reduced iron could reach 60 per cent of production by 2050, saving around 23 MtCO2 e, while all other steel production could switch to the biofuel process, leading to an 81 per cent reduction of GHG emissions in that industry by 2050 (Ford, 2021). As an additional example, according to Alexander and Tonachel (2016), electric vehicle technologies are still uncommon and not as widely adopted in South Africa as they are in other countries. However, despite this, their market is anticipated to expand gradually and their ability to reduce greenhouse gas emissions will improve. South Africa's production of electric vehicles is predicted to cut emissions by a fifth when compared to baseline levels from 2020 to 2050. In contrast, this amounts to merely one-third of what their counterparts with internal combustion engines have contributed, as the latter have consistently raised their fuel efficiency rates. However, their annual percentage of reduced emissions will be higher than that of vehicles with internal combustion engines by 2050 (Tongwane and Moeletsi, 2021).

According to Statistics South Africa (2018), the manufacturing industry is accountable for a significant portion of global resource utilisation and waste generation, whilst consuming approximately 61 per cent more energy than non-manufacturing industries. They are also major emitters of greenhouse gases, which contributes to climate change (Nova, 2018). Greenhouse gas emissions result in global warming and climate change, causing, *amongst other things,* severe weather patterns, rising sea levels, melting glaciers, and freshwater scarcity (Department of Forestry, Fisheries and the Environment, 2021). In addition, research has revealed an explicit correlation between pollution and diseases such as heart disease, cholera, lung cancer and hepatitis.
Badjatya, Akca, Alvarez, Chang and Kawashima (2022) stated that the cement production industry comprises one of the largest sources of carbon dioxide (CO_2) emitted by human beings, and it is a complicated sector to decrease its carbon footprint, which serves as a major barrier to attaining global targets to reduce greenhouse gas emissions. The authors further claimed that in response to this issue, a study was conducted to identify the critical phases in a sustainable method of converting the abundant magnesium (Mg2+) ions in seawater into carbon-neutral cement. If the electricity used to power the electrochemical reactors employed to harvest Mg2+ is obtained from carbon-free sources and the CO_2 consumed by the process is obtained from the atmosphere or ocean, this process has the potential to transform one of the world's most carbon-intensive industries into one of the largest carbon sinks on earth.

A Lean, Energy and Climate Toolkit was developed by the US Environmental Protection Agency (EPA) to aid organisations in enhancing operational efficiency through lean manufacturing practices, all while decreasing their energy and

GHG emissions. The following are some examples of energy reduction activities (United States Environmental Protection Agency, 2011):

- identifying and implementing recommendations made by staff members to minimise waste and conserve energy through rapid improvements in production processes;
- incorporating energy-saving techniques into routine maintenance tasks to ensure the efficient and effective functioning of machinery and operations;
- identifying and replacing inefficient and oversized machinery with smaller, customized devices that meet the specifications of manufacturing organisations;
- modifying or remodelling manufacturing facilities to optimise the flow of production whilst minimising the use of energy and its associated effects; and
- encouraging energy conservation through the use of visual indicators and standard operating procedures. Additionally, ensuring that energy efficiency is easy to maintain and that it contributes to the advantages of lean and energy performance.

The journey to net zero will create opportunities and challenges for companies across many industries. Demand for sustainable materials and ingredients may outstrip supply. Companies must be invasive when it comes to sustainability. They must go beyond protecting their core business during this transition so that new value pools can be created, and non-sustainable ones diminished (Hostetter, Klei, Winkler and Wolf, 2022).

2.5.1 The effects of climate change

Climate change has resulted in the emergence of global warming. Although these terminologies are occasionally used interchangeably, they are not the same (Benjamin, Por and Budescu, 2016). Global warming is merely a single aspect of climate change, and it refers to the rise of the earth's atmospheric temperature. Although global warming has historically been on the rise, the use of fossil fuels has caused it to accelerate in the last century. The amount of fossil fuels burned has risen in conjunction with the human population. The "greenhouse effect" is a byproduct of burning fossil fuels, which include coal, oil and natural gas (National Geographic, 2022). Amongst the gases that contribute to the emission of greenhouse gases are those that absorb infrared radiation and retain warmth in the atmosphere (National Geographic, 2022). Climate change refers to a shift in global weather patterns, such as temperature and rainfall. The Arctic and Antarctica and Greenland are melting at a faster rate than usual. The blooming seasons of plants and flowers are evolving. These include intensifying temperatures and changes in the amount of rainfall, in addition to the increasing sea levels and receding mountain glaciers (National Aeronautics and Space Administration (NASA), 2022). The World Health Organisation (WHO) (2023) stated that “approximately 250 000 additional deaths per year between 2030 and 2050 from extreme heat, natural disasters and changing patterns of infections, mostly in people at risk (people living in coastal regions or mega cities, children, the elderly, people with multiple and/or severe comorbidities, and finally, people living in regions with weak healthcare infrastructures)”. Tollefson (2022) claims that many people are already feeling the effects of climate change, that fluctuate according to geographical area and are affected by variables such as geographical location, how an area is governed, and its socio-economic status.

Temperatures in South Africa are rising at twice the global average, according to Silverstein (2019). Drought has plagued Southern Africa for several years. During 2018, the country was devastated by a series of cyclones, which caused flooding and damages that destroyed to existing crops. The ensuing shortage of food continues wreaking havoc on both urban and rural areas, inflicting economic ruin and catastrophic livestock losses. Tandon (2022) reported that in April 2022, one of the most fatal natural catastrophes to affect South Africa in the twenty-first century was observed as a consequence of roughly one year's worth of rainfall waterlogging the country's east coast. The rainfall prompted devastating floods and unexpected landslides in the provinces of KwaZulu-Natal and the Eastern Cape, inflicting havoc throughout the area. More than 4 000 families were displaced and had to be accommodated in halls, churches and schools; and an estimated 40 000 people were forced to leave their homes after 12 000 houses were destroyed. Furthermore, the province of KwaZulu-Natal experienced 630 school closures, affecting roughly 270 000 pupils. Overall, the rain caused R17 billion in damages to infrastructure (Tandon and

Mboto, 2022). To ascertain the contribution of climate change to the observed fluctuations in rainfall in KZN, several researchers have arrived at the conclusion that aerosol and GHG emissions are partially accountable for the observed increases after integrating observations with climate forecasts (Pinto, Zachariah, Wolski, Landman, Phakula, Maluleke, Bopape, Engelbrecht, Jack, McClure, Bonnet, Vautard, Philip, Kew, Heinrich, Vahlberg, Singh, Arrighi, Thalheimer, van Aalst, Li, Sun, Vecchi, Yang, Tradowsky, Otto and Dipura, 2022).

According to the United Nations' (2022) 'Drought in numbers report' published in 2022, weather, climate and flooding were responsible for 50 per cent of the catastrophes and 45 per cent of deaths from 1970 to 2019, primarily in countries with limited resources. Furthermore, while droughts accounted for 15 per cent of natural disasters during that period, they contributed to approximately 650 000 deaths. The European Commission (2018) emphasised that the large-scale adoption of sustainable business practices and waste management can mitigate global warming and climate change, and they further stated that green manufacturing is a viable solution that refers to production practices that emit less pollution and generate less waste overall. Changing processes to use fewer resources by, for example, developing ways to use less water in the production process or producing a more durable product with replaceable parts, that is, a product that fits into a circular economy, are all examples of this.

According to NASA (2022), the natural greenhouse effect is transforming due to human activity, such as the combustion of fossil fuels to run industries and transportation systems. The industrial sector's energy usage is projected to increase by a minimum of 1.2 per cent annually. In relation to the massive energy consumption, there is a great deal of room for the adoption of renewable energy sources since even a minuscule energy substitute has a significant influence on the global energy consumption (Hussain, Basim, JanajrehIsam and Zamzam, 2017). The United States Environmental Protection Agency (2021) suggests that proper waste management planning can reduce the effects of climate change, eliminate the production of potentially hazardous trash, encourage green building initiatives and establish a robust and profitable infrastructure for re-use and recycling, comprising recycling facilities and a market for re-purposed and recycled items.

2.6 Social and environmental impacts of mismanaged waste

McLennan-Smith (2022) stated that “the future of this planet depends on the ability to adapt to changing conditions and alter the way people do business”. Lenkiewicz (2018) added that the increase in population, urbanisation and changes in consumer habits will result in a higher volume of solid waste generated globally in the coming years. Waste that is not properly managed may end up in drains, rivers and finally the ocean. Ferronato and Torretta (2019) added that insufficient waste disposal leads to clogged drains, which results in flooding during rainy seasons. Furthermore, warm weather patterns and humidity enhances the possibility of leachate generation from discarded organic waste, which has a direct impact on ecosystems by contaminating soil and groundwater. Oneale (2016) posits that Africa has emerged into a repository for waste as several countries, notably in North and West Africa, have turned into global destinations for obsolete electrical and electronic equipment, amongst others (Baldé, Forti, Gray, Kuehr and Stegmann, 2017). Waste that is not collected or is illegally disposed of has a negative impact on human health. Water left in waste materials stagnates, luring mosquitoes and other insects that reproduce and disperse diseases carried by vectors. Additionally, the presence of waste attracts vermin such as flies, insects and rodents, amongst others, that serve as carriers of infectious diseases. Ineffective waste collection systems, in addition to both regulated and unregulated dumping of waste, has been associated with the open air burning of waste, resulting in a major adverse effect on society (Suleman, Tagoe and Agyemang-Duah, 2015).

While South Africa's waste output is expected to increase, exposure to these waste locations, especially those with insufficient management, has created major health hazards, specifically for those who reside in surrounding areas. A study conducted in Brazil from 2008 to 2015 discovered that various adverse health consequences, for example mental and physical impairments, occur as a result of work exposure in closed waste sites (Tomita, Cuadros, Burns, Tanser and Slotow, 2020). Health impairments correlated with waste site exposure are not restricted to on-site exposure. According to Elytus (2019), toxic components found in electronic waste consists of mercury, cadmium, lead, polybrominated flame retardants, the element barium, and the element lithium. Human health risks attributed to these contaminants include nervous system, kidney, liver, heart and skeletal system damage. Studies have indicated an association between an increased risk of diseases and the presence of open landfill sites. This includes a higher chance of contracting cholera, malaria, typhoid fever, dengue fever and Zika (Ziraba, Haregu and Mberu, 2016).

Suleman, Tagoe and Agyemang-Duah (2015) stated that "waste management practices in Africa results in the seepage of waste into the environment". Moreover, the negligent disposal of waste in urban areas raises the risk of contracting diseases. One of Africa's most contaminated areas in terms of persistent organic pollutants is the South Durban Industrial Basin, KwaZulu-Natal, which is located near residential areas. The basin's main emissions sources are two petroleum refineries and a pulp and paper manufacturing plant. The Merebank and Wentworth communities are highly affected by their industrial operations as it is situated in a region with one of South Africa's largest populations of petrochemical manufacturers (Xolo, 2020). The inhabitants claim that the polluted air from the refineries makes it impossible for them to breathe. Sagren Govender (47), a resident, stated that their neighbourhood is literally suffocating. He further stated, "We can hardly breathe on certain days during this pandemic. Everything is in the air. We wear masks to protect ourselves from Covid-19, but the air we breathe on a daily basis has been poisoned, slowly and silently killing us all" (The Conversation, 2020). The South Durban Community Environmental Alliance's air quality officer, Bongani Mthembu, affirms that low lung function is linked to elevated levels of toxic contaminants in the atmosphere. Poor governance, ineffective enforcement and a lack of political will all contributed to the lack of transparency.

According to Africa Institute (2013), women and children in Africa are heavily involved in the recovery of used electrical and electronic apparatuses. The re-purposing of e-waste poses possible risks to people and the natural environment. The re-purposing of abandoned lead-acid batteries in informal workshops across the continent is the primary cause of lead pollution, affecting the health of a large number of vulnerable people as well as the ecosystem. It may also adversely impact the human neurological and reproductive systems, causing sickness and congenital issues.

A systematic review was conducted in Brazil in 2018 to evaluate possible occupational hazards and ensuing health issues that waste collectors in Brazil may encounter. The results of the review revealed that waste collectors were employed in almost every region. There were numerous workplace risks for these employees, namely extended hours at work, frequent work accidents, exposure to chemicals, as well as mechanical, biological and ergonomic challenges, amongst other things. Being subjected to these risks frequently resulted in illnesses, both psychological as well as physical (Zolnikov, da Silva, Tuesta, Marques and Cruvinel, 2018).

Considering the predicted rise in waste generation in South Africa, exposure to poorly managed waste has resulted in major health concerns, particularly for people living in close proximity to the waste (Tomita, Cuadros, Burns, Tanser and Slotow, 2020). Ineffective waste management has detrimental effects on the environment and human health. If it persists, South Africa will find it increasingly difficult to meet the objectives for sustainable development (SDGs). According to the United Nations Environment Programme (UNEP) (2015), an important source of air pollution affecting human health and fuels climate change is the open fire burning of waste. Pollutants that contribute significantly to both regional and global climate change are methane and black carbon, which are emitted when waste is burned outdoors. Moreover, uncontrolled waste burning can be hazardous to both public health and climate. Kodros *et al*. (2016) developed a risk model based on health data, estimating that chronic respiratory exposure to unmanaged domestic waste burning causes approximately 270 000 premature adult deaths worldwide each year. In every aspect of business, organisations must adhere to the Triple Bottom Line (TBL), which emphasizes the well-being of "People, Planet and Profit" and asserts that organisations should prioritise social and environmental concerns just as much as profits. The TBL aims to evaluate the environmental impact of an organisation over a period of time, in addition to its level of commitment to corporate social responsibility (Kenton, 2022).

2.6.1 The Textile industry

According to numerous studies, the world's textile sector generates 92 million tons of waste per annum, and a significant portion of it ends up in landfills and incinerators (Pensupa, Leu, Hu, Du, Liu, Jing, Wang, Carol Sze Ki Lin, Yunzi and Chenyu, 2017). The production of textiles and clothing necessitates a considerable amount of water, electricity and other natural resources, as well as producing an enormous amount of waste (Islam, 2021). As a result, the textile industry has encountered extensive scrutiny for its adverse environmental effects, such as waste generation, carbon emissions and resource consumption (Niinimamp, Petrs, Dahlbo, Perry, Rissanen and Gilt, 2020). Moreover, it is projected that between 2015 and 2030, the estimated amount of waste emitted by the textile industry worldwide will increase by 60 per cent annually, resulting in an additional 57 million tons of waste being generated annually (Niinimamp *et al*., 2020; Shirvanimoghaddam, Motamed, Ramakrishna and Naebe, 2020).

Due to the lack of adequate waste treatment facilities and the rapid development of contemporary textile manufacturing facilities, pollutants including odorants, heavy metals, dyes and other hazardous materials are leaked into the environment, posing a threat to human health (Vikrant, Giri, Raza, Roy, Kim, Rai and Singh, 2018).

The textile industry is a traditional pillar industry in China. Annually, it produces as much as 1.84 billion tons of effluent, which severely pollutes the environment (Lotito, De Sanctis, Di Iaconi and Bergna, 2014; Vikrant *et al*., 2018). Given its high pH, high turbidity, low biodegradability, complex composition and high chrominance, in addition to the fact that it is produced in enormous amounts, textile dyeing effluent is considered one of the most challenging types of industrial wastewater to treat (Paz, Carballo, Perez and Dominguez, 2017). According to Chen, Zhang, Li, Qian, Lin, Yang, Wu, Zhou, He and Liao (2016) and Hong *et al*. (2017), conventional methods (for example, the coagulation process, chemical oxidation and the absorption processes) are unable to satisfy the increasing environmental requirements and the high industry and wastewater disposal standards. Given their high removal efficiency and ease of application, physicochemical methods are frequently utilised for the treatment of textile wastewater (Hong *et al*., 2017; Jorfi *et al*., 2018). However, such methods are typically expensive and resource-intensive (Holkar *et al*., 2016, Korbahti, 2007; Lin *et al*., 2014).

Considering the clothing industry's scale and global reach, unsustainable practices have a significant impact on social and environmental development metrics (Meier, 2021). The United Nations (UN) pledges to influence the sustainable production of clothing; to minimize its negative environmental and social implications; and to transform the clothing industry into a driver of the Sustainable Development Goals' (SDGs) implementation through the United Nations Alliance, which is aimed at helping to achieve the SDGs through concerted action in the clothing sector. The USA Post Conference Report states that in 2020, clothing house Ralph Lauren unveiled a new approach in 2020 that incorporates circular design principles and circularity throughout every level of product development, from design to sourcing and final production. The report further explained that issues like circularity and sustainability should not be an afterthought. The social and environmental costs of the clothing industry will continue to rise unless major changes are made to production processes and consumption patterns. The textile industry is projected to emit approximately 1.7 billion tons of carbon dioxide annually, substantially contributing to global warming (SLO Active, 2021). The Ralph Lauren Corporation (2021) asserted that the cultivation of essential raw materials demands enormous amounts of water, and the use of pesticides and other dangerous chemicals, including fabric dyes, damages the soil, biodiversity and the flow of water into local communities. With the sourcing of virgin materials accounting for 14 per cent of Ralph Lauren's carbon impact, the brand is also transitioning towards cotton and leather produced clothing, utilizing regenerative farming practices, as well as including more recycled materials in its apparel. Colour on Demand is a cotton dyeing platform that focuses on how to dye cotton in a more sustainable way, which was also introduced by the firm, and forms part of the company's goal of developing the world's first scalable zero wastewater cotton dyeing system (Ralph Lauren Corporation, 2021). The technology is currently being implemented throughout the company's supply chain (Reuters Events, 2021).

2.6.2 Pharmaceutical waste

Given the rising population growth rates and the rapidly rising economic burden of human diseases, pharmaceutical wastes are expected to rise, as per the assertions made by Magagulu, Rampedi, and Yessoufou (2022). This necessitates the implementation of suitable manufacturing, management and disposal procedures for such hazardous wastes (Magagulu, Rampedi and Yessoufou, 2022). South Africa is one of the major producers of radiopharmaceuticals and has the largest antiretroviral programme in the world. Nevertheless, more than two-thirds of pharmaceutical sales in South Africa come from imports, despite the country being the leading provider and manufacturer of pharmaceuticals in sub-Saharan Africa (Research and Markets, 2022). Miller (2022) stated that the pharmaceutical sector significantly contributes to environmental pollution and climate change, and the sector is responsible for 16.25 per cent of global carbon emissions. Dladla, Machete and Shale, 2016) asserts that inadequate waste disposal, along with inappropriate pharmaceutical waste management, can result in active pharmaceutical substances posing a threat to land, marine habitats and humans. If waste is not managed properly, it may escape into the environment and instigate further chemical reactions if it comes into contact with water or other chemicals, perhaps resulting in new risks that were not anticipated. Another major issue to be considered is the toxic emissions from the open air burning of medical waste (Dladla, Machete and Shale, 2016). As a result, pharmaceutical waste can harm human health, as well as the environment (Jovanović *et al*., 2016). Pharmaceutical waste must therefore be managed responsibly and effectively in order to reduce waste and to ensure that it is disposed of in an ecologically friendly manner. According to the Department of Health, KwaZulu-Natal (2016), pharmaceutical waste refers to “expired, unused, unusable, spilt and contaminated pharmaceutical products, medicines, cytotoxic preparations, vaccines, sera that are no longer required and need to be disposed of appropriately”. Shabaan, *et al.* (2018) assert that the presence of pharmaceutical chemicals in the environment is a major worldwide health hazard because although medications are necessary for human health, little is understood about how they affect freshwater sources and the environment. Pharmaceutical manufacturers in Africa encounter many problems, including ineffective product registration processes; inadequate communication systems for waste management and disposal; and even a lack of critical raw materials for the manufacture of pharmaceutical products, for example, maize starch and cellulose derivatives, two common additives that are primarily imported. Aboagye-Nyame (2021) reported that in low- and middle-income countries, approximately one in ten of the medicines in circulation are either counterfeit or of inferior quality, as per estimates released by the World Health Organization (WHO). In June 2018, a study conducted in the United States of America revealed that chemicals used in the production of drugs and personal care products cannot be removed by wastewater treatment plants. As a result, these chemicals escape into freshwater systems such as lakes, streams and rivers, and ultimately end up in the ocean. Pharmaceutical manufacturing plants are therefore a major source of pollution in the environment. Numerous pharmacological substances have permanent effects on water sources and the ecosystem (UNEP, 2018). According to Miller (2022), antibiotics have ingredients that might interfere with the microbial ecology of surface water and the sewage treatment process. When exposed to the environment, active pharmaceutical ingredients (APIs) can have a negative impact on both individuals and ecosystems. Moreover, APIs are typically introduced into the environment during creation, as well as during usage and disposal by consumers.

2.6.3 Plastic Waste

Plastics have been lauded for their numerous applications in everyday life. They are durable, inexpensive and long-lasting, and can take on any shape or colour (Leblanc, 2020). Plastics are versatile, non-corrosive and act as insulators, both electrically and thermally. They are used in construction materials, medical devices and electronics like computers and mobile phones due to their properties. They are also commonly used to construct lightweight packaging, which can extend the shelf-life of fresh items while reducing food waste and its associated environmental consequences. They lighten the weight of automobiles and other forms of transport, resulting in lower energy consumption. Plastics are additionally utilised in the production of synthetic fabrics such as polyester, nylon and fleece (World Wildlife Fund (WWF) South Africa, 2018).

When plastic waste is not retrieved, it contributes significantly to pollution. Lead, cadmium and mercury are plastic toxins that are extremely harmful when consumed by people and aquatic animals. These toxic compounds have the potential to cause cancer, birth defects, immune system difficulties, and developmental abnormalities in children (Andrews, 2020). Microplastics that compromise the environment and human health are amongst the most significant problems associated with plastic waste, as detecting their chemical and physical levels is becoming increasingly difficult (Science for Environmental Policy (SEP), 2011). According to Pettipas, Bernier and Walker (2016), the main sources of microplastics in the marine environment are inefficient waste management and unregulated dumping. An estimated 8 million tons of plastic are released into the ocean each year, causing marine habitat degradation and eventually affecting aquatic organisms (Alabi, Ologbonjaye, Awosolu and Alalade, 2019).

In South Africa, a mere sixteen per cent of plastic waste is re-purposed. Due to wind, littering, inadequate waste management and overflowing landfills, the remaining plastic waste eventually winds up in landfills, while some ends up in streams and finally in the ocean (World Wildlife Fund (WWF) South Africa. 2018). Hankel and Burgess (2018) claim that plastic may survive in water for hundreds of years. Unfortunately, marine creatures are engulfed in floating plastics as many of them confuse microplastics for food. Not only can these plastics endanger marine wildlife, but also humans who consume marine animals.

Plastic producers are responsible for the ongoing creation of plastic waste, which contributes to environmental pollution. Alabi, Ologbonjaye, Awosolu and Alalade (2019) stated that “varieties of plastics used in the production of many consumable products including medical devices, food packaging and water bottles contain toxic chemicals like phthalates, heavy metals, bisphenol A. brominated flame retardants, nonylphenol, polychlorinated biphenylethers, dichlorodiphenyldichloroethylene and phenanthrene, *inter alia*”. According to Greenpeace, banning single-use plastic would not solve the problem of pollution (The Coca-Cola Company, 2018) as the problem is multifaceted, necessitating, amongst others, the following actions:

- making use of 100 per cent recyclable materials;
- creating and supporting waste collection and recycling in countries and coastal communities where they do not currently exist;
- where mechanisms exist, increasing waste collection and recycling rates; and

- educating people on the necessity of recycling and material re-use.

One of the common methods used to reduce plastic pollution is recycling. Plastic recycling is a process for re-using scrap plastic or recycling plastic waste into usable items. Therefore, based on the type of waste recovered as a percentage during the process, plastics can be re-processed multiple times while still maintaining their value and functional capabilities (Milios *et al*. 2018). This technique deters plastics from landfills and unwanted places like the ocean, thereby promoting the preservation of resources (Leblanc, 2020). In order to minimise the disposal of plastic waste, manufacturers must consider recycling plastic waste as a sustainable option (Gu, Guo, Zhang, Summers and Hall. 2017). According to Satapathy (2017), recycling plastic items reduces the amount of plastic waste in landfills and allows plastics to be re-used in the manufacturing of new products. Notably, in contrast to other materials like glass, metals or paper, end-of-life polymers are seldom salvaged or re-purposed. Recycling plastic not only reduces the quantity of debris that must be managed in other ways, such as landfills, but it also reduces the use of non-renewable energy in the manufacture of new plastic products (Thompson *et al*., 2017).

According to Plastics SA (2021), plastic can be re-used, refilled, and recycled. Even when plastic can no longer be re-used, the energy that it has captured can be recovered. Thus, in order to achieve an entirely circular life-cycle for plastics across the value-chain, all stakeholders must collaborate on the development of sustainable product management principles.

2.6.4 Electronic waste

"E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use", according to the United Nations University and Step (Solving the e-waste problem) Initiative (2013/2014). It is the single most complex pollution problem globally as it severely contributes to environmental contamination and degradation. E-waste is also one of the fastest-growing waste sources in the world, with 41.8 million metric tons generated in 2014 (Esmaeilian *et al*, 2018). According to Linnenkoper (2019), South Africa generates approximately 350 000 tons of electronic scrap annually, of which only about 35 000 tons are recycled. The terms ‘Waste Electrical and Electronic Equipment (WEEE) or e-waste’ are commonly used to refer to electric and electronic equipment (for example, laptops, PCs, cellular phones, solar panels, wearables) (Garlapati, 2016). Parajuly, Kuehr, Awasthi, Fitzpatrick, Lepawsky, Smith, Widmer and Zeng (2019) stated that “popularly referred to as the fastest growing solid waste stream, around 50 million metric tons of waste EEE (WEEE) are generated globally at an estimated 6 kg per person, projected to rise to up to 111 million tons per annum by 2050”.

Tiseo (2021) reported that during 2019, China emerged as the global leader in the generation of electronic waste, generating approximately 10 million metric tons. The United States ranked in second place, generating more than seven million metric tons of electronic waste. Tiseo (2021) further stated that the global generation of electronic waste surpassed 54 million metric tons in 2019 and is projected to continue to rise in the forthcoming years. According to Deer (2021), not only can superfluous electronic devices contaminate the environment and ignite fires at waste disposal facilities, but the resources used to produce these goods are vastly recoverable and valuable. Relative to waste volumes, estimates suggest that billions of dollars’ worth of copper, aluminium and semi-conductor chips are discarded daily. Furthermore, only approximately a fifth of all electronic waste is recycled on a global scale. According to a study conducted by Kumar, Holuszko and Espinosa (2021), electronic waste is a rising global concern.

The World Economic Forum (2019) asserted that the volume of e-waste generated is steadily increasing at a three to four per cent rate and is expected to reach 120 million tons by 2050. If recycled correctly, it could offer an opportunity for urban mining for the recovery of copper, gold, silver, palladium and other metals, with an estimated value of 55 billion Euros annually. Developed countries are exporting their electronic waste to developing countries for dumping, causing serious environmental and social concerns. Garlapati (2016) stated that most electronic waste is exported to emerging economies like Africa and other developing countries (Bimir, 2020). The United Nations Environment Programme (UNEP) asserted that barely ten per cent of the global electronic waste is being recycled in developed countries, with the remaining 90 per cent being distributed to countries that are underdeveloped throughout the world. Furthermore, obsolete equipment is frequently donated to countries that are still emerging economically and cannot afford new electronic equipment or keep up with the world's increasing technology (Albuquerque, Mello, Paes, Balestrassi and Souza, 2017). Waste collection, sorting, waste prevention, emission reduction and cost-effective recycling are among the major challenges of e-waste management. In addition, only 78 countries have e-waste regulations in place, with the majority of developing countries failing to properly enforce them, rendering them easy dumping locations for e-waste (Shahabuddin, Uddin, Chowdhury, Ahmed, Uddin, Mofijur and Uddin, 2022). The inability of electronic waste to be properly recycled or disposed of is regarded as the leading cause of harm to individuals and the natural environment. Given the quantity and toxicity of the components contained in e-waste, it is a major source of concern.

According to Park, Hoerning, Watry and Burgette (2017), inadequate disassembly or burning of electronic items to remove components can be hazardous to workers and people, as well as pollute the ecosystem. Furthermore, when e-waste is improperly disposed of, harmful substances and emissions are released into the environment, causing harm to plants and animals (Ankit, Saha, Kumar, Tiwari, Sweta, Rawat, Singh and Bauddh, K. 2021). Moreover, the ingestion of such substances through plants, drinking water and direct inhalation can be fatal to mankind (Kumar, Holuszko and Espinosa, 2017). In several locations, hazardous components are often thrown in unmanaged landfills, while outdated methods are used to gather valuable components (Solving the E-waste Problem (Step, 2019).

Since lead-acid batteries have the shortest lifespan of any off-grid solar component, they make up a disproportionately large portion of the global waste stream (Hansen *et al*., 2020). Moreover, Lead constitutes approximately 65 per cent of the total mass of a battery manufactured from lead acid (Manhart *et al*., 2018). Furthermore, lead constitutes a persistent neurologically hazardous that is recognised to have a negative influence on the functioning and development of the human brain at low exposure levels, and to be life-threatening at high concentrations (Rees and Fuller, 2020). According to Charles, Davies, Douglas, Hallin and Mabbett (2019), lithium-ion batteries are frequently discarded in landfills or in the environment, which contributes to the depletion of these limited essential resources. In addition, it is associated with fire hazards. The mishandling and incorrect storage of lithium-ion batteries can be highly hazardous (Manhart, Hilbert and Magalona, 2018). Even though these practices have potentially fatal consequences, little is known about the wider social and environmental costs of improperly managing e-waste, in addition to the systematic processes of being exposed to toxic pollution (Manhart *et al*., 2016).

According to Kumar, Holuszko and Espinosa (2017), the rapid pace at which electronic waste is generated in developing countries is a significant cause of concern. When considering future mitigation strategies, a fundamental alternative would be for manufacturers to become more engaged in ensuring the enforcing return policies to effectively recycle the electronic goods they produce. An article by Sunitha (2017) mentions that placing e-waste bins or containers in public areas could potentially make a significant impact in ensuring that such waste is gathered and disposed of in an environmentally friendly manner, as opposed to being abandoned, which contributes to environmental harm. The first public e-waste bin has been installed at Bengaluru city in India by a non-governmental organisation in the year 2017. Sunitha further states that it is necessary to gain knowledge about the evolution and recycling of e-waste as the absence of knowledge about e-waste management will significantly increase ecological pollution.

2.6.5 Manufacturing facilities and office waste

Energy is commonly used by manufacturing organisations to produce the heat that is needed for the transformation of raw materials into usable goods. Compared to service organisations, factories use relatively large amounts of natural resources. Hence, they are major contributors to the depletion of the earth's natural resources. Joseph and Inambao (2020) stated that on average, factory facilities use 95.1 kilowatt-hours (kWh) of electricity and 536 500 Btu of natural gas per square foot each year, though actual consumption varies widely across sub-sectors. While some industrial machinery may automatically switch off when not in use and remain inactive for a short period of time, other machinery cannot be switched off between uses and must operate continuously, thus resulting in wasted resources; for example, compressed air systems when the compressors are not in operation (Friendly Power, 2020).

Paper is produced from 42 per cent of all trees harvested for industrial use, which has a significant environmental impact. Forest destruction is only part of the problem. In most developed countries, the usage of water in industry is most prevalent amongst the pulp and paper sector (Suraj and Khan, 2015). In addition, they are also arguably the largest polluter of water, and the third highest emitter of environmental pollutants (StopWaste, 2022). Although printers, papers and files are common objects in traditional offices, due to innovation, many offices are choosing to use less paper in their daily work. According to Beck (2018), "digital forms and data collection software can lead to greater business growth, employee productivity and retention, as well as improving the company's bottom line". Other benefits of going paperless are that it reduces waste, cost, production energy and environmental impact, and reduces the carbon footprint of the organisation. It also saves office space, makes documents easily accessible and allows for multiple employees to work on one document. According to Deer (2021), it is imperative to understand the types of waste that an organisation generates through a waste audit, and try to reduce it. Simple adjustments, such as correctly separating and disposing of waste or adopting a ceramic or aluminium coffee mug instead of paperboard/plastic or Styrofoam cups, can make a big difference in organisational waste reduction.

2.7 Management approaches to steer sustainable business activities

Durán, Capaldo and Acevedo (2018) advise incorporating the use of a new metric called Sustainable Overall Throughput Effectiveness (S.O.T.E.) as an effective practice because it has all the relevant characteristics, and it provides an integrated view of the production processes, quality control, maintenance, environmental aspects, as well as allows for the tracking of the effects of these aspects on the overall performance. Below are four approaches outlined by De Smet *et al*. (2021) that managers can use to steer the organisational redesign of their business activities:

- Design specific and achievable business activities that are sustainable (for example, waste reduction, green hydrogen or its sub-topic, operational decarbonisation), instead of overall objectives;
- Prioritise the full life-cycle of the products manufactured by the organisation;
- Comply with updated legislation pertaining to sustainable waste management practices in order to mitigate environmental degradation and natural resource depletion; and
- Ensure that sustainable packaging is used, that is, no excessive packaging must be used, and packaging must be recyclable or manufactured from biodegradable raw materials.

2.7.1 Lean Manufacturing

Transport, inventory, motion, waiting, over-production, over-processing and defects are the seven types of waste in lean manufacturing that all organisations can learn from in order to improve efficiency (Cousins, 2021). According to De *et al*. (2020), several manufacturing organisations use lean management strategies to achieve economic sustainability by prioritizing waste reduction throughout business processes. There has been a surge of interest in Lean Manufacturing and its relationship between lean management principles (LMP) and environmental sustainability. According to Landau (2023), the lean methodology was first implemented in the Toyota Production System (TPS), which revolutionised the company's manufacturing process and subsequently expanded around the world. The concept of lean manufacturing is a production approach that places emphasis on reducing waste, creating value for customers, and constantly enhancing procedures (Landau, 2023). The implementation of lean project management principles, practices and resources helps to accomplish this. The two pillars of Lean manufacturing are product quality at a low cost and customer satisfaction. It is regarded as a method of reducing waste to a bare minimum. Lean manufacturing focuses on eliminating waste to increase the value of the product; hence it is both economical and environmentally friendly (De *et al*., 2020).

The five pillars of lean manufacturing were outlined by Womack and Jones. According to Do (2017), the five concepts that follow serve as an outline for improving work-related effectiveness:

i. establishing value,
ii. configuring the value stream,
iii. developing circulation,
iv. utilizing the concept of pull, and
v. achieving perfection.

Landau (2023) asserts that when applying lean concepts to the manufacturing process, lean manufacturing technologies are critical in identifying and eliminating the generation of waste. Waste elimination in any industrial system increases quality and production time while reducing expenditures. The following are examples of management tools:

- The single minute exchange of die, or SMED, is an effective method of transitioning between manufacturing processes;
- Value stream mapping enables staff members to visualize every stage of the production process in order discover opportunities for process improvement;
- 5S, an organisation methodology for the workplace;
- Kanban boards, that demonstrate the workflow;
- Poka-yoke (proofing errors);
- Rank sequence clustering (the manufacturing flow analysis);
- Single point arranging;
- Complete productive maintenance (enhances manufacturing process integrity and quality);
- Remodelling work cells;
- Managing multiple processes; and
- Using control charts to monitor workloads.

2.7.2 Green Manufacturing

The concept of green manufacturing was established to align sustainable development in production processes and to attain a more sustainable pathway to economic growth. It includes improved industrial production processes and resource-efficient productivity. It aims to raise awareness, expand understanding, and increase organisational capabilities (United Nations Industrial Development Organisation, 2022).

The escalating environmental conditions have constituted an immense threat to human existence and advancement. According to Lin and Hao (2020), green manufacturing is a contemporary production model that assesses resource efficiency in addition to environmental impact. Its guiding principle is to ensure that products are cost-effective, high-quality and free of harmful pollutants throughout their life- cycle, that is, to minimise energy use and maximise resource capacity.

Cai *et al*. (2019) stated that focusing on lean energy-saving and emissions reduction (LESER) techniques enhances energy efficiency and minimizes waste. Although traditional LESER consists of a few technological innovations or methods that are insufficient for the entire manufacturing process, manufacturers are required to adapt to responsible production practices by employing sustainable strategies and actions. Below are examples of companies contributing to green manufacturing:

Unilever, a multinational corporation with operations in 180 countries, intends to double its revenue and cut its carbon footprint in half by 2032. McLennan-Smith (2022) stated that “the company’s manufacturing plant in Durban, Indonsa, is the first green manufacturing facility in South Africa, and it was built with three fundamental principles in mind: water neutrality, energy conservation, and zero waste. After an initial injection of water, the plant is no longer dependent on the municipality for its water supply”. McLennan-Smith (2022) further stated that “Indonsa recycles 70 per cent of its effluent water and relies on rainwater and condensate for the balance. The company recycles 60 per cent of its waste and is looking at ways to address the 40 per cent that goes to landfill sites”.

Apple is a technology giant that has built a $5 billion headquarters in Cupertino, California, dubbed the "Spaceship”. The company has installed thousands of solar panels with an estimated output of 16 megawatts of power rooftop surface area of this new building. The solar-powered building features one of the largest solar arrays for a corporate building worldwide, in addition to the largest fragments of structural glass ever made. Moreover, it has four megawatts of biogas fuel cells and attracts additional renewable power from a 130-megawatt solar arrangement in the vicinity. In addition to renewable energy sources, Apple has also planted 2500 new native trees to its existing collection of over 7000 as a component of its sustainable design endeavours. In total, their 175-acre property would be converted to 80 per cent green space (d'Estries, 2017).

In addition to being a major supplier to PETCO, a recognised Producer Responsibility Organisation (PRO), Kaytech is also a reputable geotextile manufacturer in South Africa. Kaytech manufactures various geotextile products which are made up of a 100 per cent recycled polyethylene terephthalate (rPET) from post-consumer cooldrink bottles (PETCO, 2016). It is additionally renowned for manufacturing superior quality needle-punched non-woven uninterrupted filament geotextiles from rPET. This sophisticated production line has more than double the usage of rPET at capacity and developed the processing of the rPET into an improved geotextile which has immensely increased the competitiveness of the organisation.

Novus Holdings Limited is a South African company that is recognised for commercial printing and manufacturing. Their branch based in Isithebe is dependent on an uninterrupted supply of raw materials for its production procedures. This consists of polymers, paper, pulp, pigments, water, and electrical energy. Their executives are aware of how the negligent management of plastic waste contributes to widespread environmental damage and a lack of plastic recycling once products reach consumers' hands. Therefore, they use eco-sustainable paper stock options and have implemented several green production and manufacturing initiatives. Novus Holdings continues to promote innovation in multi-purpose and re-usable plastic packaging products, where plastic functionality is critical. Novus Tissue will also expand its paper manufacturing facilities by using wastepaper generated by the Group's significant printing operations in the production of tissue paper (Novus Holdings Integrated Annual Report, 2020).

2.7.3 Sustainable Packaging

Sustainability regulations for packaging have become increasingly stringent. The packaging business is being shaped by a megatrend, with customers growing increasingly concerned about the influence of waste on the environment. Consequently, innovative and sustainable manufacturing standards must increasingly advance on varying levels (McKinsey and Company, 2022).

According to Plastics SA (2021), “South Africa’s plastics industry is dominated by the packaging sector (which accounts for approximately 52 per cent of the local market), followed by building and construction (13 per cent), agriculture (9 per cent), automotive and transport applications (7 per cent)”. Global pressure to reduce packaging waste has surged dramatically as a result of public outrage over images demonstrating packaging escaping into the ocean. In response, politicians have taken action. During the 1980s, biodegradable plastic has been proposed by scientists as a remedy that plastic manufactures could use to mitigate plastic pollution (MasterClass staff, 2020). Biodegradable plastics are most commonly used in food packaging, disposable dinnerware, plastic bags, packaging, medical materials, and other related devices.

PET (Polyethylene Terephthalate) is also a form of plastic that is a transparent, robust and lightweight plastic frequently used to package food and drinks, particularly water, juice and soft drinks in practical sizes (Plastics SA, 2021). It is a packaging material that uses less energy. Compared to glass, aluminium and other container materials, it maintains a very favourable sustainability profile even though its raw materials originate from crude oil and natural gas (PET Resin Association, 2015). On the African continent, Extrupet is amongst the biggest and most sophisticated recyclers of PET bottle materials. With the ability to recycle more than 2.5 million PET bottles daily, Extrupet can convert waste PET bottles into fibre, thermoforming, food-grade, and strapping-grade material. This process results in the production of dependable, high-quality finished goods that can be used in packaging and various other applications (Yonli and Godfrey, 2018). According to Plastics SA (2021), South Africa recorded an input recycling rate of 43.2 per cent during 2020. A significant 461 500 tons of plastic waste were collected for recycling, 312 600 tons of which were successfully recycled back into raw materials. While 97 260 tons of recycled material were used to make new packaging, 296 500 tons of recycled material were used to make new products.

Nampak Packaging Excellence (2022) is Africa's leading diversified packaging manufacturer. It operates from 19 sites in 14 locations throughout Africa, which includes South Africa. The Nampak Liquid Cartons plant in Isithebe is perpetually creating fresh, contemporary packaging alternatives for its customers. An example of the contemporary packaging is Fruitime 2litre and 330ml of liquid cartons as it possesses a board structure made up of seven layers, each of which serves a crucial purpose of preserving the product's six-month shelf life and keeping it in good condition. The polyethylene serves as a barrier between the heated aluminium foil and the filled product. The carton board is imported and complies with FDA and European Union regulations. At Nampak Liquid Cartons Isithebe, the company holds the following accreditations: ISO9001:2008 Quality Management System; HACCP 10330:2007 HACCP System; and by the end of 2022, they anticipate being accredited with ISO14001 (Environmental Management System). Packaging accounts for sixty per cent of sales. According to Neil Hurter, Operational Director of Fruitime, the organisation's prior expertise revealed that packaging represents their most crucial area for innovation, and he believes that it is even more important than price (Nampak Packaging Excellence, 2022).

A major milestone has been attained in The Coca-Cola Company's (2021) environmentally friendly packaging journey with the introduction of its first beverage bottle composed entirely of plant-based plastic (aside from the cap and label), manufactured by employing economically feasible technology. Although the process allows for flexibility in raw materials, corn sugar was used to produce the organic paraxylene for this bottle. Greenpeace Africa is an independent environmental campaigning organisation that had circulated a brand audit that detailed the quantity of material such as plastic and polystyrene that had been obtained during beach clean-up efforts in 42 countries. According to the results, the most packaging picked up was from The Coca-Cola Company (The Coca-Cola Company, 2018). The Coca-Cola

Company established the following sustainable goals to reduce pollution by taking responsibility for their packaging throughout its life-cycle:

- *Design*: aim for packaging that comprises at least 50 per cent recycled material by 2030; maintain the objective of making all consumer packaging 100 per cent recyclable by 2025 (they have already accomplished 85 per cent of this objective).
- *Collect*: reduce waste by collecting and recycling one bottle or can for every unit sold by 2030 (they are currently at 59 per cent).
- *Partner*: collaborate to promote a clean, debris-free environment and oceans (The Coca-Cola Company, 2018).

2.7.4 The Circular Economy

The Department of Forestry, Fisheries and the Environment (2021) asserted that the concept of circular thinking goes beyond the green sector's focus on reduce, re-use and recycle to eliminate waste entirely. It requires manufacturers to establish collection points, conduct regular audits, and meet stringent new targets. It supports sustainability by assuring the recycling, repair and re-use of raw materials and products. Improved efficiency and profit margins result from an emphasis on waste reduction. Circular economy provides substantial business opportunities for entrepreneurs. According to Stubbs (2020), almost 90 per cent of South Africa's waste is tossed in landfills. However, by re-purposing, modifying or refurbishing this waste, millions of rands could be generated in the country's economy (Ventureburn, 2021).

Barbara Creecy (2020), the minister of the Department of Environment, Forestry and Fisheries, explained that in a circular economy, waste does not exist because when a person is done with something, it must be employed as raw material for something else. The circular economy concept may aid in understanding how the waste management hierarchy is implemented in relation to the green economy and other Extended Producer Responsibility (EPR) measures. A circular economy closes the loop between resource extraction and waste disposal by implementing waste prevention, restoration, re-use, recycle and recovery techniques all through the

economic cycle, reducing the generation of waste and the need for virgin materials as production inputs (Department of Environment Forestry and Fisheries, 2021).
The fundamental concepts behind the circular economy are the restoration of natural systems, the reduction of waste and pollution, and the preservation of product and material usage (Kumar, 2019). The present set-up generates a substantial amount of waste. The World Resources Institute (2020) stated that more than 100 billion tons of resources flow every year and 60 per cent end up as waste or greenhouse emissions. Similarly, approximately a third of all food produced is wasted. The circular economy offers a system where waste and pollution are reduced through product design. McGinty (2020) asserts that 80 per cent of environmental impacts are identified in the design phase, and that waste and pollution, rather than being an inevitable by-product of daily consumption, become shortcomings in design.

In order to implement a circular economy approach, cooperation between all spheres of society is needed, as well as the development of novel laws pertaining to corporations, governments, employment, and cities.
McGinty (2020) advised that the following changes are necessary to facilitate the transformation towards a circular economy:

- Reduce consumption by refraining from plastic bottles, fast fashion, and waste from food;
- Use less energy by reverting to organic options, utilising carpooling, streaming online content; and
- Implement systemic change by building recycling-friendly infrastructure, imposing taxes on packaging products that contain more than 30 per cent virgin materials, and improve the quality of merchandise to be more durable.

The governance model for the Circular Smart Production System (CSPS) promotes an entirely novel way of recycling and re-using urban waste by leveraging technologies like 3D printing and concepts from Industry 4.0 to improve digital manufacturing operations (Nascimento *et al.,* 2019). As a result, this model promotes the adoption of the circular economy, thus introducing a better supply and demand path for society. The subsequent information outlines the seven phases of the three-dimensional printing processes, each of which is interrelated to the reverse logistics of materials (Nascimento *et al.,* 2019):

- **Product life-cycle**: This refers to the time-frame that the product is expected to function ordinarily. Any manufactured object can be deemed a part of the product if it is utilised in a residential or commercial setting.
- **Selective waste collection**: This refers to the procedure of gathering waste when a product's life-cycle ends, which could be due to a variety of reasons, for example, the product is broken, outdated, the user rejects it, or the product is no longer desired by the user.
- **Waste sorting**: This describes the waste separation process in authorized recycling facilities. Sorting involves categorising and sub-categorising materials in the most organized way possible in order to convert them into input material by enabling the production of contemporary and technologically advanced products from outdated components. Metallic material, wood, polyethylene and glass, in addition to other materials that are recyclable, can all be re-purposed.
- **Waste treatment**: This phase is one of the model's most difficult problems. During this phase, every element must undergo an array of chemical or physical processes that transforms its properties into input for production. Transformation is an essential component of future effective recycling strategies since it supports the innovation of contemporary and complex goods acquired from aged resources.
- **Product printing**: This is the procedure of printing in three dimensions using the outcomes of the preceding process. It is possible to print simple and complex items of various sizes and shapes using 3D and digital equipment in the designs. Products that are ready to use as soon as they are printed are forwarded for sale or transferred to the assembly stage, if it is merely a component of a larger product.
- **Product assembly**: This phase is when the finished product is assembled using components that were printed with various substances. To assemble a blender, for instance, metallic materials for the blades would need to be printed in three dimensions.

- **Product selling**: At this phase, the product that was manufactured from recycled materials is available for sale either online or in-store, and a renewed life-cycle commences.

Tony Milikin, the Chief Sustainability and Procurement Officer at **Anheuser-Busch InBev (AB InBev)**, the world's most prominent brewer (2020), stated the following: "Everything we look at in our company, we're looking at it through circularity" (Reuters Events, 2021: 15). According to Milikin, circularity entails thinking outside the box, creating and discovering new methods of doing things, as well as new ways of utilising materials. He went on to state, “Holistically, we view anything as an opportunity”. He went on to explain that during Covid, instead of burning off the alcohol extracted from non-alcoholic beer, they began re-purposing it to make hand sanitizer, which played a vital role in helping to prevent the spread of the virus during the pandemic.

2.8 The influence of the Fourth Industrial Revolution on the sustainable development of the manufacturing industry

Li and Yang (2017) stated that “Industry 4.0 was formally put forward at the Hannover Industrial Expo in April 2013. It is a common national strategy led by the German government, industry leaders, researchers, associations, and trade unions, so as to improve the definition of industry, from the centralised production mode to the basic form of decentralised production and control”. The term "Industry 4.0", also known as the "Fourth Industrial Revolution", refers to a paradigm shift in the use of technology that is centred around the idea of Cyber-Physical Systems, or CPS (a combination of computing, communication and control). This paradigm is typified by the ubiquitous presence of a wide range of individually addressable cooperating objects, such as sensors, actuators and mobile phones. It enables real-time data interchange between equipment and components of the product, allowing for continuous monitoring and oversight of relevant production processes. As a consequence, industrial production has become considerably more flexible and transparent. Furthermore, big data analytics and cloud and fog computing, which provide practically limitless storage, computing and communication capabilities as utilities, help extract value from complex data sets (Barreto *et al*., 2017; Li and Yang, 2017; Aceto, Persico and Pescapé, 2020).

According to Kituyi (2018), the Fourth Industrial Revolution is a driver of sustainable development but the connection between digital transformation and sustainability is still in its early stages.

Manufacturing procedures should be designed to maximize energy efficiency, reclaim and re-purposing unwanted materials (Nascimento, Alencastro, Quelhas, Caiado, Garza-Reyes, Rocha-Lona and Tortorella, 2019). Industry 4.0 entails fundamentally re-designing the corporate models and manufacturing processes of the organisations to enable production efficiency, energy optimisation and the reduction of waste generation (Ramakrishna, Ngowi, De Jager and Awuzie, 2020).

To address all management challenges, a waste management system in smart cities uses blockchain technology to manage waste and clean up the environment without the need for human intervention. The concept of Block-chaining involves a highly secure digital decentralised ledger that retains a chronological and public record of production transactions. A blockchain-based waste management system may provide two critical benefits: ensuring long-term sanitation and providing stakeholders with a transparent and traceable waste management approach (Steenmans, Taylor and Steenmans, 2021). Tracking waste has always been challenging, but with blockchain technology, it should be a lot easier. By pairing the internet of things detectors to a decentralized network, waste trucks can collect data and be tracked in real-time throughout their journey. Waste management service providers can be penalized or awarded if they fail to provide better time-based services through integrating a Block-chaining approach into waste management systems (Jeyabharathi *et al*., 2021).

2.9 Landfill sites

Wastes from landfill sites cut across all sectors of life. As a result, there is a need to categorise such wastes according to its origin, composition, toxicity and management. By implementing waste categorisation, it will be easier to determine what proportion of landfill wastes could be used to produce energy that can be affordable, reliable, sustainable and modern for all, which is Goal 7 of the Sustainable Development Goals (SDGs) (Dada and Mbohwa, 2018).

According to DEA (2018), most landfill sites are not managed in compliance with stipulated regulations. Studies indicate that over sixty per cent of general waste and approximately ninety-five per cent of hazardous waste are disposed of through landfilling (DEA, 2018). Landfills can serve as a repository for rodents, which can contribute to human respiratory diseases such as asthma and hantavirus pulmonary syndrome, along with other diseases caused inadvertently by an intermediate vector (Schountz and Prescott, 2014). According to Mbatha (2021), there are very few Class A landfill sites in South Africa designed to accept hazardous waste. Del Fabbro (2021) stated that although Dolphin Coast Landfill Management (DCLM) was a licenced Class A landfill, the problem was that it should not have been granted a licence because the site was unsuitable due to high rainfall and had received a mere R20 000 fine in 2020 for non-compliance due to dumping leachate into a nearby river.

The effective management of urban growth will become increasingly important for sustainable development, especially in low- and middle-income countries where urbanization is predicted to happen at the fastest rate. Moreover, during the last twenty-four years, no municipality in Gauteng has granted a licence for a new landfill. In reality, the few remaining landfills in Gauteng are rapidly closing and filling up, and no new landfills or viable alternatives for waste recovery or disposal are being built to replace them (AWARD, 2019). Furthermore, as part of updated regulations intended to significantly reduce the amount of waste that ends up in landfills, South African manufacturers are now required to incorporate more recycled material into their products and take accountability for the final destination of their products (Businesswire, 2021). The Occupational Health and Safety (OHS) Act of 1993 stipulates that an employer must protect employees, visitors and nearby communities from any hazards emanating from its working environment, and it is evident that many organisations in South Africa had failed to act responsibly in these matters (South African Legal Information Institute, 2019).

2.10 Drivers of Sustainable Waste Management practices

Global warming and the depletion of natural resources have inspired pleas for essential modifications in the way organisations produce and distribute their products and services. Several countries have enacted mandatory initiatives, for example, carbon taxation, in order to promote the sustainable development of supply chains (Younis, Sundarakani, Mahony and Barry, 2019). Some of the main forces behind sustainable waste management strategies include climate change, pollution, land and sea use, and the exploitation of organisms. Climate change, according to the World Health Organisation (WHO) (2023), has an impact on both social and environmental factors of health, such as clean and safe drinking water, fresh air, sufficient nutrition and adequate shelter. Climate change is projected to result in roughly 250 000 additional fatalities annually between 2030 and 2050 due to nutritional deficiency, malaria, bowel movements, and radiation stress (WHO, 2023). The WHO (2023) stated that "areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond. Reducing emissions of greenhouse gases through better waste management practices, responsible manufacturing practices, transport, food and energy-use choices can result in improved health, particularly through reduced air pollution". Each of these transforming agents, including local governance, consumption and production patterns, trade and technological breakthroughs, and population dynamics, is fueled by societal values and behaviours (IPBES, 2019).

According to Vijayvargy, Thakkar and Agarwal (2017), support from senior management and an organisational culture with a strategic goal to be sustainable are two internal drivers of environmentally friendly supply chain management. Some businesses are also motivated by a sense of social duty. Another major internal incentive is the potential economic benefit of embracing GSCM techniques. External GSCM drivers include various external forces that influence enterprises to adopt environmental strategies. Amongst these drivers are consumers, vendors and other stakeholders, including government agencies, the general public and charitable organisations (Younis, Sundarakani, Mahony and Barry, 2019).

The revised Municipal Infrastructure Grant (MIG) policy framework provides the necessary financial assistance to allow Municipalities to purchase yellow fleet vehicles and equipment (for example, landfill compactors, bulldozers and so forth) for 27 Municipalities. Both the Provincial and National Departments are assisting and processing MIG applications from Municipalities for yellow fleet purchases. From 2021/22, the number of MIG applications for yellow fleet will increase. From 2012/13 - 2020/21, the Department has been funding Municipalities to obtain authorisations for their landfill sites. The department has enabled the obtaining of over 325 waste management licences (WMLS) across the country for Municipal landfill sites (Department of Environment, Forestry and Fisheries, Republic of South Africa, 2020).

2.11 Barriers hampering the adoption of Sustainable Waste Management practices

According to the Department of Environmental Affairs and Development Planning (2020), population growth influences the amount of waste that is generated and the demand for waste and sanitation services. The multifaceted nature of the waste stream has a direct impact on its management, which is exacerbated by the combination of hazardous and general waste (Department of Environmental Affairs and Development Planning, 2020). The limited municipal landfill airspace availability for surrounding local municipalities will more than likely result in increasing pressures for municipalities and see the movement of waste between municipalities (GreenCape, 2020). Funding is critical for Producer responsibility organisations (PROs) and producers, and could result in switching to different materials because of a lack of EPR fees (Department of Environmental Affairs and Development Planning, 2020).

Every country has laws and rules that include measures to regulate the management of waste at the regional, national and international levels. However, a mismanagement of waste persists due to incoherence, a lack of enforcement, and inadequate implementation (GRID-Arendal Annual Report, 2015). According to Awasthi, Li, Koh and Ogunseitan (2019), the Basel Convention represents one of the management approaches that solely considered the public sector and failed to account for the private sector. Therefore, it is deficient of scientific data and technological capacity to deal with the issue of e-waste. Moreover, the Basel Convention did not ban the transport of toxic waste in developing countries, thereby permitting e-waste exports (Ghosh, Debnath, Baidya, De, Li, Ghosh, Zheng, Awasthi, Liubarskaia and Ogola, 2016).

The socio-economic transformation of developing countries is influenced by urban development, electrical energy generation, education on proper waste management practices, and infrastructure. These sorts of changes demand a large workforce, many resources, planning, and efficient waste management and monitoring, all of which are scarce in South Africa (Omwoma *et al*., 2017). According to DEA (2016), dry cell battery recycling plants do not exist in South Africa. The batteries are gathered at specific Gauteng locations, separated according to chemical composition, and despatched to a recycling facility in France.

Godfrey *et al*. (2020) asserted that "current reasons for the poor management of waste in Africa include, amongst others, weak organisational structures; lack of appropriate skills; inadequate budgets; weak legislation; lack of enforcement; low public awareness; corruption, conflict; political instability; and a lack of political will".

Other barriers include the rand's depreciation, which has increased the price of imported raw materials and completed items, and the frequent power outages that South Africa experiences (Research and Markets, 2022). Mpatane (2015) explained that one of the key factors increasing manufacturing output in any country is an uninterrupted and sufficient supply of electricity. The availability of electricity plays a key role in both the production and consumption of products and services, as well as in a country's growth potential. Eskom's extreme electricity shortages, which resulted in load-shedding and power outages, have caused the manufacturing sector in South Africa to generate excessive waste and to see a fall in output (Mpatane, 2015).

Nordin, Ashari and Rajemi (2015) reported that the lack of planning, preparation, resistance of employees to change, lack of data and standardisation, lack of vision, incorrect implementation, and lack of infrastructure are all contributing factors. Revenue is an additional barrier to the implementation of sustainable waste management practices (Nordin, Ashari and Rajemi, 2015). Ghazilla, Sakundarini, Abdul-Rashid, Ayub, Olugu and Musa (2015) agrees and states that "major barriers include lack of awareness of sustainability concepts by small firms, lack of awareness of green products by customers, inadequate publicity about green products, negative attitudes towards sustainability concepts, lack of funds and high cost".

Orisakwe, Frazzoli, Ilo and Oritsemuelebi (2020) asserted that the issue of the indecorous management of toxic waste in low-income countries has long received attention. Orisakwe, Frazzoli, Ilo and Oritsemuelebi (2020) further stated that despite the known hazards, there is a general absence of formal electrical and electronic waste (e-waste) management infrastructure across Sub-Saharan Africa (SSA), and the improper management of e-waste is recognised as a serious threat to public health. Moreover, according to Corbyn, Martinez and Cooke (2019), no single country in SSA, which includes South Africa, has an enforced and organised waste management policy for e-waste similar to Europe's WEEE Directive (a reference model for emerging policy).

Lack of skills and workforce engagement are also major barriers to sustainable manufacturing practices (Madrid-Guijarro and Duréndez, 2023). According to Betti, de Boer and Giraud (2022), a business can have the best tools, the newest technology and considerable resources at its disposal. However, if it lacks genuine workforce engagement, it will be unlikely to scale up sustainable business practices successfully. The authors further emphasise that it is vital that businesses put their workers at the core of their efforts by creating a community of involved, committed people who offer ongoing support and can meet the challenges of their emergent labour requirements.

2.12 Conclusion

This chapter captured the theoretical perspectives of waste management practices amongst manufacturing organisations. It also demonstrated a rational association between literature and research variables. These include definitions, legislation, policies and procedures, social and environmental impacts, as well as management approaches to steer sustainable business activities. Significant sources of data were consulted during this study's literature review. The subsequent chapter elaborates on the methodology and its justification for use in gathering data for the research study by expounding upon the research layout, target population, measuring instrument, pilot testing, delimitation, validity and reliability, data analysis and finally, the ethical code of conduct regarding research will be observed.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology and its justification for use in gathering data for the research study by expounding upon the research design, target population, measuring instrument, pilot testing, delimitation, validity and reliability and data analysis. The chapter concludes by outlining how the ethical code of conduct regarding research will be observed.

3.2 Objectives of the study

The objectives below are aligned to the aim of the study, namely waste management practices amongst manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal:

- to establish the types of waste generated and the waste disposal measures that manufacturing organisations in the iLembe Municipal District employ;
- to investigate the strategies employed by manufacturing organisations in the iLembe Municipal District to minimise waste;
- to identify the drivers of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District; and
- to identify the barriers hampering the adoption of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District.

3.3 Research Design

A research design, according to Creswell (2014: 12), provides a conceptual framework or blueprint for conducting research. It serves as a framework for the collection of data, measurement, and analysis. William (2021) posits that the research design can be thought of as the structure of the research as it is the “glue” that holds all the elements in a research project together. Thakur (2021) asserted that the research design refers to the plan that the researcher will adopt to combine the many components of the study in a coherent and logical manner to aid the researcher in effectively solving the research problem.

This study seeks to meet its aim and objectives by carrying out an empirical investigation. A quantitative research method was utilised to obtain primary information. The quantitative approach attempts to maximise the objectivity, replicability and generalisability of results, and are typically interested in prediction. It entails using numbers to make assertions, provide evidence, describe phenomena, and determine relationships or correlations.

According to Morrow (2021) and Sukamolson (2007), quantitative research comes in various forms. For instance, it may be categorised as survey, experimental, correlational, or causal-comparative research. The survey research method will be employed by the researcher in this investigation. Morrow (2021) and Sukamolson (2007) further stated that survey research entails the use of statistical techniques to measure the characteristics of a given population by means of a designed questionnaire and scientific sampling. The advantage of quantitative research is its simplicity of analysis, as the data collected are in numerical and statistical format. Furthermore, quantitative data is consistent in that it can be repeated; there are extremely high levels of reliability; the results can be generalised; the research is anonymous as people are not required to identify themselves with specificity in the data collected; the structure of quantitative research allows for broader studies to take place; and research can be conducted remotely (Gaille, 2019).

3.4 Research Methodology

Patel (2019) refers to methodology as a way to systematically solve a research problem. It may be understood as a science of studying how research is done scientifically. It involves various logical steps that are generally adopted by the researcher while investigating the research problem (Patel, 2019). According to Neuman (2014), methodology involves understanding the entire research process, including its social, philosophical, political and ethical aspects. The survey design method was employed for this study as it is a critical component of measurement, and it allows for the collection of standardised information from a specific population.

3.5 Target population

The target population refers to the total group of individuals from which the sample might be drawn (McLeod, 2019). The term “population” refers to the members of the group being studied, and the term “sample” refers to a small sub-group of those chosen to participate in the study (Goodenough and Waite, 2012). The total target population for this study consists of 262 manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal. The iLembe District lies on the east coast of KwaZulu-Natal (KZN). It includes several industrial areas, including the Ballito Business Park, Shaka’s Head Industrial Park (Ballito), Shaka’s Kraal Industrial Development, Stanger Industrial Development (Extension 15) and Stanger Moolla Industrial Park, amongst other industries (KwaDukuza Municipality, 2022-2023). According to Profile: iLembe District Municipality (2020), there is a total of 262 manufacturing organisations located in the iLembe district. Approximately 45 per cent of producers in the district are located in Isithebe Industrial Estate, with an additional 25 per cent situated in Stanger (iLembe District Municipality, 2015). Manufacturing activities constitute the second-highest contributor to the economy of the iLembe District, immediately following real estate and finance, accounting for an 18.8 per cent share. ‘Food, beverages and tobacco’, subsequent to ‘wood and paper’; ‘metals and machinery’; and ‘petroleum products, chemicals, plastics and rubber are amongst the main sectors that contribute to the manufacturing industry (Profile: iLembe District Municipality, 2020). The sector is also the third largest employer in the region, employing 16.47 per cent of all those employed. The manufacturing organisations that participated in this study include, but are not limited to, plastic, textiles, wood, paper, chemical, petroleum, metal and steel manufacturers. Due to the relatively small size of the target population, the entire population was surveyed. Hence, sampling was not utilised in this study.

3.6 Data collection and measuring instrument

In research, data collection refers to the systematic process of gathering observations or measurements (Bhandari, 2023). Data for this study was gathered by conducting a quantitative study using a standardised closed-ended questionnaire.

Slevitch (2011) states that quantitative research is defined as the systematic investigation of phenomena through the collection of numerical data and the application of statistical, mathematical or computational techniques. Leedy and Ormrod (2001) and Williams (2011) agreed by stating that quantitative research entails gathering data in order to quantify information and apply statistical analysis to either validate or invalidate alternative claims of knowledge.

The researcher chose a questionnaire above other data collection methods because of its convenience. According to Taherdoost (2022), in social science research, a questionnaire serves as one of the most commonly used data gathering tools. A questionnaire's primary goal in an investigation is to gather pertinent data in the most accurate and credible manner achievable. Thus, precision and consistency in survey/questionnaire administration are vital components of the research process as they are associated with validity and reliability.

For this study, a pre-coded, standardised Likert scale questionnaire was utilised. The Likert scale questionnaire consisted of a statement or a question, followed by a series of five answer statements. Respondents chose the option that best corresponded with how they felt about the statement or question. Various contact information was obtained from the internet, over the phone, through interactions with various employees in organisations within the region, and by following up on various suggestions of potential organisations and individuals to contact. The researcher had created an Excel Spreadsheet with the contact details of several manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal. The questionnaires were distributed electronically using a Google Form link. Each participant received a Uniform Resource Locator (URL) via e-mail, LinkedIn and WhatsApp. When the participant received and clicked on the link, they were directed to an online platform where they selected their answers to the questions, and finally clicked submit when they were finished. However, the initial window of the Google Form provides the participant with pertinent information about the purpose of the study and gives the potential participant the option of consenting to participate in the survey or not. If the individual had selected no, the form would not have allowed them to answer the remaining questions. The questions appeared only after the participant agreed. Participants were allowed ten days to complete and submit the questionnaire. Several reminders were directed to the participants during this time. The completed forms were automatically saved and accessed through Google Forms, before being exported into SPSS via Microsoft Excel.

Section A of the questionnaire contains demographic information about the organisation. Sections B, C and D contain a 5-point Likert scale, which is a type of psychometric response scale in which participants specify their level of agreement to a statement in five points: (1) Strongly disagree; (2) Disagree; (3) Neutral; (4) Agree; and (5) Agree strongly. Section B includes questions about the organisation's waste generation and waste management or disposal methods. Section C focuses on strategies used by manufacturing organisations to reduce waste generation in their production practices and packaging, while Section D focuses on the factors that drive waste management practices and the barriers that prevent manufacturing organisations in the iLembe District from adopting sustainable waste management practices.

3.7 Data capturing, coding and analysis

Data must be examined, separated, and re-arranged to discover significant descriptions, patterns and correlations. Data capture refers to any process that transforms the information provided by a respondent into electronic format. This conversion is either automated or involves manual inputting of the collected data (Statistics Canada, 2015). Gimenez (2020) stated that the process of standardising data to ensure that it is correct, consistent and usable is known as data cleaning. Data cleaning also makes it much easier to detect duplicates and correct incorrect or corrupt data (Gimenez, 2020). After cleaning the data, the next step is to code it. Any process that assigns a numerical value to a response is referred to as data coding. Although coding is frequently automated, more complex decisions usually necessitate human intervention (coders) (Statistics Canada, 2015). The method of coding is largely dictated by two considerations (Sultana and Tiba, 2011), namely:

- The way a variable has been measured in the research instrument (for example, is the response to a question descriptive, categorical, or quantitative?); and
- The way the result about a variable is communicated to the readers.

Once the cleaning and coding processes are completed, data analysis can begin (Gimenez, 2015). According to Rubin and Bellamy (2012:68), data analysis is the art of analysing raw data and coming up with conclusions about how best to interpret that data. After gathering data, it must be transformed into an analysis-ready format so that conclusions or new results may be discovered (Hussain, 2020).

In this quantitative research study, the completed questionnaires were collated and numerically referenced to facilitate the process of data capturing. The data was reduced to statistical categories before it could be analysed and interpreted using the Statistical Package for Social Sciences (SPSS), version 27. Charts, graphs and statistics were generated to present the quantitative data.

The following analyses were conducted:

- examining frequency distribution tables and demographic items;
- examining the variability of relevant demographic information and Likert scale items;
- cross-tabulating survey items and average factor scores; and
- conducting appropriate statistical tests on the study hypotheses.

3.8 Pilot testing

Wright (2021) asserts that “pilot testing is a rehearsal of one’s research study that allows one to evaluate one’s research method with a small group of test participants before undertaking the main study”. A pilot test is indispensable because no researcher can prepare a questionnaire perfectly at the first attempt. For this study, a sample of 10 organisations were selected from the original target population, and based on the feedback received, the questionnaire was amended to remove any ambiguities and superfluous questions.

Changes were made to the following areas:

- Under the profile of respondents’ section, Manager was changed to General Manager.

- Under Waste management/disposal methods, Sanitary landfills were changed to Landfills to avoid any confusion.

3.9 Delimitations

The study was conducted only amongst manufacturing organisations based within the iLembe Municipal District in KwaZulu-Natal.

3.10 Validity and Reliability

Middleton (2021) explained that the terminologies' "reliability" and "validity" are used to assess the quality of research. They describe the accuracy with which a method, approach or test measures what it is required to measure. Middleton (2021) further stated that while reliability is concerned with a study's coherence, validity is the extent to which the study accurately examines the particular concept that the researcher wishes to measure. According to Kobus (2016), reliability is the degree of consistency or repeatability of an instrument. The questionnaire's consistency aids in measuring what it is designed to measure in the primary study. The questionnaire will be pilot tested to ensure that it accurately assesses the topics that it is designed to measure. Validity will be determined by comparing the questions in the data collecting tool to the research objectives to see if they cover all aspects of the study. This will allow the researcher to determine whether the questionnaire accurately measures the variables of interest.

The reliability of the instrument was evaluated by means of internal consistency, as indicated by alpha coefficient reliability or Cronbach's Alpha. Tavakol (2011) reported that the Cronbach's Alpha coefficient is a metric of internal coherence that suggests how closely associated a set of items are. Tavakol (2011:54) further asserts that "a reliability co-efficient lower than 0.50 is considered unacceptable; if it falls between 0.50 and 0.60, it is regarded as significant, and if it is above 0.70, it is good and acceptable." Moreover, the measurement instrument has been reviewed by an accredited and experienced statistician to obtain independent feedback. This study's aggregate Cronbach Alpha is 0.70, which indicates that there is an acceptable degree of reliability in this investigation.

Table 3. 1: Aggregate Cronbach Alpha

Four Objectives:	**Cronbach Alpha:**
• to establish the types of waste generated and the waste disposal measures that manufacturing organisations in the iLembe Municipal District employ;	0.70
• to investigate the strategies employed by manufacturing organisations in the iLembe Municipal District to minimise waste;	0.854
• to identify the drivers of sustainable waste management practices among manufacturing organisations in the iLembe Municipal District and	0.812
• to identify the barriers hampering the adoption of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District.	0.434
AGGREGATE CRONBACH ALPHA:	**<u>0.70</u>**

3.11 Analysis of data

3.11.1 Challenges encountered during the data collection process

Due to the paucity of information available pertaining to waste management practices amongst manufacturing organisations in iLembe, obtaining contact information for the relevant organisations proved extremely difficult. The researcher had to search the internet for contact information and, where possible, requested recommendations from random entities in the iLembe Municipal District.

The total number of organisations surveyed was 262, but when the statistics were calculated and drawn from SPSS only 191 questionnaires were completed by participants and received for the purpose of this study. Out of the 191 responses, only

184 responses were deemed credible for use for in the data analysis. This means that only 70 per cent of the survey's intended target population had successfully responded. The questionnaire was submitted to only one participant from each organisation to ensure that respondents from the same organisations do not purposefully manipulate or influence the results by responding in the same way. Furthermore, data is more manageable when kept as one per organisation, and it is easier to track which organisation or participant from an organisation responded and who did not.

The survey was developed using the Google Forms software application. Google Forms is a survey management application that helps individuals and businesses create online surveys and questionnaires to collect and organise information. Questionnaires were distributed electronically via email, WhatsApp and LinkedIn. Where participants did not have an email address, the questionnaire had to be sent to them via WhatsApp.

The survey's instrument was initially designed in a way that participants were required to provide their email address in order to be eligible to participate in the survey as this could have assisted the researcher in identifying which participant had responded and who did not. As a result, the response rate was extremely low because most participants preferred to remain anonymous.

When the researcher sought an explanation from certain participants as to why they did not complete the survey, some indicated that they preferred not to disclose their email addresses because they were concerned that disclosing this information could be traced back to them. The survey's response rate only strengthened following the researcher’s removal of this requirement.

The researcher found it increasingly difficult to determine who had completed the survey and who had not as the responses began to accumulate on the Google Forms Web Application. This also made it exceedingly difficult to direct alerts to individual organisations, so the researcher had to distribute group emails to potential participants to remind them to respond to the survey without frustrating respondents who had already completed the questionnaire.

Several group reminders were directed to potential participants via e-mail, LinkedIn and WhatsApp to encourage them to complete and submit the questionnaires so that the researcher could begin the data cleaning and analysis process. Potential participants were also contacted via cellular phone and telephonically to inquire about their participation in the survey.

3.11.2 Opportunities for further research

The survey explored only four objectives, but additional information on the barriers preventing manufacturing organisations in the iLembe Municipal District from adopting sustainable waste management practices remains to be gathered.

3.11.3 Limitations of the study

This survey was designed specifically for Manufacturing companies in the iLembe Municipal District. Although a significant amount of data was available as this study pertains to a real-world problem, participation from groups outside the area was prohibited.

3.12 Ethical considerations / confidentiality and anonymity

The purpose of ethical consideration in research is to protect participants from the potentially negative effects of research activities (Marshall and Rossman, 2014:73). The researcher assured the participants that stringent confidentiality would be maintained and that they would not be required to divulge any personal information about themselves. The empirical study was carried out in accordance with the Durban University of Technology's research ethics policy and procedures. Ethical clearance for the present investigation was acquired from the Durban University of Technology's Institutional Research Ethics Committee (refer to Annexure A). The research participants provided informed consent. Letters of Information and Consent are included in Annexure B and were forwarded to potential participants from the manufacturing organisations in iLembe. The researcher assured the participants that strict confidentiality would be maintained and that they would not be required to reveal any details about themselves, as the privacy and confidentiality of participants are areas of great consideration in terms of ethics and according to the Protection of

Personal Information Act of South Africa (POPIA). Consequently, the identities of all research participants will be kept confidential, and their privacy and anonymity will be respected.

3.13 Conclusion

This chapter described the primary elements of the research approach and design employed for the present study. The data collection method, study limitations and measures taken to avoid partiality throughout the research process were all discussed here. The deliberations were concluded by real-world activities such as data collection and analysis, followed by ethical considerations.

Chapter Four focuses on analysing the analysis. The results of the survey will be presented, analysed and the empirical research results will be reviewed.

CHAPTER FOUR

PRESENTATION OF RESULTS AND ANALYSIS

4.1 Introduction

The preceding chapter offered a discussion on the research methodology of this study. This chapter analyses and reports on the results generated after executing the statistical techniques identified in Chapter 3.

This chapter focuses on the data analysis and interpreting the results. Thus, the results are analysed using various tables and numerical cross-tabulations. Responses from participants were directed towards establishing the nature and extent to which manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal have adopted sustainable waste management practices. The researcher was able to effectively interpret the results from the study by analysing and testing relevant areas of the chapter while linking them to the literature review. Comparative descriptive statistics, correlation analysis, chi-square tests, t-tests, central tendency descriptive statistics, and the interpretation of the findings are discussed in this chapter.

4.2 Descriptive statistics

Hillier (2023) stated that “the term descriptive statistics refers to the analysis, summary, and presentation of findings related to a data set derived from a sample or entire population”. Descriptive statistics are an essential component of the results and should be examined carefully by the reader and presented in a logical and comprehensive manner by the authors. They are provided in the text, tables and figures.

Tables and figures are most useful when there is a large sample size and when there is a variety of important demographic and clinical characteristics that need to be summarised. Descriptive statistics provide the necessary information for the reader to interpret the results and determine if they can be applied as a critical component of evidence-based practice (Fulk, 2023).

Descriptive analysis also incorporates frequencies, measures of central tendency, and measures of dispersion. The following Likert scale metrics will be employed to interpret the results:

1. Strongly disagree
2. Disagree
3. Neutral / uncertain (that is, neither disagree nor agree)
4. Agree
5. Strongly agree.

4.3 Measures of Central Tendency in descriptive statistics

According to Taylor (2022), measures of central tendency are general measures that summarise a range of data with a single value that accurately reflects the characteristic of the data. In addition, central tendency is a category of descriptive statistics that includes the variability (dispersion) of a set of data (Taylor, 2023). Fulk (2023) states that the mean, median and mode are the three main measures of central tendency. In this study, the mean is used.

The mean is the arithmetic average value, median the middle value and mode the most common value in a series of observations (Hayes, 2023). As indicated by Calzon (2023), a mean signifies the numerical average of several responses. When analysing a collection of data or a number of data constructs, it represents the central value of a specific set of numbers. It symbolises the sum of the values divided by the total number of values within a range of data. Arithmetic mean, average and mathematical expectations constitute additional expressions for the concept (Calzon, 2023).

Wanjohi and Syokau (2021) explained that "a Likert scale mean scoring evaluates the attitude that was determined based on the argument that a mean score of 3 in the Likert scale represents a neutral attitude, a mean score of less than 3 represents a negative attitude, and greater than 3 represents a positive attitude". The range of interpreting the Likert scale mean score was presented as follows: 1.0-2.4 (Negative attitude), 2.5-3.4 (Neutral attitude), and 3.5-5.0 (Positive attitude)".

4.4 Chi-square test

McClenaghan (2023) states that the Pearson's chi-squared test, frequently referred to as the χ^2 test, is a statistical hypothesis test used in the analysis of categorical variables to evaluate whether observed data deviate from expectations. The interpretation of a chi-square test relies on the following conditions (Bevans, 2022):

- If the p-value is less than or equal to 0.05, there is a statistically significant relationship.
- If the p-value is greater than 0.05, there is NO statistically significant relationship.

Turban (2020) agrees and states that chi-squared tests are a commonly used non-parametric test, meaning that they do not assume the distributions of the data involved (for example, a normal distribution). Rather, the test relies on the Chi-squared distribution, a theoretical distribution of values for a population.

The chi-square test is examined under three titles, namely the Goodness of fit test, Homogeneity test and Independence test, depending on its purpose and condition of application. In this study, the independence test was used. Turner (2022) explained that the Independence test determines whether there is an association between categorical variables (that is, whether the variables are independent or related). It is a non-parametric test that draws conclusions about a population from a sample Turner (2022) added that in order to perform a chi-square test of independence, the best way to organise one's data is a type of frequency distribution table called a contingency table, also known as a cross-tabulation or crosstab, which demonstrates the number of observations in each combination of groups.

4.5 Cross-tabulations

According to Yatmar, Ramli, Pasra, and Ikbal (2022), a cross-tabulation is characterised by the presence of two or more variables with a link, often in the form of qualitative data. It is typically applied to categorical data, which can be divided into mutually exclusive groups and a crosstab sub-menu presents data in a tabular format that consists of rows (Aprameya, 2016) and columns (Gupta, 2023). It is used to examine relationships within data that may not be readily apparent (Faridi, 2017). Many studies suggest that cross-tabulation is one of the most preferred methods of analysing market research or survey data and can be done through tools such as the Statistical Package for the Social Sciences (SPSS), Statistical Analysis System (SAS), and Microsoft Excel (Aprameya, 2016).

4.6 Cronbach alpha reliability tests

Bujang, Omar and Baharum (2018) state that Cronbach's alpha is a measure of the internal consistency or reliability between several statements (items), metrics or ratings. It measures the reliability of a questionnaire's (or a domain of a questionnaire's) responses, an instrumentation, or a rating provided by respondents which will indicate the stability of the tools.

According to Tavakol and Dennick (2011), Lee Cronbach established alpha in 1951 as a way to gauge the internal consistency of a rating system or test. It is represented by a numerical value between 0 and 1. The ability to reconstruct the same results from a study if it is repeated is referred to as 'reliability'. Reliability and validity are key concepts in determining the quality of research conducted (Mohajan, 2017). The reliability of the research instrument for this study was determined by the Cronbach's Alpha value. George and Mallery (2019) provided the rule of thumb for assessing the Cronbach's Alpha value for a dichotomous or Likert scale instrument. The alpha values are presented in Table 4.1 below.

Table 4. 1: Characteristic interpretations for various Cronbach Alpha values

Cronbach's Alpha	**Internal consistency**
$0.9 \leq \alpha$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Source: George and Mallery (2019); Bobbitt (2021)

The Cronbach's Alpha has a value between 0 and 1. The closer the Cronbach's Alpha value to 1, the greater the level of internal consistency of the item within the scale (Faculty Survey of Student Engagement (FSSE), 2017). According to George and Mallery (2019), a Cronbach's Alpha value above 0.90 indicates excellent internal consistency; above 0.80 is good; above 0.70 is acceptable; above 0.60 is questionable; above 0.50 is poor; and below 0.50 is unacceptable.

Alpha if Item Deleted is probably the most important column in a table as it represents the scale's Cronbach's alpha reliability coefficient for internal consistency if the individual item is removed from the scale (Gliem and Gliem, 2003). The elimination of less-reliable items should be based not only on a statistical basis but also on a theoretical and logical basis. In addition, it is recommended that the whole sample be divided into two and cross-validated (Kopalle and Lehmann, 1997).

Having described the tools and techniques used in this chapter, Section A presents and discusses the response rates of participants in this study, in addition to the profiles of respondents.

SECTION A:

Section A considers the demographic information of participants and the response rate of participants, in addition to the profiles of the respondents.

4.7 Response rate

This section was established to determine the total number of respondents who participated in this research study. Table 4.2 indicates the total population, the total number of survey responses, and the percentage of usable responses.

Table 4. 2: Response rate

TOTAL POPULATION	**262**
TOTAL RESPONSES	184

USABLE REPONSE RATE	70.23%

The researcher distributed 262 questionnaires to organisations in the study area, and 184 questionnaires were completed and submitted by participants, representing a response rate of 70.23 per cent. The response rate was adequate for drawing meaningful conclusions and was considerably higher than the response rate to a similar study conducted in Windsor, United States of America, where a response rate of 31.3 per cent from a sample size of 230 organisations was deemed acceptable for drawing meaningful conclusions (Coalition for American Electronics Recycling, 2013). The empirical research results are presented, analysed and discussed below in accordance with the research instrument's questions.

4.8 Profile of Respondents

The following sub-section presents the profiles of respondents in discrete and continuous data, which considers their occupational levels, age categories, levels of education and forms of ownership. The tables below contain Count to indicate the quantity of respondents and percentages (%) to indicate the frequency of responses.

4.8.1 Occupational levels

The occupational levels of the respondents are shown in Table 4.3 below. The purpose of this subset was to identify which occupational level the majority of the respondents belonged to.

Table 4. 3: Occupational levels of respondents

Occupational Levels		Total
Proprietor	Count	22
	% of Total	12.0%
General manager	Count	18
	% of Total	9.8%
Production manager	Count	31
	% of Total	16.8%
Head of department / Supervisors	Count	56
	% of Total	30.4%

Other	Count % of Total	57 31.0%
Total	Count % of Total	184 100%

The majority of the respondents in this segment, at 31.0 per cent, had selected Other, which included a variety of employment categories that were not specified in the above table. Heads of Department / Supervisors accounted for 30.4 per cent and had the second highest response rate. Production managers accounted for 16.8 per cent and had the third highest response rate. The remaining occupational levels were General managers at 9.8 per cent and proprietors at 12.0 per cent.

4.8.2 Age categories

The age groups of the respondents are shown in Table 4.4 beneath. Age was classified into three groups: 18-34 years, 35-59 years, and 60 years and above. The aim of this table was to determine which age group most of the respondents belonged to.

Table 4. 4: Age categories of the participants

Age range		**Total**
18-34yrs	Count % of Total	51 27.7%
35-59yrs	Count % of Total	118 64.1%
60+yrs	Count % of Total	15 8.2%
Total	Count % of Total	184 100%

The age group 35-59 years made up the highest representation of responses at 64.1 per cent. The second highest representation consisted of participants between the ages of 18-34 at 27.7 per cent. Respondents 60 years and beyond made up the lowest representation of respondents at 8.2 per cent.

4.8.3 Level of Education

Table 4.5 indicates the educational qualification of the respondents in this study. The objective of this table was to determine the diverse educational levels of the respondents.

Table 4. 5: Level of Education

Level of educational qualification		Total
Grade 12	Count % of Total	54 29.3%
Diploma/Degree	Count % of Total	69 37.5%
Postgraduate degree	Count % of Total	16 8.7%
Other	Count % of Total	45 24.5%
Total	Count % of Total	184 100%

Table 4.5 displays the distribution of respondents by level of education, with Diploma or a degree, Grade 12, Other, and Postgraduate degree at 37.5%, 29.3%, 24.5%, and 8.7% respectively.

4.8.4 Forms of Ownership

Table 4.6 depicts the various types of ownership to which the respondents belong. The objective of this table was to determine which form of ownership the majority of the respondents belong to.

Table 4. 6: Forms of Ownership

Forms of ownership		Total
Sole proprietorship	Count % of Total	42 22.8%
Partnership	Count % of Total	24 13.0%
Closed Corporation	Count % of Total	14 7.6%

Private Company	Count % of Total	67 36.4%
Public Company	Count % of Total	37 20.1%
Total	***Count*** ***% of Total***	**184** **100%**

According to Table 4.6, 36.4 per cent of respondents work for privately owned businesses, which represented the majority of the respondents. Sole proprietorships account for 22.8 per cent of all businesses. Public companies accounted for 20.1 per cent, partnerships accounted for 13.0 per cent, while responders from Closed Corporations received the lowest response rate at 7.6 per cent.

The demographic information from this study can be compared to that of Govender (2016). In terms of cohorts used, the studies were similar in that they both focused on waste management and were aimed at South African organisations, specifically those in the KwaZulu-Natal region of South Africa.

Having presented the profiles of respondents both in discrete and continuous data, the next section (B) discusses the level of participation from diverse sectors of raw materials and finished products, types of waste generated, and methods used by manufacturing organisations in the iLembe Municipal District to dispose of their waste.

SECTION B:

The purpose of Section B is to establish whether the manufacturing sectors in the Municipal District of iLembe are using environmentally conscious methods for managing waste. The following subsections will be explored: sectors of raw materials and finished products, types of waste generated, and various methods utilised by manufacturing organisations in the iLembe Municipal District to dispose of their waste.

4.9 Sectors of raw materials and finished products

The primary objective of this sub-set was to establish the level of participation from various types of manufacturing organisations in the Municipal District of iLembe. Table

4.7 displays the frequencies and percentages of responses for each of the alternatives presented below.

Table 4. 7: Sectors of raw materials and finished products

Sectors of raw materials and finished products		**Total**
Automotive components	Count % of Total	14 7.6%
Electrical machinery; Apparatus	Count % of Total	15 8.2%
Food; Beverages; Tobacco	Count % of Total	50 27.2%
Furniture manufacturing	Count % of Total	15 8.2%
Metal products; Machinery; Equipment	Count % of Total	21 11.4%
Paper; Printing	Count % of Total	18 9.8%
Petroleum; Chemical products	Count % of Total	14 7.6%
Plastic; Rubber products	Count % of Total	19 10.3%
Textiles; Clothing; Leather goods	Count % of Total	18 9.8%
Total	***Count*** ***% of Total***	**184** **100%**

4.9.1 Interpretation of the data:

Table 4.7 illustrates various sectors of raw materials and final product manufacturing sectors such as Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products manufacturing sector and Textiles, Clothing and Leather goods manufacturing sector at 7.6%, 8.2%, 27.2%, 8.2%, 11.4%, 9.8%, 7.6%, 10.3% and 9.8% respectively.

The Food, beverage and tobacco sector had the highest response rate at 27.2 per cent. Metals, Metal Products, Machinery and Equipment received the second highest response rate at 11.4 per cent. The Petroleum and Chemical products sector and the Automotive components manufacturing sector received the lowest response rate at 7.6 per cent.

4.10 Types of waste generated by Manufacturing organisations in the iLembe Municipal District

The objective of this sub-section is to determine the types of waste generated by manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal. Respondents were allowed to select more than one options in this respect. The frequencies and percentages of their responses for each of these options are presented in Table 4.8 below.

Table 4. 8: Types of waste generated in the Municipal District of iLembe in KwaZulu-Natal

Types of waste generated in iLembe		**Total**
Chemical Waste	Count	56
	% of Total	30.4%
Solid Waste	Count	55
	% of Total	29.9%
Metal waste	Count	54
	% of Total	29.3%
Plastic waste	Count	53
	% of Total	28.8%
Other	Count	50
	% of Total	27.2%
Toxic waste	Count	49
	% of Total	26.6%
Food processing waste	Count	48
	% of Total	26.1%
Used Lubricants	Count	45
	% of Total	24.5%
Electronic waste	Count	40
	% of Total	21.7%
Wood and paper waste	Count	37
	% of Total	20.1%

Laboratory waste	Count % of Total	37 20.1%
Radioactive	Count % of Total	8 4.3%

4.10.1 Interpretation of the data:

According to Table 4.8, the types of waste generated by manufacturing organisations in the Municipal District of iLembe are Chemical waste, Solid waste, Metal waste, Plastic waste, Other waste, Toxic waste, Food processing waste, Used Lubricants Electronic waste, Wood and paper waste, Laboratory waste and Radioactive waste at 30.4%, 29.9%, 29.3%, 28.8%, 27.2%, 26.6%, 26.1%, 24.5%, 21.7%, 20.1%, 20.1% and 4.3% respectively.

Chemical waste is the most prominent type of waste generated in the Municipal District of iLembe, accounting for 30.4 per cent, while radioactive waste accounts for 4.3 per cent.

4.11 Methods used by manufacturing organisations in the iLembe Municipal District to dispose of their waste

Several options were presented to respondents via a Likert scale questionnaire in respect of how their organisation's waste is disposed of, as well as the level of agreement and disagreement for each option. The sub-sections below provide information on waste re-used to manufacture other products, recycling in-house, incineration, landfills, amongst others.

4.11.1 Waste re-used to manufacture other products

The purpose of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal re-used their waste to manufacture other products. Table 4.9 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their level of agreement on re-using their waste to manufacture other products.

Table 4. 9: Waste re-used to manufacture other products

Waste re-used to manufacture other products	Disagree (N=74)	Agree (N=110)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p<0.001	
Automotive components	3 (4.1%)	11 (10.0%)	1.000	14 (7.6%)
Electrical machinery; Apparatus	6 (8.1%)	9 (8.2%)	1.000	15 (8.2%)
Food; Beverages; Tobacco	34 (45.9%)	16 (14.5%)	<0.001	50 (27.2%)
Furniture manufacturing	1 (1.4%)	14 (12.7%)	0.051	15 (8.2%)
Metals; Metal products; Machinery; Equipment	4 (5.4%)	17 (15.5%)	0.563	21 (11.4%)
Paper; Printing	8 (10.8%)	10 (9.1%)	1.000	18 (9.8%)
Petroleum; Chemical products	4 (5.4%)	9 (8.2%)	1.000	13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	0 (0.0%)	1 (0.9%)	1.000	1 (0.5%)
Plastic; Rubber products	1 (1.4%)	18 (16.4%)	0.008	19 (10.3%)
Textiles; Clothing; Leather goods	13 (17.6%)	5 (4.5%)	0.049	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.11.1.1 Interpretation of the data:

According to Table 4.9, most of the respondents, at 59.8 per cent, agreed that manufacturing organisations in the iLembe Municipal District were committed to re-using waste to manufacture other products, while 40.2 per cent disagreed.

The majority of the respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector and the Plastic and Rubber products manufacturing sector agree with the re-use of waste to manufacture other products at 10.0%, 8.2%, 12.7%, 15.5%, 9.1%, 8.2%, 0.9% and 1.4% respectively.

In the remaining sectors, 45.9 per cent of respondents in the Food, Beverage and Tobacco manufacturing sector and 17.6 per cent in the Textiles, Clothing and Leather goods sector had disagreed with the re-use of waste to manufacture other products.

The p-values for the Food, Beverage, and Tobacco manufacturing sector; Furniture manufacturing sector; Plastic and Rubber products; and the Textiles, Clothing and Leather goods sectors indicate a significant level of association between these sectors and the re-use of waste to manufacture other products with p-values less than the 0.05 level of significance at 0.001, 0.008 and 0.049 respectively. The null hypothesis is thus rejected. This indicates that these sectors are more likely than the rest to re-use their waste to manufacture other products.

4.11.1.2 Discussion:

The examples of waste re-used for manufacturing other products are tremendous. In an investigation of manufacturing organisations in Beni, Democratic Republic of the Congo, 53 percent of respondents agreed that manufacturing organisations in Beni City had adopted the re-use strategy (Jolie, 2022). The results emphasised the importance of an effective waste reduction strategy to help the organisation maintain control over the inputs, intermediate goods, finished goods and sources of waste, *inter alia* (Jolie, 2022).

Visvanathan, Parasnis and Janesiripanich (1998) conducted an environmental audit in a Thai rice cracker factory. The factory was experiencing environmental issues that hampered the operation of the Effluent Treatment Plant (ETP). The main issue was inadequate waste management as a result of the rice cracker manufacturing process, which included soaking, cooking and washing. This resulted in water waste, noise, high temperatures, and dust. An environmental audit was then conducted which identified the possibility of a 25 per cent reduction in water consumption by re-using the water, segregation of waste and solids recovery, assisting in increasing not only the operational efficiency of ETP but also in bringing financial benefits to the company.

According to a study by Li, Qin, Zhu and Zhang (2023), manufacturers of electrical and electronic products and recycling businesses are progressively integrating. Collectively, these organisations have created a reverse recycling network to prevent illegal confidential dismantling and enhance the rate at which waste electrical and electronic equipment and materials are recovered during the recycling process (Shan and Yang, 2020). Metals and plastics that have been re-purposed from further processing are immediately re-used in the manufacture of novel electrical and electronic goods, resulting in a material closed-loop process. This loop serves as a model for China and helps to steer the entire industry toward green and low-carbon processes. GEM is the first company listed for urban mining and has established 16 waste recycling and new energy material parks in 11 provinces and municipalities in China, while also addressing global technical challenges and making breakthroughs at key technical bottlenecks for green treatment and recycling of waste batteries, WEEE, waste plastics and scrap vehicles. GEM is now the world's leading waste recycling enterprise (Li, Qin, Zhu and Zhang, 2023).

In an alternative study, Wansia, D'Ansa, Gondaa, Segatoa and Degreza (2018) highlighted that "the recycling potential of neodymium and tantalum from end-of-life mobile phones is significant, given the large amounts of mobile phones that are discarded every year worldwide". The authors further emphasised that "the separation techniques used in this study were easily transferable to a larger scale. In order to reduce the costs associated with the manual dismantling step, mobile phones could be mechanically pre-treated in a work integration social enterprise". Mobile phones could be disassembled manually into component parts such as plastic structures, metal structures, PCAs, batteries, amongst other things. Moreover, there are alternative uses for engineering thermoplastic polymer-based plastic frames besides energy recovery. Given the high proportion of plastics in the total weight of mobile phones, re-using them would aid in meeting the minimum recycling target (Wansia, D'Ansa, Gondaa, Segatoa and Degreza, 2018).

4.11.2 Recycling in-house as a waste disposal method

The aim of this sub-section was to determine whether manufacturing organisations in iLembe recycled their waste in-house as a waste disposal method. Table 4.10 depicts the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the use of recycling waste in-house as a frequent waste disposal method.

Table 4. 10: Recycling in-house as a waste disposal method

Waste recycled in-house	Disagree (N=71)	Agree (N=113)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.002	
Automotive components	3 (4.2%)	11 (9.7%)	1.000	14 (7.6%)
Electrical machinery; Apparatus	6 (8.5%)	9 (8.0%)	1.000	15 (8.2%)
Food; Beverages; Tobacco	29 (40.8%)	21 (18.6%)	0.012	50 (27.2%)
Furniture manufacturing	3 (4.2%)	12 (10.6%)	1.000	15 (8.2%)
Metals; Metal products; Machinery; Equipment	5 (7.0%)	16 (14.2%)	1.000	21 (11.4%)
Paper; Printing	7 (9.9%)	11 (9.7%)	1.000	18 (9.8%)
Petroleum; Chemical products	4 (5.6%)	9 (8.0%)	1.000	13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (1.4%)	0 (0.0%)	1.000	1 (0.5%)
Plastic; Rubber products	2 (2.8%)	17 (15.0%)	0.110	19 (10.3%)
Textiles; Clothing; Leather goods	11 (15.5%)	7 (6.2%)	0.449	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.11.2.1 Interpretation of the data:

According to Table 4.10, the majority of the respondents, at 61.42 per cent, agreed that manufacturing organisations in the iLembe Municipal District were committed to recycling waste in-house as a waste disposal method, while 38.58 per cent disagreed.

The majority of respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector and the Plastic and Rubber products sector agree with the recycling of waste in-house as a waste disposal method at 9.7%, 8.0%, 10.6%, 14.2%, 9.7%, 8.0% and 15.0% respectively.

In the remaining sectors, 40.8 per cent of respondents in the Food, Beverage and Tobacco manufacturing sector; 1.4 per cent in the Petroleum and Chemical products: Foam manufacturer and 15.5 per cent in the Textiles, Clothing and Leather goods sector disagreed with the recycling of waste in-house as a waste disposal method.

The p-value for the Food, Beverage and Tobacco manufacturing sector at 0.012 indicates a significant level of association with the recycling of waste in-house as a waste disposal method, as the p-value is less than the 0.05 level of significance. Therefore, the null hypothesis is rejected. This implies that this sector is more likely than the rest to recycle their waste in-house as a waste disposal method.

4.11.2.2 Discussion:

Elsheikh, Panchal, Shanmugan, Muthuramalingam, El-Kassas and Ramesh (2022) presented a comprehensive review of Wood-plastic composite (WPC) manufacturing techniques, including the pre-processing of composite ingredients and post-processing of WPC products. WPC is a composite material made of plastic as a matrix and wood as filler (Gardner, Han and Wang, 2015). Recycling WPC lowers the cost of raw materials whilst also conserving the environment and providing economic benefits. Waste WPC may result from the manufacturing process or from post-consumer sources. The main advantage of in-house recycling is the reduced cost of material collection and transportation (Elsheikh, Panchal, Shanmugan, Muthuramalingam, El-Kassas and Ramesh, 2022). The constituent materials are preserved in their original forms, as with other composite materials, and are incorporated to create a new composite material at low cost. It exists in planks or beams and can be used in a variety of applications such as outdoor deck floors, railings, park benches, car door linens, car seat backs, fences, door and window frames, timber-plate structures, and indoor furniture (Haque, Goda, Ogoe and Sunaga, 2019).

On a positive note, in Table 4.10, a majority of the respondents at 61.42 per cent agreed, while 38.58 per cent disagreed with recycling in-house as a waste disposal method.

4.11.3 Incineration as a waste disposal method

The objective of this sub-section was to determine whether or not manufacturing organisations in iLembe incinerated their waste as a waste disposal method. Table 4.11 presents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the use of incineration as a common waste disposal method.

Table 4. 11: Incineration as a waste disposal method

Incineration	Disagree (N=96)	Agree (N=88)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p<0.001	
Automotive components	5 (5.2%)	9 (10.2%)	1.000	14 (7.6%)
Electrical machinery; Apparatus	5 (5.2%)	10 (11.4%)	1.000	15 (8.2%)
Food; Beverages; Tobacco	44 (45.8%)	6 (6.8%)	<0.001	50 (27.2%)
Furniture manufacturing	7 (7.3%)	8 (9.1%)	1.000	15 (8.2%)
Metals; Metal products; Machinery; Equipment	3 (3.1%)	18 (20.5%)	0.003	21 (11.4%)
Paper; Printing	10 (10.4%)	8 (9.1%)	1.000	18 (9.8%)
Petroleum; Chemical products	3 (3.1%)	10 (11.4%)	0.419	13 (7.1%)
Petroleum; Chemical products: Foam manufacture	1 (1.0%)	0 (0.0%)	1.000	1 (0.5%)
Plastic; Rubber products	14 (14.6%)	5 (5.7%)	0.548	19 (10.3%)
Textiles; Clothing; Leather goods	4 (4.2%)	14 (15.9%)	0.113	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.11.3.1 Interpretation of data:

According to Table 4.11, the majority of respondents at 52.18 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to the incineration of waste as a waste disposal method, while 47.82 per cent agreed.

The majority of respondents for the Food, Beverage and Tobacco manufacturing sector; Paper and Printing sector; Petroleum and Chemical products: Foam manufacture; and Plastic and Rubber products sector disagree with the incineration of waste at 45.8%, 10.4%, 1.0% and 14.6% respectively.

In the remaining sectors, 10.2 per cent of the Automotive components manufacturing sector; 11.4 per cent of Electrical machinery and Apparatus manufacturing sector, 9.1 per cent of the Furniture manufacturing sector, 20.5 per cent of the Metals, Metal products, Machinery and Equipment manufacturing sector, 11.4 per cent of the Petroleum and Chemical products manufacturing sector and 15.9 per cent of Textiles, Clothing and Leather goods manufacturing sector had agreed with the incineration of waste as a waste disposal method.

The p-values for the Food, Beverage and Tobacco manufacturing sector and Metals, Metal products, Machinery and Equipment manufacturing sectors indicate a significant level of association between these sectors and the incineration of waste as a waste disposal method with p-values less than the 0.05 level of significance, at 0.001 and 0.003 respectively. Therefore, the null hypothesis is rejected as these sectors are more likely than the rest to incinerate the waste that they generate.

4.11.3.2 Discussion:

Traditionally, a ban on landfills incentivised waste incineration, and the strategic integration of combined heat and power plants and recycling of waste heat from industry increased energy efficiency in the energy system (Johansen and Werner, 2022). For decades, wealthy countries such as Japan, South Korea, Sweden, Finland and the United Kingdom have relied on incineration to deal with rising consumer and industrial waste. There are over 1 000 incinerators in Japan and over 500 in European countries such as Germany, Sweden and Denmark, which burn thousands of tons of municipal waste each year and use the heat to generate up to 4.2 gigatonnes in Japan and 10.5 gigatonnes in Europe (Wachpanich and Coca, 2022). However, Wachpanich and Coca (2022) further stated that incineration is no longer considered green or renewable in the most recent European Union taxonomy, which specifies how the bloc's 19 member states deploy systems and technologies related to renewable energy and waste reduction. Incinerators will be required to pay a carbon tax for their emissions in Germany and, most likely, other countries soon after.

According to several Doctors from the University of Sydney, Dr Dembek, Dr Moglia, Dr Nygaard, Dr Taffe and Dr Woodcock (2021), the advantage of waste incineration is that it reduces emissions from landfills and the environment, which more than offsets the emissions associated with transporting and burning the waste. However, the net effect of burning waste versus depositing it in landfills makes it a viable climate mitigation action, but only in the short-term as there are other, more environmentally friendly solutions, such as anaerobic digestion of food waste; gasification of combustible waste; and plastic waste recycling, amongst others, which can be used as it results in greater reductions in greenhouse gas emissions than incineration.

4.11.4 Landfills as a waste disposal method

The aim of this sub-section was to establish whether manufacturing organisations in iLembe used landfills as a common waste disposal method. Table 4.12 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the use of landfills as a common waste disposal method.

Table 4. 12: Landfills as a waste disposal method

Landfills	Disagree (N=106)	Agree (N=78)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p<0.001	
Automotive components	4 (3.8%)	10 (12.8%)	0.266	14 (7.6%)
Electrical machinery; Apparatus	6 (5.7%)	9 (11.5%)	1.000	15 (8.2%)
Food; Beverages; Tobacco	41 (38.7%)	9 (11.5%)	<0.001	50 (27.2%)
Furniture manufacturing	12 (11.3%)	3 (3.8%)	1.000	15 (8.2%)
Metals; Metal products; Machinery; Equipment	9 (8.5%)	12 (15.4%)	1.000	21 (11.4%)
Paper; Printing	11 (10.4%)	7 (9.0%)	1.000	18 (9.8%)
Petroleum; Chemical products	3 (2.8%)	10 (12.8%)	0.166	13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (0.9%)	0 (0.0%)	1.000	1 (0.5%)
Plastic; Rubber products	11 (10.4%)	8 (10.3%)	1.000	19 (10.3%)
Textiles; Clothing; Leather goods	8 (7.5%)	10 (12.8%)	1.000	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.11.4.1 Interpretation of the data:

According to Table 4.12, the majority of the respondents at 57.61 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to the utilisation of landfills as a waste disposal method, while 42.39 per cent agreed.

The majority of the respondents for the Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Paper and Printing sector, Petroleum; Chemical products: Foam manufacturing sector and, Plastic and Rubber products manufacturing sector disagree with the utilisation of landfills as a waste disposal method at 38.7%, 11.3%, 10.4%, 0.9% and 10.4% respectively.

In the remaining Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector and the Textiles; Clothing and Leather goods manufacturing sector had agreed with the utilisation of landfills of waste as a waste disposal method at 12.8%, 11.5%, 15.4%, 12.8% and 12.8% respectively.

The p-values for the Food, Beverage and Tobacco manufacturing sector at 0.001 indicate a significant level of association with the incineration of waste as a waste disposal method as the p-value is less than the 0.05 level of significance. Therefore, the null hypothesis is rejected as this sector is more likely than the rest to use landfills as a waste disposal method.

4.11.4.2 Discussion:

Several countries are grappling with inefficient waste management strategies in which waste is disposed of or incinerated without further consideration. The EU waste hierarchy includes a prioritised list of measures, with prevention being the most beneficial option and disposal (for example, landfill) being the least beneficial. As a result, countries are enforcing stricter waste treatment regulations to address the serious impacts of landfills on workers and the environment (Fasting, 2019).

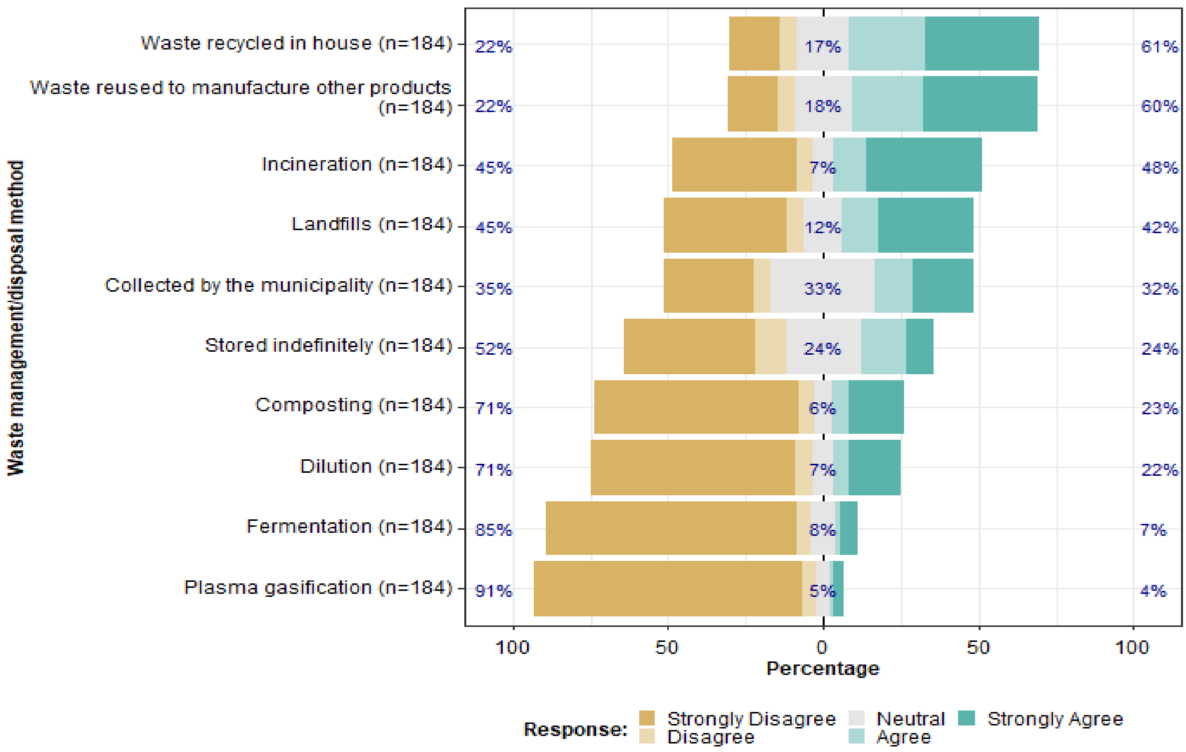
According to Jewaskiewitz (2022), president of the Institute of Waste Management of Southern Africa (IWMSA), every year, nearly 100 million tons of waste are sent to over 800 landfills across the country. To put this in context, Jewaskiewitz (2022) stated that there is enough waste each day to occupy a football field 10 meters deep. Only about 10% of this waste is diverted from landfills. One of the main reasons is that landfill is still the most cost-effective way to dispose of waste (Keerthana, 2022).

Leachate is a dark liquid produced by the solid waste disposal in an aerobic environment. It is frequently employed in the context of landfilling putrescible or industrial waste (Abdel-Shafy and Mansour, 2018). Youcai (2018) defines leachate as “a liquid that has dissolved or entrained environmentally hazardous substances that may then enter the environment. Toxic organic and inorganic pollutants, heavy metals, ammonia nitrogen compounds, and other dissolved and suspended contaminants are common in leachate”. According to El-Saadony, Saad, El-Wafai, Abou-Aly, Salem, Soliman, El-Mageed, Elrys, Selim, El-Hack, Kappachery, El-Tarabily and AbuQamar (2023), Landfill leachate (LFL) must be cautiously managed in order to reduce the leachate volume and avoid the unfavourable impact of leachate contamination on the environment.

4.11.5 Waste Management methods

Figure 4.1 illustrates the most common types of waste management methods to the least used waste management methods employed by manufacturing organisations in the iLembe Municipal District in Kwa-Zulu Natal, according to the results obtained from the data analysis conducted for this study.

Figure 4. 1: Waste management methods



4.11.5.1 Interpretation of the data:

According to the data as presented in Figure 4.1, the majority of respondents at 61 per cent agreed that their organisation's waste is recycled in-house. The second highest number of respondents at 60 per cent alluded that their organisation re-uses waste to manufacture other products, while 48 percent indicated that their organisation incinerates their waste. Alternative waste disposal methods that were presented to participants yielded results such as waste collected by the municipality at 32 per cent; waste stored indefinitely at 24 per cent; composting of waste at 23 per cent; and waste dilution at 22 per cent. Evidently, the least common waste disposal methods were dilution at 22 per cent, fermentation at 7 per cent, and plasma gasification at 4 per cent.

4.11.5.2 Discussion:

According to Boysan, Ozer, Has and Murat (2015), the constant increase in population, combined with an increase in living standards, enables the appearance and consumption of new products to meet societal demands, resulting in natural resource depletion. The re-use of recycled packaging and waste as a source of raw material management benefits both the environment and the economy. Jagyasi (2022) concurs and emphasises that recycling helps to reduce the global carbon footprint because the energy required to create new products from recycled materials is less than that required to create new products from scratch.

Having presented and analysed the results in Section B, Section C that follows presents and analyses the results of waste management measures used by manufacturing organisations in the iLembe Municipal District, and evaluates organisational access to necessary resources and effective waste management practices.

SECTION C:

Section C presents and outlines the waste management measures employed by organisations in the iLembe Municipal District. The purpose of this section is to ascertain the extent to which manufacturing organisations in the Municipal District of iLembe embrace environmentally conscious business practices.

4.12 Strategies used by manufacturing organisations in the iLembe Municipal District to manage waste

The strategies used by manufacturing organisations in iLembe include sub-sections such as the forms of ownership that effectively reduce hazardous substances into the environment; manufacturing organisations that effectively reduce hazardous substances into the environment; constant environmental auditing as an internal waste management strategy; necessary resources to design green or eco-friendly products; complies with the application of environmental management; utilisation of waste treatment techniques to reduce toxicity prior to disposal; policy to effectively manage waste; access to necessary resources; the implementation of eco-friendly product design; reduction of water and electricity; and organisational perceptions of waste value and regional waste management.

Several statements were presented to respondents via a Likert scale questionnaire regarding measures used by their organisation to effectively manage waste generated. The subsequent cross-tabulation Tables 13; 14; 15; 16; 17; 18; 19.1; 19.2; 19.3 and 19.4 illustrate and explain the level of association for each option.

4.12.1 Forms of ownership vs. the effective reduction of hazardous substances into the environment

This purpose of this sub-section was to establish which forms of ownership have effectively reduced hazardous substances into the environment. Table 4.13 depicts the various forms of ownership and their level of agreement and disagreement to effectively reducing hazardous substances in the environment.

Table 4. 13: Forms of ownership vs. the reduction of hazardous substances into the environment

Reduction of hazardous substances into the environment	**Disagree (N=114)**	**Agree (N=70)**	**p-value**	**Overall (N=184)**
Forms of ownership			Chi-sq., p = 0.025	
Sole proprietorship	32 (28.1%)	10 (14.3%)		42 (22.8%)
Partnership	18 (15.8%)	6 (8.6%)		24 (13.0%)
Close corporation (CC)	8 (7.0%)	6 (8.6%)		14 (7.6%)
Private company (Pty) (Ltd)	40 (35.1%)	27 (38.6%)		67 (36.4%)
Public company (Ltd)	16 (14.0%)	21 (30.0%)		37 (20.1%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.1.1 Interpretation of data:

According to Table 4.13, most of the respondents at 61.96 per cent disagreed with effectively reducing hazardous substances into the environment, while 38.04 per cent agreed.

The majority of the respondents for Sole proprietorship, Partnership, Close corporation (CC) and Private company (Pty) (Ltd) disagreed with effectively reducing hazardous substances into the environment at 28.1%, 15.8%, 7.0% and 35.1% respectively.

In the remaining sector, 30.0 per cent of respondents in the Public company (Ltd) agreed with effectively reducing hazardous substances into the environment.

The overall p-value of 0.025 in Table 4.13 is less than the 0.05 level of significance, which indicates that there is a statistically significant association between Forms of

Ownership and the effective reduction of hazardous substances into the environment. The null hypothesis is thus rejected. This indicates that a correlation exists between Forms of Ownership and the effective reduction of hazardous substances into the environment.

4.12.2 Manufacturing organisations vs. the effective reduction of hazardous substances into the environment

The aim of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District were effectively reducing hazardous substances into the environment. Table 4.14 below indicates the level of agreement and disagreement amongst various manufacturing sectors to effectively reduce hazardous substances in the environment.

Table 4. 14: Manufacturing organisations vs. the effective reduction of hazardous substances into the environment

Effectively reduces hazardous substances into the environment	Disagree (N=114)	Agree (N=70)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.002	
Automotive components	8 (7.0%)	6 (8.6%)	1.000	14 (7.6%)
Electrical machinery; Apparatus	13 (11.4%)	2 (2.9%)	0.512	15 (8.2%)
Food; Beverages; Tobacco	22 (19.3%)	28 (40.0%)	0.035	50 (27.2%)
Furniture manufacturing	12 (10.5%)	3 (4.3%)	1.000	15 (8.2%)
Metals; Metal products; Machinery; Equipment	18 (15.8%)	3 (4.3%)	0.174	21 (11.4%)
Paper; Printing	8 (7.0%)	10 (14.3%)	1.000	18 (9.8%)
Petroleum; Chemical products	7 (6.1%)	6 (8.6%)	1.000	13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (0.9%)	0 (0.0%)	1.000	1 (0.5%)
Plastic; Rubber products	10 (8.8%)	9 (12.9%)	1.000	19 (10.3%)
Textiles; Clothing; Leather goods	15 (13.2%)	3 (4.3%)	0.716	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.2.1 Interpretation of the data:

According to Table 4.14, most of the respondents at 62 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to effectively reducing hazardous substances into the environment, while 38 per cent agreed.

The majority of the respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products sector and the Textiles, Clothing and Leather goods manufacturing sector disagreed with the effective reduction of hazardous substances into the environment at 7.0%, 11.4%, 10.5%, 15.8%, 6.1%, 0.9%, 8.8% and 13.2% respectively.

In the remaining sectors, 40.0 per cent of respondents in the Food, Beverage and Tobacco manufacturing sector and 14.3 per cent in the Paper and Printing sector agreed with the effective reduction of hazardous substances into the environment.

Given that the p-value for Food, Beverage and Tobacco manufacturing sector at 0.035 is less than 0.05 significant level of association, indications are that there is a correlation with effectively reducing hazardous pollutants into the environment. As a result, the null hypothesis is rejected since this sector is more likely to efficiently reduce hazardous waste compounds in the environment than other industries.

4.12.2.2 Discussion:

Jewaskiewitz (2022) asserts that South Africa is at least 20 to 30 years behind developed nations in implementing modern waste management practices. Organic waste accounts for 30 to 40 per cent of domestic solid waste in South Africa. Paper and packaging account for approximately 10 per cent to 20 per cent of the waste stream, followed by electronic waste and construction and demolition waste. According to Keerthana (2022), South Africa has the potential to divert 60 to 70 per cent of municipal waste away from landfills toward re-use, recycling and recovery. However, this is not the case.

Interestingly, the majority of the respondents (62 per cent) disagreed to effectively reducing hazardous substances into the environment, and only at 38 per cent agreed.

4.12.3 Constant environmental auditing as an internal waste management strategy

The purpose of this sub-section was to identify which types of manufacturing sectors in the iLembe Municipal District had employed constant environmental auditing as an internal waste management strategy. Table 4.15 indicates the level of agreement and disagreement amongst various manufacturing sectors with regard to employing constant environmental auditing as an internal waste management strategy.

Table 4. 15: Constant environmental auditing as an internal waste management strategy

Constant environmental auditing as an internal waste management strategy	Disagree (N=78)	Agree (N=106)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.165	
Automotive components	6 (7.7%)	8 (7.5%)		14 (7.6%)
Electrical machinery; Apparatus	10 (12.8%)	5 (4.7%)		15 (8.2%)
Food; Beverages; Tobacco	14 (17.9%)	36 (34.0%)		50 (27.2%)
Furniture manufacturing	7 (9.0%)	8 (7.5%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	6 (7.7%)	15 (14.2%)		21 (11.4%)
Paper; Printing	9 (11.5%)	9 (8.5%)		18 (9.8%)
Petroleum; Chemical products	6 (7.7%)	7 (6.6%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	0 (0.0%)	1 (0.9%)		1 (0.5%)
Plastic; Rubber products	10 (12.8%)	9 (8.5%)		19 (10.3%)
Textiles; Clothing; Leather goods	10 (12.8%)	8 (7.5%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.3.1 Interpretation of data:

According to Table 4.15, most of the respondents (at 57.61 per cent) agreed to constant environmental auditing as an internal waste management strategy, while 42.39 per cent disagreed.

The majority of the respondents for the Automotive components manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector and the Petroleum and Chemical products: Foam manufacturing sector agree with constant environmental auditing as an internal waste management strategy at 7.5%, 34.0%, 7.5%, 14.2%, 6.6% and 0.9% respectively.

In the remaining sectors, the respondents in the Electrical machinery and Apparatus manufacturing sector, Paper and Printing sector, Plastic and Rubber products sector and Textiles; Clothing and Leather goods sector disagreed with constant environmental auditing as an internal waste management strategy at 12.8%, 11.5%, 12.8% and 12.8% respectively.

The overall p-value for all the sectors listed in Table 4.15 at 0.165 is greater than the 0.05 significant level of association, which implies that no statistically significant correlation exists between the various sectors and the practice of constant environmental auditing as an internal waste management strategy. As a result, the null hypothesis is accepted.

4.12.3.2 Discussion:

An environmental audit (EA) is a systematic process of collecting and objectively evaluating information, whether certain environmental activities are following audit standards, criteria and control systems (Brunelli, Murzakhmetova and Falivena, 2022). According to Gedam, Raut, Lopes De Sousa Jabbour, Narkhede, and Grebinevych (2020), the EA is an essential contributor to success in the adoption of sustainability business practices in the automotive industry. An alternate study conducted in the Indian market between 2019 and 2020 revealed that EAs for suppliers and top management support are considered to be the two critical success factors to prioritise, which indicates that by addressing these issues, automotive manufacturers may be able to better proceed with the adoption of sustainable practices (Gedam, Raut, Lopes De Sousa Jabbour, Narkhede and Grebinevych, 2020).

Internal environmental audits are performed to ensure compliance with internal environmental regulations. Lee, Park, Song and Yook (2016) conducted research on 266 Japanese manufacturing firms polled between 2010 and 2013. It was based on the importance of internal environmental auditing (EA) and its role in the continuous improvement of businesses. According to the authors, firms that used internal EAs had a 9 per cent higher firm value than those that did not. Internal EAs and firm value were discovered to be linked by the authors. Aslam, Rehman and Asad (2020) concurred and highlighted the advantages of integrating external EAs with internal environmental management practices (EMS audit).

Fortunately, the majority (57.61 per cent) of manufacturing sectors in iLembe agreed to using constant environmental auditing as an internal waste management strategy, as opposed to those that disagreed at 42.39 per cent.

4.12.4 Necessary resources to design green or eco-friendly products

This sub-section was designed to determine which manufacturing sectors have the resources required to design green or eco-friendly products. Table 4.16 reveals the level of agreement and disagreement amongst various manufacturing sectors regarding the availability of the necessary resources to design green or eco-friendly products.

Table 4. 16: Necessary resources to design green or eco-friendly products

Necessary resources to design green or eco-friendly products	Disagree (N=81)	Agree (N=103)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.339	
Automotive components	5 (6.2%)	9 (8.7%)		14 (7.6%)
Electrical machinery; Apparatus	10 (12.3%)	5 (4.9%)		15 (8.2%)
Food; Beverages; Tobacco	22 (27.2%)	28 (27.2%)		50 (27.2%)
Furniture manufacturing	7 (8.6%)	8 (7.8%)		15 (8.2%)

Metals; Metal products; Machinery; Equipment	6 (7.4%)	15 (14.6%)		21 (11.4%)
Paper; Printing	7 (8.6%)	11 (10.7%)		18 (9.8%)
Petroleum; Chemical products	4 (4.9%)	9 (8.7%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (1.2%)	0 (0.0%)		1 (0.5%)
Plastic; Rubber products	8 (9.9%)	11 (10.7%)		19 (10.3%)
Textiles; Clothing; Leather goods	11 (13.6%)	7 (6.8%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.4.1 Interpretation of data:

According to Table 4.16, most of the respondents at 56 per cent agreed to the availability of necessary resources to design green or eco-friendly products as a waste management strategy, while 44 per cent disagreed.

The majority of respondents for the Automotive components manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector and, Petroleum and Chemical products: Foam manufacturing sector agree with the ability to obtain the necessary resources to design green or eco-friendly products as a waste management strategy at 8.7%, 27.2%, 7.8%, 14.6%, 10.7%, 8.7% and 10.7% respectively.

In the remaining sectors, the respondents in the Electrical machinery and Apparatus manufacturing sector, Plastic and Rubber products sector and the Textiles; Clothing and Leather goods sector at 12.3%, 1.2% and 13.6% respectively, disagreed with the accessibility of the necessary resources to design green or eco-friendly products as a waste management strategy.

The overall p-value for all the sectors listed in Table 4.16 is greater than the 0.05 significant level of association at 0.339. This implies that no statistically significant correlation exists between the various sectors and the accessibility of the necessary resources to design green or eco-friendly products as a waste management strategy. As a result, the null hypothesis is accepted.

4.12.4.2 Discussion:

As the awareness that products and services cause serious environmental degradation (that is, climate change, ecosystem change, natural-resource usage and pollution) has increased, the focus has shifted from finding end-of-pipe solutions to designing products that prevent such degradation from occurring in the first place, or reduce such problems (Svanes, Vold, Møller, Pettersen, Larsen and Hanssen, 2010).

According to Le Mouëllic, Ventura, Heller, Loh, Roch, Spitzbart and Zanotelli (2023), a product's design strongly influences its ecological sustainability because numerous engineering-related aspects affect the environment, including the product's composition, lifespan, efficiency and recyclability. Measuring the impact provides insights that organisations can use to apply design strategies that advocate ecological sustainability.

Machine learning, robotics and smart sensors can lead to further increases in productivity and the quality of textile production, while the internet of things and big data can lead to better planning and resource management, thus improving costing and profit margins.

Fortunately, the majority of the manufacturing sectors in iLembe (at 56 per cent) have agreed with having the necessary resources to design eco-friendly products, as opposed to those that disagreed (at 44 per cent).

4.12.5 Complies with the application of Environmental Management

The goal of this sub-section was to determine whether manufacturing sectors were adhering to environmental management practices. The information in Table 4.17 depicts the relationship between various manufacturing sectors and their adherence to environmental management practices.

Table 4. 17: Complies with the application of environmental management

Complies with the application of environmental management	Disagree (N=55)	Agree (N=129)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.332	

Automotive components	3 (5.5%)	11 (8.5%)		14 (7.6%)
Electrical machinery; Apparatus	6 (10.9%)	9 (7.0%)		15 (8.2%)
Food; Beverages; Tobacco	14 (25.5%)	36 (27.9%)		50 (27.2%)
Furniture manufacturing	6 (10.9%)	9 (7.0%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	6 (10.9%)	15 (11.6%)		21 (11.4%)
Paper; Printing	4 (7.3%)	14 (10.9%)		18 (9.8%)
Petroleum; Chemical products	2 (3.6%)	11 (8.5%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	0 (0.0%)	1 (0.8%)		1 (0.5%)
Plastic; Rubber products	4 (7.3%)	15 (11.6%)		19 (10.3%)
Textiles; Clothing; Leather goods	10 (18.2%)	8 (6.2%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.5.1 Interpretation of data:

According to Table 4.17, most of the respondents at 70.11 per cent agreed to complying with the application of environmental management as a waste management strategy, while 29.89 per cent disagreed.

The majority of the respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector and the Plastic and Rubber products manufacturing sector agree with complying with the application of environmental management as a waste management strategy at 8.5%, 7.0%, 27.9%, 7.0%, 11.6%, 10.9%, 8.5%, 0.8% and 11.6% respectively.

In the remaining sector, the respondents in the Textiles; Clothing and Leather goods sector at 18.2 per cent disagreed with complying with the application of environmental management as a waste management strategy.

The overall p-value for all the sectors listed in Table 4.17 is greater than the 0.05 significant level of association at 0.332. This implies that no statistically significant correlation exists between the various sectors and compliance with the application of environmental management as a waste management strategy. As a result, the null hypothesis is accepted.

4.12.5.2 Discussion:

Brunelli, Murzakhmetova and Falivena (2022) cite ISO 14001 as an example of an environmental policy that outlines the overall intentions and direction of how organisations shall relate to their overall environmental impact. By integrating internal and external environmental audits through the application of ISO 14001 standards, it is possible to establish a fundamental framework aimed at improving environmental performance and increasing market value for listed companies. In the absence of continuous waste auditing, chemicals and a lack of waste management by industries will endanger people, animals and plants.

4.12.6 Utilisation of waste treatment techniques to reduce toxicity prior to disposal

The objective of this sub-section was to determine whether manufacturing sectors in iLembe utilised waste treatment techniques to reduce toxicity prior to disposal. The information in Table 4.18 presents the level of agreement and disagreement by various manufacturing sectors in the iLembe Municipal District of KwaZulu-Natal.

Table 4. 18: Utilisation waste treatment techniques to reduce toxicity prior to disposal

Use waste treatment techniques to reduce toxicity prior disposal	**Disagree (N=118)**	**Agree (N=66)**	**p-value**	**Overall (N=184)**
Raw materials used / Final products			Chi-sq., p<0.001	
Automotive components	8 (6.8%)	6 (9.1%)	1.000	14 (7.6%)
Electrical machinery; Apparatus	13 (11.0%)	2 (3.0%)	0.892	15 (8.2%)
Food; Beverages; Tobacco	34 (28.8%)	16 (24.2%)	1.000	50 (27.2%)
Furniture manufacturing	14 (11.9%)	1 (1.5%)	0.120	15 (8.2%)
Metals; Metal products; Machinery; Equipment	16 (13.6%)	5 (7.6%)	1.000	21 (11.4%)
Paper; Printing	11 (9.3%)	7 (10.6%)	1.000	18 (9.8%)
Petroleum; Chemical products	1 (0.8%)	12 (18.2%)	<0.001	13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (0.8%)	0 (0.0%)	1.000	1 (0.5%)

Plastic; Rubber products	11 (9.3%)	8 (12.1%)	1.000	19 (10.3%)
Textiles; Clothing; Leather goods	9 (7.6%)	9 (13.6%)	1.000	18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.12.6.1 Interpretation of data:

According to Table 4.18, most respondents at 64.1 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to the utilisation of waste treatment techniques to reduce toxicity prior to disposal as a waste management practice, while 35.9 per cent agreed.

The majority of respondents for the Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Paper and Printing sector, Petroleum and Chemical products: Foam manufacturing sector and, Plastic and Rubber products manufacturing sector disagree with the utilisation of waste treatment techniques to reduce toxicity prior to disposal at 6.8%, 11.0%, 28.8%, 11.9%, 13.6%, 9.3%, 0.8% and 9.3% respectively.

In the remaining sectors, 18.2 per cent of respondents in the Petroleum and Chemical products sector and 13.6 per cent in the Textiles, Clothing and Leather goods sector disagreed with the utilisation of waste treatment techniques to reduce the toxicity of waste prior to disposal.

The p-value for the Petroleum and Chemical products sector at 0.001 indicates a significant level of association with the utilisation waste treatment techniques to reduce the toxicity of waste prior to disposal as the p-value is less than the 0.05 level of significance. The null hypothesis is thus rejected as this sector is more likely than the rest to to the use waste treatment techniques to reduce the toxicity of waste prior to disposal.

4.12.6.2 Discussion:

Fasting (2019) asserts that treating waste through recycling or waste-to-energy generally proves more environmentally friendly than not treating it. The author further states that countries around the globe are grappling with inefficient waste management strategies in which waste is disposed of in landfills or incinerated without further consideration. As a result, countries are enforcing stricter waste treatment regulations to address the profound consequences of landfills on workers and the environment.

Interestingly, only 35.9 per cent of the participants, as shown in the table above, agreed that manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal are committed to using waste treatment techniques to reduce the volume of toxic waste that is released into the environment prior to disposal.

After presenting the various waste management measures used by manufacturing organisations in the iLembe Municipal District in both discrete and continuous data, the second half of Section C discusses access to necessary resources and effective waste management practices. In this instance, a different analytical technique will be used, namely the MEAN.

4.13 Access to necessary resources and effective waste management practices

In this segment, the Cronbach coefficient alpha was utilised to determine the reliability of waste management measures used by manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal. The Mean was employed to evaluate the numerical average of a set of responses (Calzon, 2023) and the Alpha-if-deleted represents the Cronbach's alpha reliability coefficient for the scale's internal consistency if a variable is eliminated (Gliem and Gliem, 2003).

According to George and Mallery (2019), the rule of thumb for assessing the Cronbach’s Alpha value for a dichotomous or Likert scale instrument is: if the Cronbach’s Alpha value is above 0.90, it indicates excellent internal consistency; above 0.80 is good; above 0.70 is acceptable; above 0.60 is questionable; above 0.50 is poor; and below 0.50 is unacceptable. The Likert scale mean scores are also interpreted below. According to Wanjohi and Syokau (2021), attitudes are identified using a Likert scale mean score and can be interpreted as follows: 1.0 - 2.4 (Negative attitude), 2.5 - 3.4 (Neutral attitude), and 3.5 - 5.0 (Positive attitude).

In order to analyse the approaches adopted by manufacturing organisations in KwaZulu-Natal's iLembe Municipal District, a total of 18 variables were presented to respondents via a Likert scale questionnaire. The sections that follow will evaluate the Mean and Cronbach Alpha value for each of the 18 variables included in this category. The Mean will indicate the level of agreement or disagreement amongst respondents, while the Cronbach Alpha will reflect the level of reliability for each variable.

4.13.1 Total Mean and Cronbach Alpha for measures used to manage waste

The cumulative Mean and Cronbach Alpha value for waste management measures used by manufacturing organisations in the iLembe Municipal District are presented in Table 4.19 below. The measurements are made up of 18 variables that add up to the total for the mean and Cronbach alpha, which will be discussed further below.

Table 4. 19: Total Mean and Cronbach Alpha for measures used to manage waste

Mean and Cronbach Alpha for measures used to manage waste	Mean	Alpha-if-deleted
Total	3.106	0.854

The overall Mean value of 3.106, as shown in Table 4.19, suggests that most respondents had neutral responses to the variables that were evaluated in this category. The total Cronbach Alpha-if-deleted value at 0.854 is favourable and indicates a high level of reliability of the research instrument.

4.13.2 Policy to effectively manage waste

The purpose of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal utilised policies to effectively manage waste. Table 4.19.1 represents the level of agreement or disagreement between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their use of policies to effectively manage waste.

Table 4.19. 1: Policy to effectively manage waste

Policy to effectively manage waste.	Mean	Alpha-if-deleted
Policy for managing waste during production	4.571	0.849

Effectively reduces hazardous substances into the environment	2.946	0.833
Constant environmental auditing as an internal waste management strategy	3.543	0.833
Complies with the application of environmental management	3.728	0.837
Use waste treatment techniques to reduce toxicity prior disposal	2.826	0.849
Collection points for post-consumer waste products or packaging	2.451	0.846

4.13.2.1 Interpretation of data:

The data on Table 4.19.1 indicates that all the variables listed in the above table had a high level of reliability as the Cronbach alpha was greater than 0.8.

The Mean values indicate that the majority of respondents agreed with the statements presented in the table. The level of agreement for the statements: Policy for managing waste during production; Complies with the application of environmental management; and Constant environmental auditing as an internal waste management were at 4.571, 3.728 and 3.543 respectively.

The Mean values for the remaining statements ranged from neutral to disagree. The average response to the statements: Effectively reduces hazardous substances in the environment; Use waste treatment techniques to reduce toxicity prior to disposal; and Collection points for post-consumer waste products or packaging were at 2.946, 2.826 and 2.451 respectively.

Table 4.19.1 represents a high level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their use of policies to effectively manage waste.

4.13.2.2 Discussion:

Del Ro González (2008) claims that carbon pricing policy encourages manufacturing companies to increase the energy efficiency of their production plants and to reduce carbon emissions without sacrificing output. The author further states that in order to reduce carbon emissions, organisations must decrease inputs that compromise of carbon, which include fuels for electricity generation and energy for the manufacturing industry, *inter alia.*

According to Kimani (2020), waste management is frequently neglected in many countries, resulting in negative consequences for the society, environment and the economy. Waste generators such as individuals or entities may choose the cheapest option available to manage their waste if proper policy and legislation are not effectively implemented. Consequently, a lack of funding, a lack of an enabling institutional and policy framework, and a lack of data have all combined to have a negative impact on the adoption and implementation of modern waste management solutions (Liyala, 2011; Simatele and Etambakonga, 2015; Simatele, Dlamini and Kubanza, 2017).

4.13.3 Access to essential resources

The aim of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal had access to essential resources to effectively manage waste. Table 4.19.2 represents the level of agreement or disagreement between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their access to essential resources to manage waste.

Table 4.19. 2: Access to essential resources

Access to essential resources	Mean	Alpha-if-deleted
Technology is current and adequate for clean production processes	3.592	0.838
Necessary resources to design green or eco-friendly products	3.527	0.838
Adequate training to employees on how to dispose of toxic waste	4.179	0.856
Employs waste pickers to collect our post-consumer waste	1.940	0.850

4.13.3.1 Interpretation of data:

The data in Table 4.19.2 indicates that all the variables listed had a high level of reliability as the Cronbach alpha was greater than 0.8.

The Mean values indicate that the majority of respondents agreed with the statements presented in the above table. The level of agreement for the statements: Adequate training to employees on how to dispose of toxic waste; Technology is current and adequate for clean production processes; and Necessary resources to design green or eco-friendly products were 4.179, 3.592 and 3.527 respectively.

The Mean value for the remaining statement: Employs waste-pickers to collect our post-consumer waste at 1.940 implies that respondents disagreed with this statement.

Table 4.19.2 represents a high level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and access to essential resources to effectively manage waste.

4.13.3.2 Discussion:

According to a study conducted by Mourtzis, Zogopoulos and Xanthi (2019), the re-skilling of operators, modern automation, and flexible production technologies are vital examples of sustainable practices. A lack of technical skills, a lack of financial support, unreliable data, limited waste collection vehicles, inaccessible roads, and a lack of infrastructure have all hampered the adoption of waste management practices in various countries worldwide (Guerrero, Maas and Hogland, 2013; Tozlu, Zahi and Abuşolu, 2016). Furthermore, internal operations, according to Ribeiro and Barbosa-Povoa Citation (2018), should be considered alongside an effective and robust supply chain management approach in order to achieve the required levels of resilience.

Except for the use of waste-pickers to collect post-consumer waste, the majority of respondents in the aforementioned segment agreed with all of the statements in Table 19.2 above.

4.13.4 The implementation of eco-friendly product design

The objective of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal have implemented eco-friendly product design to manage the generation of waste. Table 4.19.3 represents the level of agreement or disagreement between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the implementation of eco-friendly product design to manage waste.

Table 4.19. 3: The implementation of eco-friendly product design

The implementation of eco-friendly product design	Mean	Alpha-if-deleted
Utilises biodegradable and or compostable raw materials	2.815	0.853

Often make fundamental changes to product design and processes	4.272	0.848
Products are packaged in reusable packaging	2.359	0.857
Incorporates recycled material in certain product formulations	4.033	0.861

4.13.4.1 Interpretation of data:

The data in Table 4.19.3 indicates that all the variables listed in the above table had a high level of reliability as the Cronbach alpha was greater than 0.8.

The Mean values indicate that the majority of respondents agreed with the statements presented in the above table. The level of agreement for the statements: Often make fundamental changes to product design and processes and Incorporates recycled material in certain product formulations are 4.272 and 4.033 respectively.

The Mean value for the remaining statement ranges from neutral to disagree. The average response to the statements: Utilises biodegradable and/or compostable raw materials and Products are packaged in re-usable packaging are 2.815 and 2.359 respectively.

Table 4.19.3 represents a high level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the implementation of eco-friendly product design to effectively manage waste.

4.13.4.2 Discussion:

According to Mussatto and Teixeira (2010), lignocellulose biomass, which comprises of forestry, agricultural and agro-industrial wastes, is an abundant, renewable and economical energy source. Sawdust, poplar trees, sugarcane bagasse, wastepaper, brewer's spent grains, switchgrass, and straws, stems, stalks, leaves, husks, shells, and peels from cereals such as rice, wheat, corn, sorghum, and barley, amongst others, are all examples of such wastes. Agricultural residues, such as corn stover and corn cobs, are "waste" that remains after corn harvesting in agricultural industries, and previous research has shown great potential for converting corn residue to biofuel while providing agro-economic benefits (Mussato and Teixeira, 2010). Maize is also used as a raw material in the production of paints, textiles, paper, food and medicine (Mogala, 2012).

According to a study conducted by Zondo (2019), the polyhydroxyalkanoates (PHAs) production process is environmentally friendly due to the use of agricultural feedstock and by-products. Zondo (2019) explained that PHAs are natural aliphatic polyesters that are manufactured by micro-organisms via a fermentation process of sugars (glucose, sucrose) or lipids (vegetable oils, even glycerine from bio-diesel production) and are stored as an intra-cellular carbon and energy reserve when cells develop under stressful conditions. In addition, PHAs contain vital properties of biodegradability. Furthermore, through a fermentation process, a biodegradable co-polymer poly was produced from an agricultural by-product, corn silage. A co-polymer is a polymer composed of two or more monomer species. It is frequently used to enhance or modify the properties of plastics. Polymer degradation occurs in natural environments via thermal, mechanical, hydrolysis and photochemical destruction, as well as biodegradation (Zondo, 2019).

This section of the study indicates that manufacturing organisations in iLembe use a negligible amount of biodegradable and compostable raw materials, and that inadequate products are packaged in re-usable packaging. More can be done to improve these aspects.

4.13.5 Reduction of water and electricity

The objective of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal reduce their use of water and electricity in their production processes. Table 4.19.4 represents the level of agreement or disagreement between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their ability to reduce water and electricity in their production processes.

Table 4.19. 4: Reduction of water and electricity

Reduction of water and electricity	Mean	Alpha-if-deleted
Reduced water consumption in production processes	2.859	0.837

Reduced electricity consumption in production processes	2.484	0.834

4.13.5.1 Interpretation of data:

The data in Table 4.19.4 indicates that all the variables listed in the above table had a high level of reliability as the Cronbach alpha was greater than 0.8.

The mean value for the statement: Reduced water consumption in production processes at 2.859 indicates that respondents had a neutral response to this statement. The Mean value for the statement: Reduced electricity consumption in production processes at 2.484 indicates a level of disagreement from the respondents.

Table 4.19.4 indicates that manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their ability to reduce water and electricity in their production processes requires more initiative.

4.13.5.2 Discussion:

While certain entities are working hard to implement sustainable waste reduction practices, others remain vulnerable. Ford Motor Company is an example of an organisation that goes above and beyond to minimise risk and maximise opportunity in its water usage. Between 2000 and 2012, the company reduced its water use in the United States by 71% and globally by 62 per cent, saving 10.6 billion gallons. The automaker decreased its per-vehicle water use from 9.8 cubic meters (2588 gallons) in 2000 to 4.3 cubic meters (1136 gallons) in 2012, using 2009 as the baseline year, in both its power train and vehicle assembly plants (Koel, 2013).

According to Rao, Sholes and Cresko (2019), the manufacturing sector in the United States (U.S.) is vulnerable to physical water shortages. Primary metals, fabricated metals, transportation equipment, petroleum refining, and plastics and rubber manufacturing all draw significant amounts of water from areas with physical water scarcity (Rao, Sholes and Cresko, 2019). Many manufacturing plants have the untapped potential to reduce water withdrawals through efficient water use. Waste efficiency measures are established and proven, and there is a wide range of implementation expertise on new and retrofit installations. As a result, their adoption could drastically reduce water withdrawal with significantly less effort and cost than alternative water supply methods such as desalination or water reclamation (Rao and Karki, 2023).

Furthermore, in recent years, the manufacturing sector has developed a pronounced awareness concerning energy generation and consumption. According to Key World Energy Statistics (2017), industry accounts for 42 per cent of global electrical energy consumption. According to statistics from the U.S energy information administration, machinery and equipment account for a significant portion of the total amount of electricity consumed in manufacturing, which is estimated to be 50 per cent of the total manufacturing electricity consumption (Hu, Peng, Evans, Peng, Liu, Tang and Tiwari, 2017).

4.13.6 Organisational perception on waste value and regional waste management

The objective of this sub-section was to identify the level of organisational perception on waste value and regional waste management amongst manufacturing organisations in the iLembe Municipal District of KwaZulu-Natal. Table 4.19.5 represents the level of agreement or disagreement between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their perception on waste value and regional waste management.

Table 4.19. 5: Organisational perception on waste value and regional waste management

Organisational perception on waste value and regional waste management	Mean	Alpha-if-deleted
Obsolete or redundant waste contains no value	2.022	0.849
No serious waste management problem in iLembe	1.766	0.854

4.13.6.1 Interpretation of data:

The data in Table 4.19.5 indicates that all the variables listed in the table had a high level of reliability as the Cronbach alpha was greater than 0.8.

The mean values of the statements: Obsolete or redundant waste contains no value and no serious waste management problem in iLembe are 2.022 and 1.766 respectively, which indicates that there is a level of disagreement from respondents with these statements.

Table 4.19.5 implies that manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal have a positive perception on waste value and regional waste management, which bodes well for the future of the district.

4.13.6.2 Discussion:

Waste contains toxic substances such as heavy metals, plastics, polymeric resins, and chemicals used for mechanical and thermal stability. Therefore, the proper management of certain waste products is extremely crucial. The improper handling of waste has not only severe environmental impacts, but also results in the loss of high economic potential. According to Guo and Yan (2017), amongst the several types of e-waste, obsolete mobile phones are considered the most ubiquitous discarded electronic products. Printed circuit boards (PCBs) for example, are essential components of mobile phones, accounting for 20 - 30 per cent of the device's weight depending on the model, manufacturing year and brand (Wansia, D'Ansa, Gondaa, Segatoa and Degreza, 2018). According to Jha, Rao, Meshram, Verma and Singh (2020), waste printed circuit boards (WPCBs) contain a wealth of precious metals as well as an array of hazardous materials that are both secondary resources and environmental pollutants. Researchers have developed several efficient recovery techniques, such as recrystallisation, chemical precipitation, ion exchange and solvent extraction, but recovery of lower concentration metals such as gold, silver, palladium, nickel and zinc remain a global issue. WPCBs are consequently valuable for "urban mining" processes aimed primarily at the recovery of copper, silver and gold, which account for more than 95 per cent of their value (Garg, Nagar, Ellamparuthy, Angadi and Gahan, 2019).

In this study, a majority of the respondents agreed that obsolete waste has value, and they also agreed that iLembe has a serious waste management problem.

SECTION D:

Section D outlines and analyses the variables that influence sustainable waste management practices, along with the barriers that hamper sustainable waste management practices amongst manufacturing organisations in the Municipal District of iLembe, KwaZulu-Natal.

4.14 Factors influencing waste management practices amongst manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

The factors influencing waste management practices used by manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal include sub-sections such as Compliance with government environmental regulations; Employs digitalised technology to reduce water consumption; Employs digital technology to reduce energy of electricity consumption; and Cost reductions due to the adoption of cleaner production processes.

Several variables were presented to respondents using a Likert scale questionnaire. The following values indicate their level of association, agreement or disagreement with each variable in Tables 4.20, 4.21, 4.22 and 4.23 below.

4.14.1 Compliance with government environmental regulations

The purpose of this sub-set was to establish if a statistically significant relationship between different types of ownership and their compliance with government regulations exists. Table 4.20 indicates the level of correlation between various kinds of ownership in the manufacturing sector in the Municipal District of iLembe in KwaZulu-Natal and their adherence to government regulations.

Table 4. 20: Compliance with government regulations

Complies with government environmental regulations	**Disagree (N=24)**	**Agree (N=160)**	**p-value**	**Overall (N=184)**
Form of ownership			Chi-sq.,	

			p<0.001	
Sole proprietorship	14 (58.3%)	28 (17.5%)	<0.001	42 (22.8%)
Partnership	2 (8.3%)	22 (13.8%)	1.000	24 (13.0%)
Close corporation (CC)	2 (8.3%)	12 (7.5%)	1.000	14 (7.6%)
Private company (Pty) (Ltd)	6 (25.0%)	61 (38.1%)	1.000	67 (36.4%)
Public company (Ltd)	0 (0.0%)	37 (23.1%)	0.025	37 (20.1%)

| % and p-values based on non-missing cases | * parametric p-value.

4.14.1.1 Interpretation of data:

According to Table 4.20, most of the respondents at 87 per cent agreed with complying with government regulations, while 13 per cent disagreed.

The majority of the respondents for Partnership, Close corporation (CC), Private Company (Pty) (Ltd) and Public company (Ltd) agreed with complying with government regulations at 13.8%, 7.5%, 38.1% and 23.1% respectively.

In the remaining form of ownership, 58.3 per cent of respondents in the Sole Proprietorship disagreed with complying with government regulations.

The p-values for Sole proprietorship and Public company (Ltd) indicate a significant level of association between these forms of ownership and adherence with government regulations, with p-values less than the 0.05 level of significance at 0.001 and 0.025 respectively. The null hypothesis is thus rejected. This indicates that these forms of ownership are more likely than the rest to comply with government regulations.

4.14.1.2 Discussion:

Corporate compliance strategies are actions taken by businesses to comply with environmental regulations while minimising their impact on the environment (Xie, Wu, Li and Tian, 2023). However, according to varying levels of environmental regulation, some organisations increase their investment in emission-reduction technologies and develop green products, whereas others choose to relocate to regions with lower regulatory intensity due to high local environmental compliance costs (Li, Du and Tang, 2021). In response to stringent environmental assessments, China's largest steel company, Capital Steel, relocated from Beijing to Tangshan in Hebei, where environmental regulations are relatively lax. It has been found that the various compliance strategies used by firms offer a new perspective on understanding differentiated productivity (Xie, Wu, Li and Tian, 2023). Past studies have confirmed the positive impact of environmental regulations on the ecological environment (Yan, Zhang, Zhang and Li, 2020).

Zhang, Li, Uddin and Guo (2020) investigated the relationship between environmental regulations, overseas investment and carbon emissions in 30 Chinese provinces using data from 2008 to 2016. In this study, it was discovered that environmental legislation effectively regulates carbon dioxide emissions. Zhang *et al*. (2020) added that it is critical for the development of environmental policies to reduce carbon emissions, such as carbon pricing, command-and-control mechanisms, and incentive-based regulations.

4.14.2 Employs digitalised technology to reduce water consumption

The purpose of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal employ digitalised technology to reduce water consumption. Table 4.21 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the employment of digitalised technology to reduce water consumption as a waste management strategy.

Table 4. 21: Employs digitalised technology to reduce water consumption

Employs digitalised technology to reduce water consumption	**Disagree (N=119)**	**Agree (N=65)**	**p-value**	**Overall (N=184)**
Raw materials used / Final products			Chi-sq., p = 0.177	
Automotive components	6 (5.0%)	8 (12.3%)		14 (7.6%)
Electrical machinery; Apparatus	13 (10.9%)	2 (3.1%)		15 (8.2%)

Food; Beverages; Tobacco	31 (26.1%)	19 (29.2%)		50 (27.2%)
Furniture manufacturing	13 (10.9%)	2 (3.1%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	15 (12.6%)	6 (9.2%)		21 (11.4%)
Paper; Printing	9 (7.6%)	9 (13.8%)		18 (9.8%)
Petroleum; Chemical products	9 (7.6%)	4 (6.2%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (0.8%)	0 (0.0%)		1 (0.5%)
Plastic; Rubber products	11 (9.2%)	8 (12.3%)		19 (10.3%)
Textiles; Clothing; Leather goods	11 (9.2%)	7 (10.8%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.14.2.1 Interpretation of data:

According to Table 4.21, most of the respondents at 64.68 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to the employment of digitalised technology to reduce water consumption as a waste management strategy, while 35.32 per cent agreed.

The majority of respondents for the Electrical machinery and Apparatus manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products sector and the Textiles, Clothing and Leather goods manufacturing sector disagree with the employment of digitalised technology to reduce water consumption as a waste management strategy at 10.9%, 26.1%, 10.9%, 12.6%, 7.6%, 0.8%, 9.2% and 9.2% respectively.

In the remaining sectors, 12.3 per cent of respondents in the Automotive components manufacturing sector and 13.8 per cent of the respondents in the Paper and Printing sector disagreed with the employment of digitalised technology to reduce water consumption as a waste management strategy.

The overall p-value for all the sectors listed in Table 4.21 at 0.177 is greater than the 0.05 significant level of association, which implies that no statistically significant correlation exists between the various sectors and the employment of digitalised technology to reduce water consumption as a waste management strategy. As a result, the null hypothesis is accepted.

4.14.2.2 Discussion:

According to Yaqub and Lee (2019), in a number of countries, the concept of zero-liquid discharge (ZLD) has transformed wastewater treatment. The ability of zero-liquid discharge technology to optimise water recycling while simultaneously lowering wastewater quantities generated broad interest in its re-use and resource recovery potential. Yaqub and Lee (2019) further stated that as water resources become scarce, re-use options are becoming more prevalent. To achieve the highest treatment efficiency, scientists have proposed various tertiary treatment techniques that include adsorption, electrochemical processes, advanced oxidation, and membrane-based filtration (Wang, Jiang and Gao, 2022).

4.14.3 Employs digital technology to reduce the energy or electricity consumption

The purpose of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal employ digitalised technology to reduce the energy or electricity. Table 4.22 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the employment of digitalised technology to reduce the energy or electricity as a waste management strategy.

Table 4. 22: Employs digital technology to reduce the energy or electricity consumption

Employs digitalised technology to reduce energy or electricity consumption	Disagree (N=115)	Agree (N=69)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.142	

Automotive components	6 (5.2%)	8 (11.6%)		14 (7.6%)
Electrical machinery; Apparatus	12 (10.4%)	3 (4.3%)		15 (8.2%)
Food; Beverages; Tobacco	29 (25.2%)	21 (30.4%)		50 (27.2%)
Furniture manufacturing	13 (11.3%)	2 (2.9%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	10 (8.7%)	11 (15.9%)		21 (11.4%)
Paper; Printing	9 (7.8%)	9 (13.0%)		18 (9.8%)
Petroleum; Chemical products	9 (7.8%)	4 (5.8%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (0.9%)	0 (0.0%)		1 (0.5%)
Plastic; Rubber products	13 (11.3%)	6 (8.7%)		19 (10.3%)
Textiles; Clothing; Leather goods	13 (11.3%)	5 (7.2%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.14.3.1 Interpretation of data:

According to Table 4.22, most of the respondents at 62.5 per cent disagreed that manufacturing organisations in the iLembe Municipal District were committed to the employment of digitalised technology to reduce electricity consumption as a waste management strategy, while 37.5 per cent agreed.

The majority of the respondents for the Electrical machinery and Apparatus manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products manufacturing sector and the Textiles, Clothing and Leather goods manufacturing sector disagree with the employment of digitalised technology to reduce the consumption of electricity as a waste management strategy at 10.4%, 25.2%, 11.3%, 7.8%, 0.9%, 11.3% and 11.3% respectively.

In the remaining sectors, 11.6 per cent of respondents in the Automotive components manufacturing sector; 15.9 per cent in the Metals, Metal products, Machinery and Equipment manufacturing sector and 13.0 per cent of the respondents in the Paper and Printing sector disagreed with the employment of digitalised technology to reduce the consumption of electricity as a waste management strategy.

The overall p-value for all the sectors listed in Table 4.22 at 0.142 is greater than the 0.05 significant level of association, which implies that no statistically significant correlation exists between the various sectors and the employment of digitalised technology to reduce the consumption of electricity as a waste management strategy. As a result, the null hypothesis is accepted.

4.14.3.2 Discussion:

The Panasonic Group (2020), a major Japanese manufacturer of electric appliances and consumer electronics products, announced the launch of its innovative, CO_2-saving energy solution for the smart city project Future Living® Berlin on July 1, 2020. The installation in Berlin combines sustainable, digital and connected living. It is realised through the installation of smart energy solutions, including Panasonic's highly efficient air to water heat pumps, photovoltaic (PV) panels and storage batteries integrated into an intelligent and efficient energy management system. The technologies have been integrated into an energy saving solution that is not only controlled, but also constantly optimised by Panasonic's smart energy management solution (Panasonic Group, 2020). Renewable energy production and consumption, according to Rehman, Islam, Ullah, Khan and Rehman (2023), are primarily dependent on digitally controlled information technologies. In this regard, information digitalisation is critical in dealing with renewable energy, specifically renewable electricity generation technology, renewable electricity consumption, and production.

Only 37.5 per cent of respondents in this study agree to using digitalised technology to reduce electricity consumption, whilst the remaining respondents disagreed.

4.14.4 Cost reductions due to the adoption of cleaner production processes

The purpose of this sub-section was to determine whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal realised cost reductions due to the adoption of cleaner production processes. Table 4.23 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and the realisation of cost reductions due to the adoption of cleaner production processes.

Table 4. 23: Cost reductions due to the adoption of cleaner production processes

Realised cost reductions due to adoption of cleaner production processes	Disagree (N=72)	Agree (N=112)	p-value	Overall (N=184)
Raw materials used / Final products			Chi-sq., p = 0.185	
Automotive components	3 (4.2%)	11 (9.8%)		14 (7.6%)
Electrical machinery; Apparatus	8 (11.1%)	7 (6.2%)		15 (8.2%)
Food; Beverages; Tobacco	22 (30.6%)	28 (25.0%)		50 (27.2%)
Furniture manufacturing	6 (8.3%)	9 (8.0%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	6 (8.3%)	15 (13.4%)		21 (11.4%)
Paper; Printing	7 (9.7%)	11 (9.8%)		18 (9.8%)
Petroleum; Chemical products	3 (4.2%)	10 (8.9%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	1 (1.4%)	0 (0.0%)		1 (0.5%)
Plastic; Rubber products	5 (6.9%)	14 (12.5%)		19 (10.3%)
Textiles; Clothing; Leather goods	11 (15.3%)	7 (6.2%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.14.4.1 Interpretation of data:

According to Table 4.23, most of the respondents at 60.87 per cent agreed that manufacturing organisations in the iLembe Municipal District had realised cost reductions due to the adoption of cleaner production processes, while 39.13 per cent disagreed.

The majority of the respondents for the Automotive components manufacturing sector, Food, Beverages and Tobacco sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment sector, Paper and Printing sector, Petroleum and Chemical products sector, and Plastic and Rubber products sector agree with the realisation of cost reductions due to the adoption of cleaner production processes at 9.8%, 25.0%, 8.0%, 13.4%, 9.8%, 8.9% and 12.5% respectively.

In the remaining sectors, 11.1 per cent of respondents in the Electrical machinery and Apparatus manufacturing sector, 1.4 per cent of respondents in the Petroleum and

Chemical products: Foam manufacture sector and 15.3 per cent of the respondents in the and Textiles; Clothing and Leather goods sector disagree with the realisation of cost reductions due to the adoption of cleaner production processes.

The overall p-value for all the sectors listed in Table 4.23 at 0.185 is greater than the 0.05 significant level of association, which implies that no statistically significant correlation exists between the various sectors listed above and the realisation of cost reductions due to the adoption of cleaner production processes. The null hypothesis is thus accepted.

4.14.4.2 Discussion:

Industrial waste has a high potential for recovery, and extracting rare precious metals from waste is one solution to resource scarcity (El-Saadony *et al*. 2023) and organisational cost reduction. According to Wu, Liu and Qu (2022), when extracting precious metals from waste, care must be taken to minimise secondary contamination by controlling critical technical parameters so that the amount of newly valuable waste is reduced while valuable metals are not lost.

Globally, mills that produce pulp and paper generate significantly large quantities of waste. The vast majority of these wastes end up in landfill facilities, with minimal incineration and no recycling taking place. According to a study conducted on pulp and paper mill waste by Haile, Gelebo, Tesfaye, Mengie, Mebrate, Abuhay and Limeneh (2021), waste which has been generated from paper and wood pulp mills can be profitable when treated according to traditional and integrated bio-refinery advances in technology. Advanced carbon fibre and bio-based polymer could be produced from pulping waste black liquor, and cellulosic waste from sawdust and sludge can be utilised to synthesize cellulose nanocrystals and regenerated fibres such as viscose rayon and acetate, *inter alia* (Haile, *et al*., 2021). The authors further stated that it is critical, from an environmental and socio-economic standpoint, to convert waste from pulp and paper mills into highly lucrative products using suitable technological innovations. Mabitsela, Telukdarie and Munsamy (2023) agree and asserted that managing raw material consumption, equipment performance and process parameters are all critical components of cost management in manufacturing.

4.15 Barriers that hamper waste management practices amongst manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal

This section will explain the barriers to waste management practices utilised by manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal. Several variables were presented to respondents using a Likert scale questionnaire. The following Mean values in Table 4.24 indicate their level of agreement or disagreement with each variable, and the Alpha-if-deleted will reflect the level of item reliability.

Table 4. 24: Barriers that hamper waste management practices amongst manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal

Items	**Mean**	**Alpha-if-deleted**
Employee reluctance to adopt new cleaner industrial processes	2.163	0.303
Lacks effective waste management solutions	1.783	0.255
Total	**1.973**	**0.434**
Items dropped	**Improvement**	**Overall, Alpha**
Insufficient supply of biodegradable raw materials in our area	2	0.2985
Lack of capital to invest in new technologies to reduce waste	3	0.4205

4.15.1 Interpretation of data:

According to George and Mallery (2019), Cronbach's alpha coefficients for reliability typically range from 0 to 1. The closer Cronbach's alpha is to 1.0, the higher the internal consistency of the scale's items.

Due to the limited number of variables listed in Table 4.24, the total level of reliability is low, as the total Alpha-if-deleted is 0.434. The total Mean at 1.973 indicates a significant level of disagreement with the variables by respondents.

The Mean value for assessing employee resistance to adopting new cleaner industrial processes was 2.163 and 0.303 Alpha-if-deleted. The Mean value for assessing the lack of effective waste management solutions was 1.783 and 0.255 Alpha-if-deleted. The results indicate that respondents disagreed significantly with the variables, indicating that the employees employed by their organisations are keen to embrace cleaner industrial processes, and that their organisations do have efficient waste management solutions in place.

The remaining two variables on the above table, namely Insufficient supply of biodegradable raw materials in our area at 0.2985 alpha-if-deleted and Lack of capital to invest in new technologies to reduce waste at 0.4205, had to be dropped in order to improve the total Alpha-if-deleted value. Due to the miniscule number of variables in this table, the results were insignificant.

4.15.2 Discussion:

The compositions of various wastes have changed over time, with waste materials being directly associated with industrial development and innovation. According to a study conducted by Jahan (2017) to identify barriers to recycling as well as marketing strategies that would be appropriate for products made from recycled materials, the most significant barriers to recycling were a lack of recycling equipment and technology, a lack of recyclable materials, and a lack of consumer awareness.

Annosi, Brunetta, Bimbo and Kostoula (2021) conducted a qualitative study based on eighteen in-depth interviews with managers of large multinational and local organisations covering diverse and relevant roles on the digital food supply chain to investigate how the digitalisation of the food supply chain operations affects organisational and food supply chain progressions. Several barriers to the adoption of digital technologies for sustainable production and consumption have been identified. Weak environmental regulations, a lack of experts, a lack of change management capabilities, a less skilled workforce, and a lack of priority for digital transformation were amongst the 21 barriers identified (Sharma, Joshi and Govindan, 2023; Annosi *et al*., 2021).

4.16 Organisations supporting a waste recycling plant in iLembe

The purpose of this sub-set was to establish whether manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal would support a waste recycling plant in iLembe. Table 4.25 represents the level of association between diverse manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal and their level of agreement or disagreement in support of a waste recycling plant in iLembe.

Table 4. 25: Manufacturing organisation vs. the support of a waste recycling plant in the Municipal District of iLembe

Organisation supporting waste recycling plant in iLembe	No (N=5)	Unsure (N=25)	Yes (N=154)	p-value	Overall (N=184)
Raw materials used / Final products				Chi-sq., p = 0.436	
Automotive components	1 (20.0%)	1 (4.0%)	12 (7.8%)		14 (7.6%)
Electrical machinery; Apparatus	1 (20.0%)	4 (16.0%)	10 (6.5%)		15 (8.2%)
Food; Beverages; Tobacco	1 (20.0%)	10 (40.0%)	39 (25.3%)		50 (27.2%)
Furniture manufacturing	0 (0.0%)	1 (4.0%)	14 (9.1%)		15 (8.2%)
Metals; Metal products; Machinery; Equipment	0 (0.0%)	1 (4.0%)	20 (13.0%)		21 (11.4%)
Paper; Printing	1 (20.0%)	2 (8.0%)	15 (9.7%)		18 (9.8%)
Petroleum; Chemical products	0 (0.0%)	0 (0.0%)	13 (8.4%)		13 (7.1%)
Petroleum; Chemical products: Foam manufacturer	0 (0.0%)	0 (0.0%)	1 (0.6%)		1 (0.5%)
Plastic; Rubber products	0 (0.0%)	2 (8.0%)	17 (11.0%)		19 (10.3%)
Textiles; Clothing; Leather goods	1 (20.0%)	4 (16.0%)	13 (8.4%)		18 (9.8%)

| % and p-values based on non-missing cases | * parametric p-value.

4.16.1 Interpretation of data:

According to Table 4.25, 83.7 per cent of the respondents agreed that their organisation would support a waste recycling plant in the area. Furthermore, 13.6 per cent of the respondents indicated that they were unsure if their organisations would support a waste recycling plant in iLembe, and a miniscule amount of 2.7 per cent stated that their organisations would not support a waste recycling plant in the area.

The overall p-value for all the sectors listed in Table 4.25 (at 0.436) is greater than the 0.05 significant level of association, which implies that no statistically significant correlation exists between the various sectors listed above and their enthusiasm to support a waste recycling plant in iLembe. The null hypothesis is thus accepted.

4.16.2 Discussion:

Recycling plays an increasingly important role in an integrated waste management system. According to Akoon (2023), the City of Ekurhuleni in South Africa signed a Memorandum of Understanding with Oxfam in 2010 with the goal of providing value to waste-pickers throughout the city. Over the course of six years, this partnership saw the development of five recycling facilities throughout the city, with more projects in the works. The City of Ekurhuleni and Oxfam later decided to establish a plastic beneficiation project, with major companies such as Unilever, Tiger Brands and Serioplasts already committed to being end-users of the pellets produced. Akoon (2023) further stated that creating partnerships between the community, private business, the recycling industry and multinational companies can address the common goals of reducing poverty, creating jobs and importantly addressing climate change and the associated environmental challenges.

In this study, most respondents (at 83.7 per cent) supported the idea of a waste recycling plant in the area. This indicates that there is a willingness to recycle and eradicate the region of waste. The support received from most respondents at 83.7 per cent for a recycling plant in iLembe bodes well for the future of both the iLembe Municipal District and the environment at large.

4.17 Concluding remarks

The data obtained from the participants facilitated the analysis and discussion on the state of waste management practices within the Municipal District of iLembe in

KwaZulu-Natal. The analysis revealed that not all organisations in the study area were managing their waste in an environmentally responsible manner.

According to the results of this study, 61% of respondents agreed that their organisation's waste is recycled in-house. The second-highest number of respondents, 60%, stated that their organisations re-use waste to manufacture other products, while 48% stated that their organisations burn waste. Another significant finding of the study was that chemical waste was the most common type of waste generated in the Municipal District of iLembe in KwaZulu-Natal, which is concerning and can be harmful if toxins such as mercury and lead are not properly disposed of, with certain chemicals having high global warming potential due to their accumulation and persistence in the environment. Respondents were presented with various drivers of waste management practices. However, two of the most popular drivers noted were complying with government regulations, where the majority of the respondents at 87% agreed while 13% disagreed, and cost reductions due to the adoption of cleaner production processes, where the majority of the respondents at 60.87% agreed that manufacturing organizations in the iLembe Municipal District had realised cost reductions due to the adoption of cleaner production processes, while 39.13%. Respondents were also presented with barriers that hamper waste management practices. The mean value for assessing employee resistance to adopting new cleaner industrial processes was 2.163 and the mean value for evaluating the lack of effective waste management solutions was 1.783. These results indicate that respondents strongly disagreed with the barriers, indicating that the employees within their organisations are keen to adopt cleaner industrial processes, and that their organisations do have efficient waste management solutions in place.

Waste that is not recycled in an environmentally responsible manner not only degrades the environment, but also has a negative impact on human health in South Africa. This study only considers the iLembe region of KwaZulu-Natal. If other industrial hubs in KwaZulu-Natal and the other eight provinces of South Africa are included, the estimated volume of waste generated in South Africa over the next five years will be significantly higher and hence, its impact will be significantly rigorous.

In the final chapter, the major findings of the study are summarised and, based on the findings, some tentative conclusions and recommendations regarding the management of waste are presented. The chapter concludes by outlining the constraints of the study, and by suggesting areas for future research.

CHAPTER FIVE

RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

The previous chapter used descriptive and inferential statistics to analyse and interpret the results of the study. Central tendency descriptive statistics; Chi-Square tests; and T-tests were amongst the statistical tests used to analyse and interpret the data.

Following an expansion on some of the previous section's results, this chapter will provide an overview of the theoretical orientation; provide an empirical overview of the study; ascertain if the study objectives were achieved; emphasize constraints encountered during the study process; and provide tentative conclusions and recommendations for future research.

5.2 Overview of the Theoretical Orientation

Zamboni (2018) asserts that a theoretical orientation, sometimes referred to as a theoretical framework, is a set of ideas and assumptions that a researcher uses to begin writing a research paper. A researcher's theoretical orientation serves as a starting point for arranging the notions that emerge during their research and writing. According to Ndubisi, Zai and Lai (2019), manufacturing organisations are responsible for depleting a large portion of the world's natural resources and contributing towards air pollution, water contamination and waste generation. Emerson (2020) contends that non-sustainable manufacturing and waste management practices compromise the health of the general population by contaminating the air, drinking water, soil, crops, cattle fish and other resources. Therefore, the theoretical orientation of this study focused on the nature and the extent to which manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal have adopted sustainable waste management practices.

The subsequent section summarises the empirical research that was conducted. This includes the fundamental concepts that aided the researcher in obtaining the results, as well as the logical steps that were followed in carrying out this investigation.

5.3 Empirical overview of the study

Bouchrika (2023) claims that the term ‘empirical’ “refers to data gained through experience, observation or experimentation. In empirical research, knowledge is derived through real experience rather than theoretical assumptions”. Logical reasoning was applied in this study. According to Chen (2020), logical or deductive reasoning involves the use of a given set of facts or data to deduce additional facts via logical reasoning. It involves drawing specific inferences based on premises.

The following stages were used in carrying out the research:

5.3.1 Planning and framing

The researcher had to determine the topic, define the objectives of the study, develop a research proposal and set out the time-frame for the study. The review of the literature aided the researcher in identifying the broader context of waste management practices amongst manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal.

5.3.2 Gathering and recording data

The literature review enabled the researcher to generate relevant questions from research instruments used in previous studies of a similar nature. A self-administered approach was employed in this investigation. The researcher developed an electronic questionnaire to obtain meaningful data from the respondents.

5.3.3 Analysing data and interpretation of study results

This study was quantitative in nature. The data obtained from the electronic questionnaires were statistically analysed. A statistician was appointed to assist with data analysis. The data was analysed using standardised tables to ensure consistency.

5.3.4 Report writing

The report was structured in five chapters. Chapter One introduced the study and its contents and the legislative framework supporting ethical waste management practices, while Chapter Two discussed the literature review and provided explanations of keys terms in light of the study's objectives. The research design and methodology utilised in the study were explained in detail in Chapter Three. The data analysis and interpretation were reported in Chapter Four with the use of figures and tables. Furthermore, the conclusion and recommendations for further research are presented in Chapter Five.

The subsequent section presents the demographic results of the study.

5.4 Achievement of the Research Objectives

This research study is navigated by well-defined research aims and objectives as they are the fundamental building blocks of any research project. They provide a clear direction and purpose for the study, ensuring that the researcher remains focused and on track throughout the investigation. The aim of this study was to investigate the nature and the extent to which manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal have adopted sustainable waste management practices.

The achievements of the research objectives are discussed below.

5.4.1 Objective One

To establish the types of waste generated and the waste disposal measures that manufacturing organisations in the iLembe Municipal District employ:

Several options were presented to respondents via an electronic Likert scale questionnaire in respect of the types of waste they generate and how their organisations dispose of the waste they generate.

The types of waste presented to participants were Chemical Waste, Solid waste, Metal waste, Plastic waste, Other waste, Toxic waste, Food processing waste, Used Lubricants Electronic waste, Wood and paper waste, Laboratory waste and Radioactive waste.

The results indicated that Chemical, Solid and Metal waste were amongst the most prominent types of waste generated in the Municipal District of iLembe, accounting for 30.4 per cent, 29.9 per cent and 29.3 per cent respectively, while radioactive waste accounts for 4.3 per cent of the waste generated in the Municipal District of iLembe in KwaZulu-Natal, which is the least generated type of waste.

The results also indicated that the most prominent waste disposal measures were Waste recycled in-house, Waste re-used to manufacture other products and Incineration at 61 per cent, 60 per cent and 48 per cent respectively, while the least used waste disposal measure was Plasma gasification at 4 per cent.

5.4.2 Objective Two

To investigate the strategies employed by manufacturing organisations in the iLembe Municipal District to minimise waste:

Several alternatives were presented to respondents via an electronic Likert scale questionnaire in respect of the measures or strategies employed by manufacturing organisations in the iLembe Municipal District to minimise waste.

The measures presented to the respondents included manufacturing organisations vs. the effective reduction of hazardous substances into the environment; constant environmental auditing as an internal waste management strategy; necessary resources to design green or eco-friendly products; complies with the application of environmental management; utilisation of waste treatment techniques to reduce toxicity prior to disposal; policy to effectively manage waste; access to essential resources; the implementation of eco-friendly product design; reduction of water and electricity; and organisational perception on waste value and regional waste management.

The results indicate that only 40.0 per cent of respondents in the Food, Beverage and Tobacco manufacturing sector and 14.3 per cent in the Paper and Printing sector had agreed with the effective reduction of hazardous substances into the environment. The remaining sectors disagreed.

The majority of the respondents for the Automotive components manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector, and the Petroleum and Chemical products: Foam manufacturing sector agree with constant environmental auditing as an internal waste management strategy at 7.5 per cent, 34.0 per cent, 7.5 per cent, 14.2 per cent, 6.6 per cent and 0.9 per cent respectively.

The majority of the respondents for the Automotive components manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, and the Petroleum and Chemical products: Foam manufacturing sector agree with having access to the necessary resources to design green or eco-friendly products as a waste management strategy at 8.7 per cent, 27.2 per cent, 7.8 per cent, 14.6 per cent, 10.7 per cent, 8.7 per cent and 10.7 per cent respectively.

The majority of the respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Food, Beverage, and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, and the Plastic and Rubber products sector agree with complying with the application of environmental management as a waste management strategy at 8.5 per cent, 7.0 per cent, 27.9 per cent, 7.0 per cent, 11.6 per cent, 10.9 per cent, 8.5 per cent, 0.8 per cent and 11.6 per cent respectively.

The majority of the respondents for the Automotive components manufacturing sector, Electrical machinery and Apparatus manufacturing sector, Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector and the Plastic and Rubber products manufacturing sector agree with complying with the application of environmental management as a waste management strategy at 8.5 per cent, 7.0 per cent, 27.9 per cent, 7.0 per cent, 11.6 per cent, 10.9 per cent, 8.5 per cent, 0.8 per cent and 11.6 per cent respectively.

The majority of the respondents for the Food, Beverage and Tobacco manufacturing sector, Furniture manufacturing sector, Paper and Printing sector, Petroleum and Chemical products: Foam manufacturing sector, and Plastic and Rubber products sector disagree with the utilisation of waste treatment techniques to reduce toxicity prior to disposal at 6.8 per cent, 11.0 per cent, 28.8 per cent, 11.9 per cent, 13.6 per cent, 9.3 per cent, 0.8 per cent and 9.3 per cent respectively.

The majority of respondents agreed with having Policy to effectively manage waste; agreed to having access to essential resources to effectively manage waste; and agreed with the implementation of eco-friendly product design to effectively manage waste. The results indicated that respondents had a neutral response to the reduction of water and electricity in production processes. Furthermore, the results indicated that manufacturing sectors in the iLembe Municipal District in KwaZulu-Natal have a positive perception on waste value and regional waste management which bodes well for the future of the district.

5.4.3 Objective Three

To identify the drivers of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District:

Several variables were presented to respondents using an electronic Likert scale questionnaire to identify their level of association, agreement or disagreement with the factors that influence sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District.

Various factors influencing waste management practices used by manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal were presented to participants, such as Compliance with government environmental regulations; Employs digitalised technology to reduce water consumption; Employs digital technology to reduce energy consumption; and Cost reductions due to the adoption of cleaner production processes.

The majority of the respondents for Partnership, Close Corporation (CC), Private Company (Pty) (Ltd) and Public Company (Ltd) agreed with complying with government regulations at 13.8 per cent, 7.5 per cent, 38.1 per cent and 23.1 per cent respectively.

The majority of respondents for the Electrical machinery and Apparatus manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal Products, Machinery and Equipment manufacturing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products manufacturing sector, and the Textiles; Clothing and Leather goods manufacturing sector disagree with the employment of digitalised technology to reduce water consumption as a waste management strategy at 10.9 per cent, 26.1 per cent, 10.9 per cent, 12.6 per cent, 7.6 per cent, 0.8 per cent, 9.2 per cent and 9.2 per cent respectively.

The majority of the respondents for the Electrical machinery and Apparatus manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Petroleum and Chemical products sector, Petroleum and Chemical products: Foam manufacturing sector, Plastic and Rubber products sector and Textiles; Clothing and Leather goods sector disagree with the employment of digitalised technology to reduce the consumption of electricity as a waste management strategy at 10.4 per cent, 25.2 per cent, 11.3 per cent, 7.8 per cent, 0.9 per cent, 11.3 per cent and 11.3 per cent respectively.

The majority of the respondents for the Automotive components manufacturing sector, Food, Beverages and Tobacco manufacturing sector, Furniture manufacturing sector, Metals, Metal products, Machinery and Equipment manufacturing sector, Paper and Printing sector, Petroleum and Chemical products sector and, Plastic and Rubber products manufacturing sector agree with the realisation of cost reductions due to the adoption of cleaner production processes at 9.8 per cent, 25.0 per cent, 8.0 per cent, 13.4 per cent, 9.8 per cent, 8.9 per cent and 12.5 per cent respectively.

5.4.4 Objective Four

To identify the barriers hampering the adoption of sustainable waste management practices amongst manufacturing organisations in the iLembe Municipal District:
Several barriers were presented to respondents using an electronic Likert scale questionnaire. Amongst the barriers presented were employee reluctance to adopt new cleaner industrial processes and the lack of effective waste management solutions.

The results indicated that respondents significantly disagreed with the variables, which indicates that their organisations are keen to embrace cleaner industrial processes and that their organisations do not lack efficient waste management solutions.

5.5 Implications of the study

According to Khan, Anjum, Raza, Bazai and Ihtisham (2020), waste is a symptom of inefficiency and a misallocation of resources in any modern civilisation. Improper waste management not only exhausts the world's natural resources but can also gravely pollute ecosystems, air, water and soil. These impacts may be both short- and long-term in nature. If chemicals are not properly disposed of, they can pass through wastewater treatment systems and endanger human health and biodiversity by contaminating drinking water or oceans. Pollution and toxic substances may adversely affect plants, livestock, aquaculture, and various other sources of food. Ultimately, the most evident and immediate result of incorrect waste disposal is the irreparable environmental harm that will impact future generations to come. Consequently, promoting effective waste management has become a major challenge worldwide and there is an urgent need for emerging waste management approaches to maximise resource recovery while minimising environmental pollution.

The limitations and scope of the study are addressed in the section that follows.

5.6 Limitations and scope (Delimitations)

According to Bhasin (2023), limitations are constraints or restrictions that inhibit a study and its results. Due to financial and time constraints, the study was confined to 262 manufacturing sectors within the Municipal District of iLembe in KwaZulu-Natal. The results of the study indicate that only 70.23 per cent of participants from the 262 industrial sectors participated in this study. The results, however, have far broader ramifications as there is a substantial amount of data available for the international arena and not just South Africa.

The recommendations for future studies are proffered in the following section.

5.7 Recommendations for future studies

Following an extensive journey into the field of waste management practices in the manufacturing industry, it was discovered that there are numerous opportunities for further research and professional development for both researchers as well as practitioners. After analysing the data for this study, it is suggested that the following be addressed:

The results reveal that chemical waste is the most common type of waste generated in the Municipal District of iLembe. If chemicals are not disposed of in a proper manner, they can enter wastewater treatment systems and damage human health and biodiversity by contaminating the air, drinking water and oceans. Future studies could focus on whether or not there is adequate awareness and training on laboratory and chemical safety amongst manufacturing organisations.

According to the results of the study, insufficient waste treatment techniques are being applied in the Municipal District of iLembe. More waste treatment techniques must be implemented prior to waste disposal in order to limit toxicity. Further studies could be focused on the barriers that hamper manufacturing organisations from adopting waste treatment techniques.

Incineration is the third most common method of disposal in the Municipal District of iLembe. Incinerators produce additional hazardous chemicals and pollutants that deteriorate the quality of the local air, harming both humans and the environment. Future studies could be conducted to determine whether manufacturing organisations are adequately educated on the environmental repercussions of waste incineration.

The results demonstrate that respondents had a neutral reaction to the reduction of water and electricity in their organisations' production processes. Future studies could aim to identify the hurdles that hamper businesses from reducing their consumption of water and/or electricity used in their manufacturing processes.

This study focused on all manufacturing sectors in the Municipal District of iLembe in KwaZulu-Natal. Future studies could focus on the waste management practices of a specific manufacturing sector and/or specific manufacturing processes used to reduce waste and expand the body of knowledge when dealing with certain manufacturing processes.

5.8 Conclusion

This section will briefly elaborate on the major theoretical highlights of this study. The significance of the research design, the influence of those who participated in the successful completion of this study, in addition to its potential effect on the body of knowledge will be presented.

While expanding urbanisation, growing populations and technological advances may result in higher production levels, the downside is that the depletion of natural resources and the volume of waste generated are rising at an alarming rate. If drastic measures to manage the expanding waste problem are not implemented soon, the environment and human health will experience harsh consequences. Consequently, the purpose of this study was to investigate the nature and extent to which manufacturing organisations in the Municipal District of iLembe in KwaZulu-Natal have adopted sustainable waste management practices and to discuss their implications for waste management.

Due to the relatively small size, the entire target population was surveyed. This consisted of 262 manufacturing organisations in the iLembe Municipal District of South Africa. Although 191 individuals, representing 191 manufacturing organisations, participated in the study and answered the electronic questionnaire, only 184 questionnaires were deemed credible for use in the data analysis, when the statistics were calculated and drawn from SPSS. Comparative descriptive statistics, correlation analysis, chi-square tests, t-tests and central tendency descriptive statistics were employed in this study. Tables and figures were especially useful since there was a substantial number of participants and a variety of important demographic and clinical characteristics to define. Upon evaluation of the occupational levels of respondents that participated in the study, it was discovered that the majority of respondents at 31.0%, selected the category titled ‘Other’, which included a range of diverse employment categories within the relevant manufacturing sectors that were not specified in the questionnaire. Heads of Department / Supervisors responded at the second highest rate at 30.4%. Production managers accounted for 16.8 percent of all responses, ranking third highest. The remaining occupational levels were general managers at 9.8 percent and proprietors at 12.0%.

The research objectives were achieved, and the research questions posed at the beginning of the study have all been answered. The majority of respondents at 61%, agreed that their organisation's waste is recycled in-house. The second highest number of respondents, at 60%, stated that their organisation re-uses waste to manufacture other products, whereas 48% stated that their organisation incinerated waste. A further noteworthy outcome of the study was that chemical waste was the most common type of waste generated in the Municipal District of iLembe in KwaZulu-Natal, which is concerning and can be hazardous if toxins such as mercury and lead are not correctly disposed of, with certain chemicals having high global warming potential due to their accumulation and persistence in the environment. Respondents were presented with various drivers that influence sustainable waste management practices. Nevertheless, two of the most prevalent drivers noted were compliance with government regulations, where the majority of the respondents at 87% agreed while

13% disagreed, and cost reductions due to the adoption of cleaner production processes, where the majority of the respondents at 60.87% agreed that manufacturing organisations in the iLembe Municipal District had realised cost reductions due to the adoption of cleaner production processes, while 39.13% had disagreed. Respondents were also presented with barriers that hamper sustainable waste management practices. The results indicated that the average value for assessing employee resistance to adopting new cleaner industrial processes was 2.163 and 0.303 Alpha-if-deleted. The average score for determining the lack of effective waste management solutions was 1.783 and 0.255 Alpha-if-deleted. The outcomes reveal that respondents strongly disagreed with the variables, implying that the employees of their organisations are eager to promote cleaner industrial processes and that their organisations have effective waste management solutions in place.

Taking cognizance of the outcomes of this study, it is critical that more awareness, training and development on sustainable waste management methods be adopted in order for organisations to actively innovate in the waste domain. The industrial sector is vital to economic progress. However, industrial pollution poses environmental and economic concerns. Therefore, sustainable waste management practices should not be considered an option as it is critical in reducing negative environmental and social impacts throughout the product life-cycle, from design to production, consumption and ultimate disposal, and perhaps a more effective policing of the various waste management strategies and regulations will compel organisations to dispose of their waste in an environmentally responsible manner.

The results of this study will undoubtedly enhance to the body of knowledge and could be generalised and beneficial to other researchers and academics who are interested in working on this subject matter.

REFERENCES

3DEO. 2018. Environmental Impact of Additive Manufacturing. Available: https://news.3deo.co/environmental-impact-of-additive-manufacturing (Accessed: 13 September 2021).

Abdel-Shafy, H.I. and Mansour, M.S.M. 2018. Solid waste issue: Sources, composition, disposal, recycling, and valorization. Available: https://doi.org/10.1016/j.ejpe.2018.07.003 (Accessed: 04 January 2024).

Aboagye-Nyame, F. 2021. Four blocking medicines being manufactured in Africa. Available: https://mg.co.za/health/2021-04-26-four-factors-blocking-medicines-being-manufactured-in-africa/ (Accessed: 04 September 2022).

Aceto, Persico and Pescapé. 2020. Industry 4.0 and Health: Internet of Things, Big Data, and Cloud Computing for Healthcare 4.0. Available: https://www.sciencedirect.com/science/article/pii/S2452414X19300135 (Accessed: 12 April 2022).

Africa Institute. 2013. Regional Policy Guidelines: Economic Instruments for the Environmentally Sound Management of Used Lead Acid Batteries. Available: https://wedocs.unep.org/bitstream/handle/20.500.11822/40379/ACID_BATTERIES_AFRICA.pdf?sequence=3&isAllowed=y (Accessed: 07 April 2022).

Afrika, M., Oelofse, S., Strydom, W., Mvuma, G. and John, J. Statistics South Africa. 2018. Only 10% of waste recycled in South Africa. Available: http://www.statssa.gov.za/?p=11527 (Accessed 29 September 2021).

Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., and Daud, N. N. N. (2014). As-sessment of Municipal Solid Waste Management System in a Developing Country. Chinese Journal of Engineering, 14, 1–11. Available: https://www.hindawi.com/journals/cje/2014/561935/ (Accessed: 14 June 2022).

Akhtar, I. 2016. Research Design. Available: https://www.researchgate.net/publication/308915548_Research_Design (Accessed: 04 March 2022).

Akoon, I. 2023. Community Recycling Program. Available: https://www.sacities.net/community-recycling-program/ (Accessed: 18 July 2023).

Alabi, O.A., Ologbonjaye, K.I., Awosolu, O. and Alalade, O.E. 2019. Public and Environmental Health Effects of Plastic Wastes Disposal: A Review. Available: https://clinmedjournals.org/articles/ijtra/international-journal-of-toxicology-and-risk-assessment-ijtra-5-021.php (Accessed: 08 September 2022).

Albuquerque, C.A.; Mello, C.H.P.; Paes, V.C.; Balestrassi, P.P. and Souza, L.B. 2017. Electronic Junk: Best Practice of Recycling and Production Forecast Case Study in Brazil. Available:https://www.researchgate.net/profile/Vinicius_Paes2/publication/318380957_Electronic_Junk_best_practice_of_recycling_and_production_forecast_case_study_in_Brazil/links/598094ae0f7e9bd660eb5605/Electronic-Junk-best-practice-of-recycling-and-production-forecast-case-study-in-Brazil.pdf (Accessed: 07 September 2022).

Alexander and Tonachel. 2016. Status of electric vehicles in South Africa and their carbon mitigation potential. Available: wevj8040987.pdf (amazonaws.com). (Accessed: 22 August 2022).

Alhumayani, H., Gomaa, M., Soebarto, V. and Jabi, W. 2020. Environmental assessment of large-scale 3D printing in construction: A comparative study between cob and concrete. Journal of Cleaner Production, 270: 122463.

Available: https://doi.org/10.1016/j.jclepro.2020.122463 (Accessed: 03 September 2021).

Andrew, R. M. 2018. Global CO2 emissions from cement production. Earth System Science Data, 10 (1): 195-217. Available: https://doi.org/10.5194/essd-10-195-2018 (Accessed: 22 June 2022).

Andrews, G. 2020. Plastics in the Ocean Affecting Human Health. Geology and Human Health. Available: https://serc.carleton.edu/NAGTWorkshops/health/case_studies/plastics.html (Accessed: 12 February 2022).

Ankit, Saha, L., Kumar, V., Tiwari, J., Sweta, Rawat, S., Singh, J. and Bauddh, K. 2021. Electronic waste and their leachates impact on human health and environment: Global ecological threat and management. Available: https://www.sciencedirect.com/science/article/pii/S2352186421006970#! (Accessed: 23 August 2022).

Annosi, M.C., Brunetta, F., Bimbo, F. and Kostoula, M., 2021. Digitalization within food supply chains to prevent food waste. Drivers, barriers and collaboration practices. Available: https://doi.org/10.1016/j.indmarman.2021.01.005 (Accessed: 17 July 2023).

Ansari, M., Ehrampoush, M. H., Farzadkia, M and Ahmadi, E. (2019). Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; A state of the art of review. Environment International 132: 105073. Available:

https://www.sciencedirect.com/science/article/pii/S016041201931342X (Accessed: 26 January 2022).

Aprameya, A. 2016. Cross Tabulation: How It Works and Why You Should Use It. Available: https://humansofdata.atlan.com/2016/01/cross-tabulation-how-why/ (Accessed: 18 July 2023).

Aslam, S.; Ur Rehman, R. and Asad, M. Linking Environmental Management Practices to Environmental Performance: The Interactive Role of Environmental Audit. Available: http://hdl.handle.net/10419/216866 (Accessed: 23 June 2023).

Asprone, D., Auricchio, F., Menna, C. and Mercuri, V. 2018. 3D printing of reinforced concrete elements: Technology and design approach. Construction and Building Materials, 165: 218-231. Available: https://doi.org/10.1016/j.conbuildmat.2018.01.018 (Accessed: 03 September 2021).

Association for Water and Rural Development (AWARD), 2019. South Africa is drowning in its own waste – Are our regulations taking this crisis seriously. Available: http://award.org.za/index.php/2019/02/01/south-africa-is-drowning-in-its-own-waste-are-our-regulators-taking-this-crisis-seriously/ (Accessed: 09 February 2021).

Averda - South Africa. 2021. Solutions to SA's waste management problems. Available: https://www.averda.com/rsa/news/solutions-waste-management-problems (Accessed: 02 August 2021).

Averda-South Africa, 2022. South Africa's latest recycling figures. Available: https://www.averda.com/rsa/news/south-africas-latest-recycling-figures (Accessed: 09 February 2021).

Awasthi, A.K.; Li, J.; Koh, L. and Ogunseitan, O.A. 2019. Circular economy and electronic waste. Available: https://doi.org/10.1038/s41928-019-0225-2 (Accessed: 01 September 2022).

Ayompe LM., Davis SJ. and Egoh BN. 2020. Trends and drivers of African fossil fuel CO 2 emissions 1990–2017. Available: 10.1088/1748-9326/abc64f (Accessed: 23 August 2022).

Baldé C, Forti V, Gray V, Kuehr R and Stegmann P. 2017. The Global E-Waste Monitor. Bonn/Geneva/Vienna: United Nations University (UNU), International Telecommunication Union (ITU) and International Solid Waste Association (ISWA); 2017. Available: https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-Ewaste%20Monitor%202017%20.pdf (Accessed: 07 April 2022).

Barreto, L., Amaral, A. and Pereira, T. (2017), "Industry 4.0 implications in logistics: an overview", Procedia Manufacturing, Vol. 13, pp. 1245-1252. (Accessed: 22 March 2022).

Beck, B. 2018. Reduce Paper Usage and Save the Environment. Available: https://greenoffice.co.za/reducing-your-paper-usage-can-save-you-money-and-the-environment/ (Accessed: 27 February 2022).

Beier, G., Niehoff, S. and Xue, B. 2018. More Sustainability in Industry through Industrial Internet of Things? Applied Sciences, 8 (2). (Accessed: 22 March 2022).

Beier, G., Niehoff, S., Ziems, T. and Xue, B. (2017). Sustainability aspects of a digitalized industry – A comparative study from China and Germany. Int. J. Precis. Eng. Manuf. Technol. 2017, 4, 227–234. (Accessed: 22 March 2022).

Bela-Bela Local Municipality Integrated Waste Management Plan (IWMP). 2020. Integrated Waste Management Plan. Available: http://www.belabela.gov.za/docs/notices/Inputs%20on%20the%20Intergrated%20Waste%20Management%20Plan.pdf (Accessed: 04 January 2024).

Betti, de Boer and Giraud (2022). Lighthouses reveal a playbook for responsible industry transformation. Available: https://www.mckinsey.com/business-functions/operations/our-insights/lighthouses-reveal-a-playbook-for-responsible-industry-transformation?cid=other-eml-dre-mip-mck&hlkid=a774e1a8976d4a078406df70a8406fd5&hctky=12941357&hdpid=617e4b82-4715-4434-b364-9dadbbe864ec (Accessed: 07 April 2022).

Benjamin, D., Por, H. and Budescu, D. 2016. Climate Change Versus Global Warming: Who Is Susceptible to the Framing of Climate Change? Available: https://journals.sagepub.com/doi/10.1177/0013916516664382 (Accessed: 03 January 2024).

Bevans, R. 2020. An Introduction to t Tests | Definitions, Formula and Examples. Available: https://www.scribbr.com/statistics/t-test/ (Accessed: 28 May 2023).

Bhasin, H. 2023. What are Research Limitations and Tips to Organize Them. Available: https://www.marketing91.com/research-limitations/ (Accessed: 10 October 2023).

Bhandari, P. 2023. Data Collection | Definition, Methods & Examples. Available: https://www.scribbr.com/methodology/data-collection/#:~:text=Revised%20on%20June%2021%2C%202023,insights%20into%20your%20research%20problem (Accessed: January 2024).

Bimir, M.N. 2020. Revisiting E-Waste Management Practices in Africa: Selected Countries. Available: https://doi.org/10.1080/10962247.2020.1769769 (Accessed: 01 September 2022).

Bobbitt, Z. 2023. How to Report Cronbach's Alpha (With Examples). Available: https://www.statology.org/how-to-report-cronbachs-alpha/ (Accessed: 28 May 2023).

Bouchrika, I. 2023. What Is Empirical Research? Definition, Types and Samples. Available: https://research.com/research/what-is-empirical-research#:~:text=Empirical per cent20research per cent20is per cent20defined per cent20as,evidence per cent20in per cent20investigating per cent20its per cent20assertions (Accessed: 18 August 2023).

Bowan, A., Kayaga, S.M, Cotton. A, P. and Fisher, J. 2020. Municipal solid waste Management Performance. (Accessed: 07 May 2023).

Boysan,F., Ozer, C., Has, M., and Murat, M. 2015. Project on Solid Waste Recycling Plant in Sakarya University Campus. Available: Project on Solid Waste Recycling Plant in Sakarya University Campus - ScienceDirect (Accessed: 07 May 2023).

Brand South Africa. 2021. South Africa's manufacturing sector a unique option for investors. Available: https://brandsouthafrica.com/south-africas-manufacturing-sector-a-unique-option-for-investors/#:~:text=Despite%20the%20Coronavirus%20disrupting%20the,7%2Dbillion%20(7%25) (Accessed: 24 March 2022).

Brown, J.D. 2001. Using surveys in language programs. Cambridge. University Press.

Brunelli, S.; Murzakhmetova, A. and Falivena, C. 2022. Environmental Auditing in Rural Areas: Current Patterns and Future Challenges in Central Asia. Sustainability 2022, 14, 15163. Available: https://doi.org/10.3390/su142215163 (Accessed: 21 June 2023).

Bujang, M. A., Omar, E.D. and Baharum, N.A. 2018. A Review on Sample Size Determination for Cronbach's Alpha Test: A Simple Guide for Researchers. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6422571/#b1-09mjms25062018_oa6 (Accessed: 22 May 2023).

Cai, W., Lai, K.-h., Liu, C., Wei, F., Ma, M., Jia, S., Jiang, Z. and Lv, L. 2019. Promoting sustainability of manufacturing industry through the lean energy-saving and emission-reduction strategy. Science of The Total Environment, 665: 23-32. (Accessed: 31 August 2021).

Calzon, B. 2023. A Guide to The Methods, Benefits & Problems of The Interpretation of Data. Available: https://www.datapine.com/blog/data-interpretation-methods-benefits-problems/ (Accessed: 26 May 2023).

Cane, M. and Parra, C., 2020. Digital platforms: mapping the territory of new technologies to fight food waste. Available: https://www.emerald.com/insight/content/doi/10.1108/BFJ-06-2019-0391/full/html (Accessed: 17 July 2023).

Carnie, T. 2008. Residents treated after gas leak. Available: https://www.iol.co.za/news/south-africa/residents-treated-after-gas-leak-423230 (Accessed: 25 February 2022).

Chan, M. 2020. 7 types of manufacturing wastes and how to reduce them. Available: https://www.unleashedsoftware.com/blog/7-types-of-manufacturing-wastes-and-how-to-reduce-them (Accessed: 28 August 2022).

Chandler, A. J., Eighmy, T. T., Hjelmar, O., Kosson, D. S., Sawell, S. E., Vehlow, J. and Sloot, H. A. (1997). Municipal Solid Waste Incinerator Residues. Amsterdam: Elsevier. (Accessed: 14 June 2022).

Charles, R, G., Davies, M. L., Douglas, P., Hallin, I.L. and Mabbett, I. 2019. Sustainable energy storage for solar home systems in rural Sub-Saharan Africa – A comparative examination of lifecycle aspects of battery technologies for circular economy, with emphasis on the South African context. Available: https://reader.elsevier.com/reader/sd/pii/S0360544218320437?token=3A3F0D2598299D295217939CFBDDD1BDBE6BE51E6DDC7DC40CF7F41D781B9C00290A39964D0F79B127099FA98848C42B&originRegion=eu-west-1&originCreation=20220907170626 (Accessed: 07 September 2022).

Chen, J. Zhang, M. Li, F. Qian, L. Lin, H. Yang, L. Wu, X. Zhou, X. He. and Liao, B.-Q. Membrane fouling in a membrane bioreactor: high filtration resistance of gel layer and its underlying mechanism. Water Res., 102 (2016), pp. 82-89. Available: https://reader.elsevier.com/reader/sd/pii/S0043135416304663?token=6C2A40A5FA23F829DC0854D5375E5C373D0F23FABA4198A8CA9FE67EC03235D49E3EC432694528F5CC5F17A0A4E8CE12&originRegion=eu-west-1&originCreation=20220126122432 (Accessed: 26 January 2022).

Chen, Y. (2018). Effects of urbanisation of municipal solid waste composition. Waste Management (New York, N.Y.), 79, 828–836. Available: https://pubmed.ncbi.nlm.nih.gov/30078496/ (Accessed: 14 June 2022).

Chen, Z. 2020. Milestones: Cognitive. Available: https://www.sciencedirect.com/science/article/abs/pii/B9780128093245218257 (Accessed: 12 October 2023).

Chisholm, J. M., Zamani, R., Negm, A. M., Said, N., Abdel Daiem, M. M., Dibaj, M. and Akrami, M. 2021. Sustainable waste management of medical waste in African developing countries: A narrative review. Waste Manag Res, 39 (9): 1149-1163. Available: https://journals.sagepub.com/doi/10.1177/0734242X211029175 (Accessed: 04 February 2022).

Climate Analytics. 2022. What is South Africa's pathway to limit global warming to 1.5°C? Available: https://1p5ndc-pathways.climateanalytics.org/countries/south-africa/sectors/#power (Accessed: 10 April 2022).

Climate Analytics. 2020. Climate Transparency Report – South Africa. Available: https://www.climate-transparency.org/countries/africa/south-africa (Accessed: 14 June 2022).

Compactor Management Company. 2022. 7 Waste Disposal & Management Methods. Available: https://www.norcalcompactors.net/waste-disposal-methods/ (Accessed: 12 April 2022).

Conserve Energy Future. 2021. Causes, Effects and Solutions to Huge Piles of Wastes Available: https://www.conserve-energy-future.com/causes-effects-solutions-illegal-dumping.php (Accessed 01 November 2021).

Corbyn, D., Martinez, J. and Cooke, R. (2019). Off-grid solar waste in sub-Saharan Africa: Market dynamics, barriers to sustainability, and circular economy solutions. Available: https://www.sciencedirect.com/science/article/pii/S0973082622001405#bb0095 (Accessed: 25 August 2022).

Cousins, M. 2021. What are the 7 Wastes that are Killing Business Efficiency? Available: https://blog.triaster.co.uk/blog/what-are-the-7-wastes-killing-business#one (Accessed: 25 February 2022).

Creamer Media. 2019. S Africa legislation bans liquid waste from landfills. Available: https://www.engineeringnews.co.za/article/s-africa-legislation-bans-liquid-waste-from-landfills-2019-09-27 (Accessed: 19 February 2022).

Creswell, J. W. 2014. Research design: Qualitative, quantitative, and mixed

Cucchiella F., D'adamo I., Koh S.C.L. and Rosa P. 2015. Recycling of WEEEs: an economic assessment of present and future e-waste streams. Available: https://doi.org/10.1016/j.rser.2015.06.010 (Accessed: 10 April 2022).

d'Estries, M. 2017. 5 Solar-Powered Buildings That Will Forever Change Architecture. Available: https://www.treehugger.com/solar-powered-buildings-will-forever-change-architecture-4868157 (Accessed: 22 June 2022).

Dada, O. and Mbohwa, C. 2018. Energy from waste: A possible way of meeting goal 7 of the sustainable development goals. Available:

https://www.sciencedirect.com/science/article/pii/S2214785317333965 (Accessed: 24 August 2022).

Daniel, E. 2021. Common goods: Fighting materials' impact on climate change: McKinsey and Company. Available: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/common-goods-fighting-materials-impact-on-climate-change (Accessed: 02 August 2021).

Daniel, L. 2020. Business Insider SA. Here's how SA's radical new recycling laws will affect you. Available: https://www.businessinsider.co.za/how-the-recycling-laws-will-affect-south-africans-2020-11 (Accessed: 08 May 2021).

Daniel, L. 2020. Here's how SA's radical new recycling laws will affect you. Available: https://www.businessinsider.co.za/how-the-recycling-laws-will-affect-south-africans-2020-11 (Accessed: 09 February 2021).

Darnall, N. 2007. 'Why Firms Mandate ISO 14001 Certification'. Available: https://www.researchgate.net/publication/228285197_Why_Firms_Mandate_ISO_14001_Certification (Accessed: 21 June 2022).

De Groot, J. 2021. What is Data Classification? A Data Classification Definition. Available: https://digitalguardian.com/blog/what-data-classification-data-classification-definition (Accessed: 08 May 2022).

De Smet, A., Gao, W., Henderson, K. and Thomas, H. 2021. Organizing for sustainability success: Where, and how, leaders can start. Available: https://www.mckinsey.com/business-functions/sustainability/our-insights/organizing-for-sustainability-success-where-and-how-leaders-can-start (Accessed: 10 September 2021).

De, D., Chowdhury, S., Dey, P. K. and Ghosh, S. K. 2020. Impact of Lean and Sustainability Oriented Innovation on Sustainability Performance of Small and Medium Sized Enterprises: A Data Envelopment Analysis-based framework. International Journal of Production Economics, 219: 416-430. (Accessed: 18 February 2022).

DEA. (2011). South Africa state of waste report, first draft. DEA. Pretoria: RSA. (Accessed: 07 May 2024).

DEA. (2018). South Africa state of waste. A report on the state of the environment. First draft report. Pretoria: RSA. (Accessed: 18 February 2022).

DEA. (2018). South Africa state of waste. Second draft report. Page 2. Available: https://remade.co.za/wp-content/uploads/2020/01/South-Africa-State-of-Waste-Report.pdf (Accessed: 27 February 2022).

Deer, R. 2021. The Facts: Office Workers and Their Waste Generation. Available: https://www.roadrunnerwm.com/blog/office-worker-waste-generation#:~:text=Between%20print%20mistakes%2C%20junk%20mail,recycling%20its%20mixed%20paper%20products. (Accessed: 27 February 2022).

Del Río González, P. 2008. Policy implications of potential conflicts between short-term and long-term efficiency in CO_2 emissions abatement. Available: https://doi.org/10.1016/j.ecolecon.2007.06.013 (Accessed: 30 July 2023).

Dembek, K., Moglia, M., Nygaard, C., Taffe, S. and Woodcock, I. 2021. Is waste incineration burning a hole in our sustainable future? Available: https://thefifthestate.com.au/columns/spinifex/is-waste-incineration-burning-a-hole-in-our-sustainable-future/ (Accessed: 02 June 2023).

Department of Energy. (2019). SA Energy Sector Report 2019. Available: http://www.energy.gov.za/files/media/explained/2019-South-African-Energy-Sector-Report.pdf (Accessed: 14 June 2022).

Department of Environment Forestry and Fisheries. 2019. National waste management strategy, 2019. Available: https://cer.org.za/wp-content/uploads/2019/12/NEMWA-Waste-Strategy-for-comment-03.12.2019-Pt-1.pdf (Accessed: 07 August 2022).

Department of Environment Forestry and Fisheries. 2021. National waste management strategy, 2020. Available: http://sawic.environment.gov.za/documents/12777.pdf (Accessed: 16 June 2022).

Department of Environmental Affairs and Development Planning. 2020. State of waste management report 2020. Available: https://www.westerncape.gov.za/eadp/files/atoms/files/Annual%20State%20of%20Waste%20Management%20Report%202020%20-%20March%202022SHsigned.pdf (Accessed: 09 September 9, 2022).

Department of Environmental Affairs. 2017. Industry Waste Tyre Management Plan. Tyre Waste Abatement and Minimisation Initiative of South Africa. http://sawic.environment.gov.za/documents/8596.pdf. (Accessed: 30 August 2022).

Department of environmental affairs. 2018. South Africa state of waste report. Available: http://sawic.environment.gov.za/documents/8635.pdf (Accessed 29 September 2021).

Department of Forestry, Fisheries and Environment, 2020. National Assembly. Available: https://www.dffe.gov.za/sites/default/files/parliamentary_updates/pq2711of2020_wastemanagementcrisis.pdf (Accessed: 09 September 2022).

Department of Forestry, Fisheries and Environment, 2021. Environment, Forestry and Fisheries on Extended Producer Responsibility in the waste sector. Available: https://www.gov.za/speeches/environment-forestry-and-fisheries-extended-producer-responsibility-waste-sector-28-mar (Accessed: 25 February 2022).

Department of Forestry, Fisheries and the Environment. 2021. State of the Environment. https://soer.environment.gov.za/soer/CMSWebSite/Content.aspx?menuId=8234,8073 (Accessed: 08 June 2021).

Department of Health (DOH). 2020. COVID-19 National Public Hygiene Strategy and Implementation Plan. Republic of South Africa Department of Health, Pretoria. Available: http://www.health.gov.za/index.php/component/phocadownload/category/676-national-public-hygiene-strategy-and-implementation-plan (Accessed: 07 April 2022).

Department of Health, KwaZulu Natal Province. 2016. Policy and procedures for the disposal of pharmaceutical waste. Page 2-9. Available: http://www.kznhealth.gov.za/mcwh/polio/kzn_policy_procedures_disposal_pharmaceutical_waste.pdf (Accessed: 03 February 2021).

Department of Health, State Government of Victoria, Australia. 2021. Hazardous waste. Available:

https://www.betterhealth.vic.gov.au/health/healthyliving/hazardous-waste#bhc-content (Accessed: 29 August 2022).

Department of Environment, Forestry and Fisheries South Africa. 2020. National waste management strategy 2020. Available: https://www.dffe.gov.za/sites/default/files/docs/2020nationalwaste_managementstrategy1.pdf Accessed: 04 September 2023.

Department: Government Communication and Information System Republic of South Africa. 2018/2019. Official Guide to South Africa 2018/19. Available: https://www.gcis.gov.za/sites/default/files/docs/resourcecentre/pocketguide/2012/complete%20guide.pdf (Accessed: 16 February 2022).

Department: Statistics South Africa. 2022. The South African economy records a positive fourth quarter. Available: http://www.statssa.gov.za/?p=15214 (Accessed: 24 March 2022).

Dladla, I, Machete, F, Shale, K (2016) A review of factors associated with indiscriminate dumping of waste in eleven African countries. African Journal of Science, Technology, Innovation and Development 8: 475–481. https://journals.co.za/doi/abs/10.1080/20421338.2016.1224613 (Accessed: 25 January 2022).

Dlamini, S., Simatele, M. and Kubanza, M. 2019. Municipal solid waste management in South Africa: From waste-to-energy recovery through waste-to-energy technologies in Johannesburg. Local Environment, 24(3), 249–257. doi:10.1080/13549839.2018.1561656. (Accessed: 18 February 2022).

Dlamini, S., Simatele, M.D. and Kubanza, N.S. 2019. 'Municipal solid waste management in South Africa: From waste to energy recovery through waste-to-energy technologies in Johannesburg.' Local Environment, 24(3):249-257. Available: https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.1080%2F13549839.2018.1561656 (Accessed: 21 June 2023).

Dmitrienko, M. A., Nyashina, G. S. and Strizhak, P. A. 2018. Major gas emissions from combustion of slurry fuels based on coal, coal waste, and coal derivatives. Available: Major gas emissions from combustion of slurry fuels based on coal, coal waste, and coal derivatives - ScienceDirect. (Accessed: 27 August 2022).

Do, D. 2017. The Five Principles of Lean. Available: https://theleanway.net/The-Five-Principles-of-Lean (Accessed: 05 September 2022).

Dörnyei, Z. 2007. Research methods in applied linguistics: Quantitative, qualitative, and mixed methodologies. Oxford: University Press. (Accessed: 05 September 2022).

Durán, O., Capaldo, A. and Duran Acevedo, P. 2018. Sustainable Overall Throughputability Effectiveness (S.O.T.E.) as a Metric for Production Systems. (Accessed: 18 February 2022).

Dwarika, R.'A. 2015. Comparative Study of Responsible Care and ISO 14001 as an Effective Environmental Management System in the Chemical and Allied Industry. Available: https://researchspace.ukzn.ac.za/handle/10413/13434 (Accessed: 21 June 2022).

Earley, K. 2016. More than half of all businesses ignore UN's sustainable development goals. Available: https://www.theguardian.com/sustainable-business/2016/sep/30/businesses-ignore-un-sustainable-development-goals-survey (Accessed: 04 August 2021).

EcoEnclose. 2021. Post-Consumer vs Post Industrial Recycled Content. Available: https://www.ecoenclose.com/blog/post-consumer-vs-post-industrial-recycled-content/ (Accessed: 27 February 2022).

El-Saadony, M.T., Saad, A.M., El-Wafai, N.A., Abou-Aly, H.E., Salem, H.M., Soliman, S.M., El-Mageed, Elrys, A.S., Selim, S., El-Hack, M.E.A, Kappachery, S., El-Tarabily, K.A. and AbuQamar, S.F. 2023. Hazardous wastes and management strategies of landfill leachates: A comprehensive review. Available: https://doi.org/10.1016/j.eti.2023.103150 (Accessed: 10 July 2023).

Elsheikh, A. H., Panchal, H., Shanmugan, S., Muthuramalingam, T., El-Kassas A. M., and Ramesh, B. 2022. Recent progresses in wood-plastic composites: Pre-processing treatments, manufacturing techniques, recyclability and eco-friendly assessment. Available: https://doi.org/10.1016/j.clet.2022.100450 (Accessed: 25 June 2023).

Elytus, Ltd. 2019. E-Waste and its Negative Effects on the Environment. Available: https://elytus.com/blog/e-waste-and-its-negative-effects-on-the-environment.html#:~:text=The%20air%20pollution%20caused%20by,creating%20irreversible%20damage%20in%20ecosystems. (Accessed: 07 April 2022).

Emberson, L. 2020. The Sustainable Manufacturing and Environmental Pollution Programme. Available: https://unctad.org/news/sustainable-manufacturing-and-environmental-pollution-programme (Accessed: 14 October 2023).

Emberson, L. 2020. The Sustainable Manufacturing and Environmental Pollution Programme. Available: https://unctad.org/news/sustainable-manufacturing-and-environmental-pollution-programme (Accessed: 20 June 2021).

Environmental Assurance. 2020. The waste management Hierarchy concept. Available: https://www.envass.co.za/the-waste-management-hierarchy-concept/ (Accessed: 30 August 2022).

Environmental Hazards Services (EHS), 2022. What Are the 4 Types of Hazardous Waste? Available: https://leadlab.com/what-are-the-4-types-of-hazardous-waste/ (Accessed: 15 February 2022).

Environmental Protection Agency. 2018. Sustainable Manufacturing. Available: https://www.epa.gov/sustainability/sustainable-manufacturing (Accessed: 31 August 2021).

Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C. and Behdad, S. 2018. The future of waste management in smart and sustainable cities: A review and concept paper. Waste Management, 81: 177-195. (Accessed: 07 April 2022).

Espinoza, R. 2020. How Hazardous Waste Disposal Affects the Environment. Available: https://blog.idrenvironmental.com/how-hazardous-waste-disposal-affects-the-environment (Accessed: 02 August 2021).

European Commission. 2018. Eco-Innovation of products: Case studies and policy lessons from EU Member States for a product policy framework that contributes to a circular economy. European Commissions, p.13. Available at: https://ec.europa.eu/environment/ecoap/sites/ecoap_stayconnected/files/documents/eio_report_2018.pdf(Accessed: 18 May 2021).

Eurostat. 2020. Greenhouse gas emissions from waste. Available: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200123-1 (Accessed: 14 June 2022).

Eurostat. 2021. Quarterly greenhouse gas emissions in the EU. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Quarterly_greenhouse_gas_emissions_in_the_EU#Greenhouse_gas_emissions (Accessed: 14 June 2022).

Faculty Survey of Student Engagement (FSSE). 2017. Internal Consistency Reliability. Available: https://scholarworks.iu.edu/dspace/bitstream/handle/2022/24498/FSSE17_Internal_Consistency_Reliability.pdf?sequence=1&isAllowed=y#:~:text=Cronbach's%20alpha%20ranges%20in%20value,should%20be%20used%20with%20caution. (Accessed: 04 January 2024).

Fakoya, M.B. 2014. Institutional challenges to municipal waste management service delivery in South Africa. J. Hum. Ecol. 2014, 45, 119–125. (Accessed: 14 June 2022).

Fakoya, M.B. 2017. Institutional Challenges to Municipal Waste Management Service Delivery in South Africa. Available: https://doi.org/10.1080/09709274.2014.11906685 (Accessed: 07 May 2024).

Faridi, R. 2017. Cross Tabulation in Geographical Research. Available: https://rashidfaridi.com/2017/10/15/cross-tabulation-in-geographical-research/ (Accessed: 04 January 2024).

Fasting, M. S. 2019. Industry 4.0 in Waste Management. Available: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2619874/no.ntnu%3Ainspera%3A2562880.pdf?sequence=1 (Accessed: 19 June 2023).

Ferronato N. and Torretta V. 2019. Waste management in developing countries: A review of global issues. Int. J. Environ. Res. Public Health. https://doi.org/10.3390/ijerph16061060 (Accessed: 19 June 2022).

Ford, V. 2021. Africa's green manufacturing crossroads. Available: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/africas%20green%20manufacturing%20crossroads/mck-gmr_full%20report_fa-2.pdf (Accessed: 02 September 2022).

Friendly Power. 2020. Manufacturing facilities. Available: https://esource.bizenergyadvisor.com/article/manufacturing-facilities (Accessed: 22 June 2022).

Fulk, G. 2023. Descriptive Statistics, An Important First Step. Journal of Neurologic Physical Therapy 47(2): p 63. Available: https://journals.lww.com/jnpt/Fulltext/2023/04000/Descriptive_Statistics,_An_Important_First_Step.1.aspx (Accessed: 16 May 2023).

Fuss, S., Lamb, W. F., Callaghan, M. W., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., Garcia, W. O., Hartmann, J., Khanna, T., Luderer, G., Nemet, G. F., Rogelj, J., Smith, P., Vicente, J. L. V., Wilcox, J., Dominguez, M. D. Z. and Minx. J. C. 2018. Negative emissions - Part 2: Costs, potentials and side effects. Available: https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f (Accesed: 08 September 2022).

Gaille, L. 2019. 13 Pros and Cons of Quantitative Research Methods. Available: https://vittana.org/13-pros-and-cons-of-quantitative-research-methods (Accessed: 08 May 2022).

Galal, S. 2022. Number of people employed in South Africa 2021, by industry. Available: https://www.statista.com/statistics/1129815/number-of-people-employed-in-south-africa-by-industry/ (Accessed: 08 September 2022).

Gardner, D.J., Han, Y. and Wang, L. 2015. Wood–plastic composite technology. Available: https://link.springer.com/article/10.1007/s40725-015-0016-6?utm_source=getftr&utm_medium=getftr&utm_campaign=getftr_pilot (Accessed: 25 June 2023).

Garg, H., Nagar, N., Ellamparuthy, G., Angadi, S. I. and Gahan, C. S. 2019. Bench scale microbial catalysed leaching of mobile phone PCBs with an increasing pulp density. Available: https://doi.org/10.1016/j.heliyon.2019.e02883 (Accessed: 05 July 2023).

Garlapati, V.K. 2016. E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. Available: https://www.sciencedirect.com/science/article/abs/pii/S1364032115011855 (Accessed: 20 June 2022).

Gedam, V.V.; Raut, R.D.; Lopes De Sousa Jabbour, A.B.; Narkhede, B.E. and Grebinevych, O. 2020. Sustainable manufacturing and green human resources: Critical success factors in the automotive sector. Available: https://onlinelibrary.wiley.com/doi/10.1002/bse.2685 (Accessed: 21 June 2023).

George, D. and Mallery, P. 2019. IBM SPSS Statistics 25 Step by Step a Simple Guide and Reference. Fifteenth Edition. Available: file:///C:/Users/allan/Downloads/9781138491045%20(2).pdf (Accessed: 09 October 2023).

Ghazilla, R.A.R., Sakundarini, N., Abdul-Rashid, S.H., Ayub, N.S., Olugu, E.U., and Musa, S.N. 2015. Drivers and Barriers Analysis for Green Manufacturing Practices in Malaysian SMEs: A Preliminary Results. Procedia CIRP, 26, 658-663. (Accessed: 22 June 2022).

Ghosh, S.K.; Debnath, B.; Baidya, R.; De, D.; Li, J.; Ghosh, S.K.; Zheng, L.; Awasthi, A.K.; Liubarskaia, M.A. and Ogola, J.S. 2016. Waste electrical and electronic equipment management and Basel Convention compliance in Brazil, Russia, India, China and South Africa (BRICS) nations. Available: https://journals.sagepub.com/doi/abs/10.1177/0734242x16652956 (Accessed: 01 September 2022).

Gimenez, L. 2020. 6 steps for data cleaning and why it matters. Available: https://www.geotab.com/blog/data-cleaning/ (Accessed: 24 October 2022).

Gliem, J. A. and Gliem, R. R. 2003. Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales. Available: https://scholarworks.iupui.edu/bitstream/handle/1805/344/gliem+&+gliem.pdf?sequence=1 (Accessed: 12 July 2023).

Godfrey, L., & Oelofse, S. (2017). Historical Review of Waste Management and Recycling in South Africa. Resources, 6(4), 57. Available: Doi:10.3390/resources6040057 (Accessed: 07 May 2024)

Godfrey, L.K. and Oelofse, S.H.H. 2017. Historical Review of Waste Management and Recycling in South Africa. Resources, vol.6(4):57. Available: https://researchspace.csir.co.za/dspace/bitstream/handle/10204/9717/Godfrey_19704_2017.pdf?sequence=1&isAllowed=y (Accessed: 16 March 2022).

Godfrey, L., Ahmed, M. T., Gebremedhin, K. G., Katima, J. H. Y., Oelofse, S., Osibanjo, O., Richter, U. H. and Yonli, A. H., 2019. Solid Waste Management in Africa: Governance Failure or Development Opportunity? In: Regional Development in Africa. Available: https://www.intechopen.com/chapters/68270 (Accessed: 16 March 2022).

Godfrey, L., Strydom, W. and Phukubye, R. (2016). Integrating the informal sector into the South African waste and recycling economy in the context of extended producer responsibility. Retrieved on 12 July 2019 from: https://www.wasteroadmap.co.za/download/informal_sector_2016.pdf (Accessed: 18 February 2022).

Goodenough, A. and Waite, S. 2012. Real world research: a resource for users of social research methods in applied settings. Journal of Education for Teaching, 38(4), 13-51.

Gorard, S. 2013. Research design: Creating robust approach for social sciences. (Accessed: 04 March 2022).

Gourley, L. (2020). The 7 wastes of lean production. Available: https://www.ptc.com/en/blogs/iiot/7-wastes-of-lean-production (Accessed: 25 January 2022).

Grainger Editorial Staff. 2020. How Does Autoclave Sterilization Work? Available: https://www.grainger.com/know-how/equipment-information/kh-how-does-autoclave-sterilization-work (Accessed: 04 February 2022).

GRID-Arendal Annual Report. 2015. Stories and Solutions. Available: https://grid.cld.bz/Stories-and-Solutions-GRID-Arendal-Annual-Report-2015 (Accessed: 04 January 2024).

GreenCape. 2020. Waste 2020: Market Intelligence Report 2020. Available: https://www.greencape.co.za/assets/WASTE_MIR_20200331.pdf (Accessed: 09 September 2022).

Gu, F., Guo, J., Zhang, W., Summers, P. A. and Hall, P. 2017. From waste plastics to industrial raw materials: A life cycle assessment of mechanical plastic recycling practice based on a real-world case study. Science of the total environment, 601: 1192-1207. (Accessed: 04 February 2022).

Guo, X. and Yan, K. 2017. Estimation of obsolete cellular phones generation: A case study of China. Available: https://doi.org/10.1016/j.scitotenv.2016.10.054 (Accessed: 05 July 2023).

Gupta, R. 2023. How to use the CROSSTAB function in PostgreSQL. Available: https://www.sqlshack.com/how-to-use-the-crosstab-function-in-postgresql/ (Accessed: 18 July 2023).

Haile, A., Gelebo, G.G., Tesfaye, T., Mengie, W., Mebrate, M.A., Abuhay, A. and Limeneh, D.Y., 2021. Pulp and paper mill wastes utilizations and prospects for high value-added biomaterials. http://dx.doi.org/10.1186/s40643-021-00385-3 (Accessed: 10 July 2023).

Hankel and Burgess. 2018. Plastic Marine Pollution in South Africa. Available: https://ocims-dev.dhcp.meraka.csir.co.za/plastic-marine-pollution-in-south-africa/#:~:text=In%20South%20Africa%2C%20only%2016,in%20the%20ocean%20%5B4%5D. (Accessed: 08 September 2022).

Haque, M. M., Goda, K., Ogoe, S. and Sunaga, Y. 2019. Fatigue analysis and fatigue reliability of polypropylene/wood flour composites. Available: https://doi.org/10.1016/j.aiepr.2019.07.001 (Accessed: 25 June 2023).

Hayes, A. 2022. Adam Smith and "The Wealth of Nations". Available: https://www.investopedia.com/updates/adam-smith-wealth-of-nations/ (Accessed: 02 September 2022.

Hayes, A. 2023. Mode: What It Is in Statistics and How to Calculate It. Available: https://www.investopedia.com/terms/m/mode.asp (Accessed: 04 January 2024).

Helm R.C., Costa D.P., DeBruyn T.D., O'Shea T. J., Wells R. and Williams T. M. 2015. Overview of Effects of Oil Spills on Marine Mammals. Available: https://www.researchgate.net/publication/275959547_Overview_of_Effects_of_Oil_Spills_on_Marine_Mammals (Accessed: 18 February 2022).

Hertow, M., Krones, J. and Li, X., 2020. Non-Hazardous Industrial Waste in the United States: 100 Million Tons of Recoverable Resources. Available: https://www.sciencedirect.com/science/article/pii/S0921344920306844 (Accessed: 07 September 2022).

Hillier, W. 2023. What's the Difference Between Descriptive and Inferential Statistics? Available: https://careerfoundry.com/en/blog/data-analytics/inferential-vs-descriptive-statistics/ (Accessed: 22 May 2023).

Honest Mobile. 2021. Honest mobile is now carbon negative (it's a positive thing, we promise). Available: https://honestmobile.co.uk/2021/02/12/honest-mobile-is-now-carbon-negative/ (Accessed: 13 September 2021).

Hostetter, Klei, Winkler and Wolf, 2022. How green can green growth be? Available: How green can green growth be? | McKinsey (Accessed: 26 August 2022).

Hu, L., Peng, C., Evans, S., Peng, T., Liu, Y., Tang, R. and Tiwari, A. 2017. Minimising the machining energy consumption of a machine tool by sequencing the features of a part. Available: https://doi.org/10.1016/j.energy.2017.01.039 (Accessed: 30 July 2023).

Hussain J. 2020. Processing of data, editing coding and classification. Available: https://mmhapu.ac.in/doc/eContent/Management/JamesHusain/May2020/Processing%20of%20Data,MBA-II%20Sem.pdf (Accessed: 02 May 2022).

Hussain, M. N., Basim, Q., JanajrehIsam, I. and Zamzam, S., 2017. Solar PV Implementation in Industrial Buildings: Economic Study. Available from: https://www.researchgate.net/publication/328991600_Solar_PV_Implementation_in_Industrial_Buildings_Economic_Study (Accessed: 22 June 2022).

iLembe Chamber of Commerce and Tourism. 2019. Waste beneficiation and Linkage Survey: Isithebe Industrial Park. Final Report on Opportunities for On-Site Waste Beneficiation. Available: https://www.iLembechamber.co.za/wp-content/uploads/2020/03/2019-05-13-iLembe-IBC-Final-Report.pdf (Accessed: 27 February 2022).

iLembe District Municipality. 2015. iLembe District Growth and Development Plan. Available: http://www.kznppc.gov.za/images/downloads/DGDP/Galebe/DC%2029%20Ilembe%20DGDP.pdf (Accessed: 03 July 2022).

In. J. 2017. Introduction of a pilot study. Available: https://doi.org/10.4097/kjae.2017.70.6.601 (Accessed: 03 January 2024).

Infrastructure News, 2022. State of the South African waste industry. Available: https://infrastructurenews.co.za/2022/03/10/state-of-the-south-african-waste-industry/ (Accessed: 22 June 2022).

Inter-governmental Panel on Climate Change. 2018. Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. Available: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/ (Accessed: 08 September 2022).

International Energy Agency. 2018. Global energy and CO2 status report. Available: https://www.iea.org/publications/freepublications/publication/GECO2017.pdf (Accessed: 04 September 2021).

Intrakamhaeng V., Clavier K.A. and Townsend T.G. 2020. Hazardous waste characterization implications of updating the toxicity characteristic list. Available: https://www.sciencedirect.com/science/article/pii/S0304389419311252 (Accessed: 23 March 2022).

IPBES. 2022. The global assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES. Available: https://ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf (Accessed: 09 September 2022).

IPCC. 2021. Climate change widespread, rapid, and intensifying – IPCC. Available: https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/?cid=other-eml-shl-mip-mck&hlkid=82b73652a5fc4c70bf423c79f44fa0a4&hctky=12941357&hdpid=84dc821c-252d-4fc9-aa72-dd917ad20bc3 (Accessed: 06 September 2021).

Ireland, K. 2019. Why are eco-friendly products more expensive? Available: https://clarifygreen.com/eco-friendly-products-cost-more/ (Accessed 18 August 2021).

Islam S. 2021. Waste management strategies in fashion and textiles industry: challenges are in governance, materials culture and design centric. Available: 10.1016/b978-0-12-818758-6.00015-6 (Accessed: 24 March 2022).

Jagyasi, P. 2022. 7 Important Eco-Friendly Methods of Waste Disposal. Available: https://ecofriend.org/7-important-eco-friendly-methods-of-waste-disposal/ (Accessed: 05 June 2023).

Jahan, I. 2017. A study on waste management and minimization in ready-made garments (RMG) Industry. Available: https://www.researchgate.net/publication/320150032_A_STUDY_ON_WASTE_MANAGEMENT_AND_MINIMIZATION_IN_READY_MADE_GARMENTS_RMG_INDUSTRY (Accessed: 23 June 2023).

Jee, C. and Shagufta. 2010. Dictionary of environmental science. New Delhi: A.P.H. Pub. Corp. (Accessed: 08 June 2022).

Jeyabharathi, D., Thava, A. M., Idas, S. J. P. and Sangeetha, T. 2021. Chapter 9 - Waste management in smart cities using blockchaining technology. In: Krishnan, S., Balas, V. E., Julie, E. G., Robinson, Y. H. and Kumar, R. eds. Blockchain for Smart Cities. Elsevier, 171-181. Available: https://www.sciencedirect.com/science/article/pii/B9780128244463000144 (Accessed: 21 February 2021).

Jha, R., Rao, M. D., Meshram, A., Verma, H. R. and Singh, K. K. 2020. Available: Potential of polymer inclusion membrane process for selective recovery of metal values from waste printed circuit boards: A review. Available: https://doi.org/10.1016/j.jclepro.2020.121621 (Accessed: 05 July 2023).

Johansen, K and Werner, S. 2022. Something is sustainable in the state of Denmark: A review of the Danish district heating sector. Available: https://www.sciencedirect.com/science/article/pii/S1364032122000466/pdfft?md5=2cd2534412684024682d05edeb3aca0f&pid=1-s2.0-S1364032122000466-main.pdf (Accessed: 02 June 2023).

Johnson, A.G. 2019. Assessing the change in hydro-geochemical properties of fly ash over time when disposed into opencast coal mines in Mpumalanga, South Africa. Available: http://etd.uwc.ac.za/xmlui/handle/11394/6927 (Accessed: 25 February 2022).

Jolie, S. K. 2022. Use of the Solid Waste Management Strategies Adopted by Manufacturing Companies in Beni, Democratic Republic of Congo. Available: https://www.scirp.org/journal/articles.aspx?searchcode=Sifa+Kpaka++Jolie&searchfield=authors&page=1 (Accessed: 19 June 2023).

Joseph, J. and Inambao, F.L. 2020. Trends: Energy Efficiency and Energy Security. Available: https://www.ripublication.com/irph/ijert20/ijertv13n12_06.pdf (Accessed: 07 September 2022).

Jovanović V., Manojlović J., Jovanović D., Matic B. and Đonović N. Management of pharmaceutical waste in hospitals in Serbia–challenges and the potential for improvement. Indian Journal of Pharmaceutical Education and Research. 2016;50(4):695–702. (Accessed: 25 January 2022).

Kanagamani, K., Geethamani, P and Narmatha, M. 2020. Hazardous Waste Management. Available: https://www.intechopen.com/chapters/74184 (Accessed: 28 August 2022).

Keerthana, R. 2022. South Africa Waste Management Landscape: An Overview. Available:https://www.wasterecyclingmea.com/news/waste-management/south-africa-waste-management-landscape-an-overview (Accessed: 31 July 2023).

Kenton, W. 2022. Triple Bottom Line (TBL). Available: https://www.investopedia.com/terms/t/triple-bottom-line.asp (Accessed: September 2022).

Key World Energy Statistics 2017. International Energy Agency, 2017. [Online]. Available: https://doi.org/10.1016/j.energy.2017.01.039 (Accessed: 30 July 2023).

Khan, S., Anjum, R., Raza, S. T., Bazai, N.A. and Ihtisham, M. 2020. Technologies for municipal solid waste management: Current status, challenges, and future perspectives. Available: https://www.sciencedirect.com/science/article/abs/pii/S0045653521028757 (Accessed: 12 October 2023).

Kimani, A. 2020. GIS Mapping of community perceptions of illegal waste dumping in Mbekweni, Paarl. Available: https://etd.uwc.ac.za/bitstream/handle/11394/8251/kimani_m_art_2020.pdf?sequence=1&isAllowed=y (Accessed: 21 June 2023).

Kituyi, M. .2018. The 'fourth industrial revolution' can power sustainable development, if we get it right. Available: https://unctad.org/news/fourth-industrial-revolution-can-power-sustainable-development-if-we-get-it-right (Accessed: 22 June 2022).

Klarin, T. 2018. The Concept of Sustainable Development: From its Beginning to the Contemporary Issues. Zagreb International Review of Economics and Business, 21 (1): 67- 94. (Accessed: 12 February 2022)

Kobus, M. 2016. First steps in research. 2nd edition. Pretoria: van Schaik Publishers. (Accessed: 18 July 2022).

Kodros, J., Wiedinmyer, C., Ford, B., Cucinotta, R., Gan, R., Magzamen, S. and Pierce, J. 2016. The aerosol radiative effects of uncontrolled combustion of domestic waste. Atmospheric Chemistry and Physics 16, 6771–6784. Available: https://www.researchgate.net/publication/303801151_The_aerosol_radiative_effects_of_uncontrolled_combustion_of_domestic_waste (Accessed: 16 February 2022)

Koel, J. 2013. How 5 manufacturers reduce water use. Available: https://www.fmamfg.org/blog/5-manufacturers-reduce-water-use#:~:text=It's%20reassuring%20that%20companies%20such,industrial%20processes%20in%20the%20future (Accessed: 05 July 2023).

Kopalle, P. K.; Lehmann, D. R. 1997. "Alpha inflation? The impact of eliminating scale items on Cronbach's alpha". Organisational Behavior and Human Decision Processes. Available: doi:10.1006/obhd.1997.2702 (Accessed: 12 July 2023).

Koppiahraj, K., Bathrinath, S. and Saravanasankar, S. 2019. Leather Waste Management Scenario in Developed and Developing Nations. International Journal of Engineering and Advanced Technology, 9 (1S4): 852-857. (Accessed: 03 January 2024).

Kumar, R. 2019. What are the four main concepts of the circular economy? Available: https://timesofindia.indiatimes.com/blogs/voices/what-are-the-four-main-concepts-of-the-circular-economy/ (Accessed: 03 January 2024).

Kumar, A. Holuszko, M. and Espinosa, D.C.R. 2017. E-waste: An overview on generation, collection, legislation and recycling practices. Available: https://www.sciencedirect.com/science/article/abs/pii/S0921344917300290?via%3Dihub (Accessed: 23 August 2022).

Kumar, A., Holuszko, M.e. and Espinosa, S. 2021. Recycling Technologies – Physical Separation. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/9783527816392.ch6 (Accessed: 23 August 2022).

KwaDukuza Municipality. 2022-2023. FIFTH GENERATION Integrated Development Plan. Available: https://www.kwadukuza.gov.za/IDP2223/Final_IDP_23.pdf (Accessed: 25 October 2022).

KwaZulu Natal's top business portfolio. 2022. KwaZulu Natal Economy. Available: https://www.kzntopbusiness.co.za/site/manufacturing (Accessed: 21 Junee 2022).

Landau, P. 2023. What Is Lean Manufacturing? Available: https://www.projectmanager.com/blog/what-is-lean-manufacturing (Accessed: 03 January 2023).

Le Mouëllic, M., Ventura, A., Heller, K., Loh, A., Roch, R., Spitzbart, J. and Zanotelli, P. 2023. Six Strategies for Designing Sustainable Products. Available: https://www.bcg.com/publications/2023/six-strategies-to-lead-product-sustainability-design (Accessed: 31 July 2023).

Le, T.-H. Chang, Y. and Park D. 2016. Trade openness and environmental quality: international evidence Energy Pol., 92 (2016), pp. 45-55, 10.1016/J.ENPOL.2016.01.030 (Accessed: 12 February 2022).

Leblanc, R. 2020. An Introduction to Solid Waste Management. Available: https://www.thebalancesmb.com/an-introduction-to-solid-waste-management-2878102 (Accessed: 23 August 2022).

Leblanc, R. 2020. An Overview of Plastic Recycling. Available: https://www.thebalancesmb.com/an-overview-of-plastic-recycling-4018761 (Accessed: 09 September 2022).

Lee, K.H.; Park, B.J.; Song, H. and Yook, K.H. (2016). The Value Relevance of Environmental Audits: Evidence from Japan. Available: https://doi.org/10.1002/bse.1940 (Accessed: 23 June 2023).

Leedy, P. and Ormrod, J. (2001). Practical research: Planning and design (7th ed.). Upper Saddle River, NJ: (Accessed: 23 May 2022).

Legislation.Gov.UK. 2020. Environmental Protection Act 1990. Available: https://www.legislation.gov.uk/ukpga/1990/43/section/33/2020-12-31 (Accessed: 12 April 2022).

Lenkiewicz, Z. 2018. Marine Plastic: From the Land to the Sea. Wasteaid. Available: https://wasteaid.org/marine-plastic-pollution-from-the-land-to-the-see/# (Accessed: 12 February 2022).

Li, K., Qin, Y., Zhu, D. and Zhang, S. 2023. Upgrading waste electrical and electronic equipment recycling through extended producer responsibility: A case study. Available: Upgrading waste electrical and electronic equipment recycling through extended producer responsibility: A case study - ScienceDirect (Accessed: 25 June 2023).

Li, M., Du, W. and Tang, S. 2021. Assessing the impact of environmental regulation and environmental co-governance on pollution transfer: Micro-evidence from China. Available: https://doi.org/10.1016/j.eiar.2020.106467 (Accessed: 07 July 2023).

Li, J. and Yang, H. (2017), "A research on development of construction industrialization based on BIM technology under the background of Industry 4.0". https://pdfs.semanticscholar.org/226d/89f3042dcd808d6704c19e1076144e129e35.pdf?_ga=2.21545787.1665192914.1661285406-121982560.1661285406 (Accessed: 22 March 2022).

Lin, G. and Hao, B. 2020. Research on green manufacturing technology. Available: https://iopscience.iop.org/article/10.1088/1742-6596/1601/4/042046/pdf (Accessed: 05 September 2022).

Linnenkoper, K. 2019. Latest recycling stats for South Africa. Available: https://recyclinginternational.com/business/latest-recycling-stats-for-south-africa/27327/ (Accessed: 30 August 2022).

Liyala, C. 2011. "Modernising Solid Waste Management at Municipal Level: Institutional Arrangements in Urban Centres of East Africa." Available: https://edepot.wur.nl/179700 (Accessed 21 June 2023).

Lotito, A.M. De Sanctis, M. Di Iaconi, C. and Bergna, G. (2014). Textile wastewater treatment: aerobic granular sludge vs activated sludge systems. Water Res., 54 (2014), pp. 337-346. Available:

https://reader.elsevier.com/reader/sd/pii/S0043135414000955?token=80F89F6B686F5FE49B3C602F90D0ABE5C144122F569183122A95956A99553B85FD9FD6CAA0C0FE5E33BF24B158860B59&originRegion=eu-west-1&originCreation=20220126112759 (Accessed: 26 January 2022).

Lu, C. 2020. Apple Supply Chain - The Best Supply Chain in the World. Available: https://www.tradegecko.com/blog/supply-chain-management/apple-the-best-supply-chain-in-the-world (Accessed: 22 June 2022).

Mabitsela, L., Telukdarie, A. and Munsamy, M. 2023. Modelling for Cleaner Production & Optimization. Available: https://doi.org/10.1016/j.procs.2022.12.264 (Accessed: 10 July 2023)

Madrid-Guijarro, A. and Duréndez, A. 2023. Sustainable development barriers and pressures in SMEs: The mediating effect of management commitment to environmental practices. Available: https://doi.org/10.1002/bse.3537 (Accessed: 04 January 2024).

Magagulu, B. K., Rampedi, I.T. and Yessoufou, K., 2022. Household Pharmaceutical Waste Management Practices in the Johannesburg Area, South Africa. Available: https://www.researchgate.net/publication/361409343_Household_Pharmaceutical_Waste_Management_Practices_in_the_Johannesburg_Area_South_Africa (Accessed: 04 September 2022).

management performance. Available: https://www.researchgate.net/publication/343127173_Municipal_Solid_Waste_Management_Performance (Accessed: 23 May 2023).

Manhart, A., Hilbert, I. and Magalini, F. 2018. End-of-life management of batteries in the off-grid solar sector. Available: https://www.giz.de/en/downloads/giz2018-en-waste-solar-guide.pdf (Accessed: 07 September 2022).

Maniyamkott, M. 2018. 7 Reasons why Likert scale survey is the next best thing since sliced bread. Available: https://surveysparrow.com/blog/7-reasons-why-likert-scale-is-the-next-best-thing-since-sliced-bread/ (Accessed: 01 July 2022).

Marshall, C. and Rossman, G.B. 2014. Designing qualitative research. Thousand Oaks: Sage (Accessed: 23 May 2022).

MasterClass staff. 2020. Biodegradable Plastic Guide: Explore the Pros, Cons, and Uses. Available: https://www.masterclass.com/articles/biodegradable-plastic-guide#what-is-biodegradable-plastic (Accessed: 18 August 2021).

Mboto, S. 2022. Costs related to KZN floods stands at R17 billion. Available: https://www.iol.co.za/mercury/news/costs-related-to-kzn-floods-stands-at-r17-billion-ca130329-5caa-40c6-8f29-346cd0f51397 (Accessed: 14 June 2022).

McClenaghan, E. 2023. The Chi-Squared Test. Available: https://www.technologynetworks.com/informatics/articles/the-chi-squared-test-368882 (Accessed: 17 May 2023).

McGinty, D. 2020. How to Build a Circular Economy. Available: https://www.wri.org/insights/how-build-circular-economy (Accessed: 22 June 2022).

McKinsey and Company. 2022. Sustainability in packaging: Global regulatory development across 30 countries. Available: https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/sustainability-in-packaging-global-regulatory-development-across-30-countries?cid=other-eml-alt-mip-mck&hdpid=198399fb-3014-48bd-a421-65901ad600e8&hctky=12941357&hlkid=fe1d2810245c40818f560a28ac82eb80 (Accessed: 21 February 2022).

McLennan-Smith, G. 2022. Thinking Green. Available: https://www.kzntopbusiness.co.za/site/kzn-brands (Accessed: 21 June 2022).

Meier, L. 2021. Synthesis report on United Nations system-wide initiatives related to fashion. Available: https://unfashionalliance.org/wp-content/uploads/2021/07/UN-Alliance-for-Sustainable-Fashion-Synthesis-Mapping-Report.pdf (Accessed: 14 August 2021).

methods approach. 4th ed. Available: http://155.0.32.9:8080/jspui/bitstream/123456789/1091/1/Qualitative,%20Quantitative,%20and%20Mixed%20Methods%20Approaches%20(%20PDFDrive%20)-1.pdf (Accessed: 04 March 2022).

Meyer, D. 2021. The world's 'most polluting power company' has a bold net-zero strategy: tap foreign donors. Available: https://fortune.com/2021/10/06/eskom-coal-air-pollution-so2-crea-cop26/#:~:text=South%20Africa's%20embattled%20national%20utility,reliance%20on%20dirty%20coal%20technology.&text=Indeed%2C%20according%20to%20CREA's%20analysis,and%20China's%20power%20sectors%2C%20combined. (Accessed: 19 February 2022).

Michalsons, 2020. Protection of Personal Information Act Summary | POPIA. Available: https://www.michalsons.com/focus-areas/privacy-and-data-protection/protection-of-personal-information-act-popia (Accessed: 08 May 2022).

Milano, S. 2021. The definition of sustainable business practices. Available: https://smallbusiness.chron.com/definition-sustainable-business-practices-18748.html (Accessed: 03 September 2021).

Milios, L., Holm Christensen, L., McKinnon, D., Christensen, C., Rasch, M. K. and Hallstrom Eriksen, M. 2018. Plastic recycling in the Nordics: A value chain market analysis. Available: https://www.sciencedirect.com/science/article/abs/pii/S0956053X18301764?via%3Dihub (Accessed: 12 February 2022).

Miller, P. 2022. Advancing sustainability within the pharmaceutical industry. Available: https://www.iol.co.za/the-star/news/advancing-sustainability-within-the-pharmaceutical-industry-d69d038c-b402-43cc-b6e4-5f2a91ad4d05 (Accessed: 05 September 2022).

Mogala, M. 2012. Maize Market Value Chain Profile. Available: Maize market value chain profile 2010-11.pdf (daff.gov.za) (Accessed: 04 July 2023).

Mohajan, H. K. 2017. Two Criteria for Good Measurements in Research: Validity and Reliability. Available: https://mpra.ub.uni-muenchen.de/83458/1/MPRA_paper_83458.pdf (Accessed: 19 June 2023).

Mohammad, M., Masad, E. and Al-Ghamdi, S. G. 2020. 3D Concrete Printing Sustainability: A Comparative Life Cycle Assessment of Four Construction Method Scenarios. Buildings, 10 (12)

Möhl, S. 2020. South African townships take on a decades-old waste problem. Available: https://www.dw.com/en/south-african-townships-take-on-a-decades-old-waste-problem/a-53980339 (Accessed: 09 February 2021).

Morrow, D. and Rondinelli, D. 2002. Environmental Management Systems : Motivations and Results of ISO 14001 and EMAS Certification. Available: https://econpapers.repec.org/article/eeeeurman/v_3a20_3ay_3a2002_3ai_3a2_3ap_3a159-171.htm (Accessed: 21 June 2022).

Morrow, M. K. 2021. 7 Useful Types of Quantitative Research to Know. Available: https://zipreporting.com/en/quantitative-research/types-of-quantitative-research.html (Accessed: 30 April 2023).

Mourtzis, D., V. Zogopoulos, and F. Xanthi. 2019. Augmented Reality Application to Support the Assembly of Highly Customized Products and to Adapt to Production Re-Scheduling. Available: https://doi.org/10.1007/s00170-019-03941-6 (Accessed: 04 July 2023).

Mpatane, L. M., 2015. The Impact of Electricity Supply on the Manufacturing Sector Output in South Africa. Available: https://repository.nwu.ac.za/bitstream/handle/10394/20696/Mpatane_LM.pdf?sequence=1 (Accessed: 09 September 2022).

Munsamy, M., Telukdarie, A. and Fresner, J. (2019). "Business process centric energy modelling", Business Process Management Journal, Vol. 25 No. 7, pp. 1867-1890. Available: https://doi.org/10.1108/BPMJ-08-2018-0217 (Accessed: 22 March 2022).

Mussatto, S. I. and Jose A. Teixeira, J. A. Lignocellulose as raw material in fermentation processes. Available:

https://www.researchgate.net/publication/261710556_Lignocellulose_as_raw_material_in_fermentation_processes (Accessed: 04 July 2023).

Nampak Packaging Excellence. 2022. Nampak Liquid Cartons produces new Fruitime 330ml and 2litre pack. Available: http://www.nampak.com/Investors/Media-Release/2013/nampak-liquid-cartons-produces-new-fruitime-33 (Accessed: 26 August 2022).

Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Rocha-Lona, L. and Tortorella, G. (2019), "Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal", Journal of Manufacturing Technology Management, Vol. 30 No. 3, pp. 607-627. Available: https://doi.org/10.1108/JMTM-03-2018-0071 (Accessed: 22 March 2022).

National Aeronautics and Space Administration. 2022. What is Climate Change? Available: https://climatekids.nasa.gov/climate-change-meaning/ (Accessed: 07 September 2022).

National Environmental Management: Waste Act 59 of 2008. Available: https://www.gov.za/documents/national-environmental-management-waste-act (Accessed: 16 June 2022).

National Geographic. 2019. Greenhouse gases, facts and information. Available: https://www.nationalgeographic.com/environment/article/greenhouse-gases#:~:text=Greenhouse%20gases%20have%20far%2Dranging,change%20caused%20by%20greenhouse%20gases. (Accessed: 22 June 2022).

National Geographic. 2022. Global warming. Available: Global Warming | National Geographic Society (Accessed: 06 September 2022).

Ndubisi, N.O., Zhai, X. and Lai, K.-H. al. 2019. Small and medium manufacturing enterprises and Asia's sustainable economic development. Available: https://doi.org/10.1016/j.ijpe.2020.107971 (Accessed: 17 April 2021).

Neuman, W. L. (2014). Social Research Methods: Qualitative and Quantitative Approaches: Pearson New International Edition. Pearson Education Limited. (Accessed: 25 May 2022).

Nielsen, T. D., Hasselbalch, J., Holmberg, K. and Stripple, J. 2020. Politics and the plastic crisis: A review throughout the plastic life cycle. WIREs Energy and Environment, 9 (360): 1- 18. (Accessed: 12 February 2021).

Niinimamp K., Peters G., Dahlbo H., Perry P., Rissanen T. and Gilt A. 2020. The environmental price of fast fashion. Nat. Rev. Earth Environ., 14 (2020), 10.1038/s43017-020-0039-9 (Accessed: 24 March 2022).

Nyika, J., Onyari, E., Mishra, S. and Dinka, M. O. 2019. Waste Management in South Africa. Available: DOI:10.4018/978-1-7998-0198-6.ch014 (Accessed: 07 May 2024).

Nordin, N, Ashari, H, and Rajemi, MF. 2015. A case study of sustainable manufacturing practices. Journal of Advanced Management Science, 2(1), 12–16. (Accessed: 14 June 2022).

NOVA. 2018. Community Source Survey Training Manual. (Accessed: 16 February 2021).

Nyika, J., Onyari, E., Mishra, S. and Dinka, M.O., 2019. Waste management in South Africa. Available: DOI:10.4018/978-1-7998-0198-6.ch014. (Accessed: 14 June 2022).

Oelofse S, Nahman A and Godfrey L. 2018. Waste as a resource: Unlocking opportunities for Africa. In: Godfrey L, editor. Africa Waste Management Outlook. Nairobi, Kenya: UNEP; 2018. pp. 101-118. Available from: https://t.co/BYjYbHpwwz (Accessed: 07 April 2022).

Omalley G.F and Omalley R. 2020. Hydrocarbon Poisoning. Available: https://www.msdmanuals.com/home/injuries-and-poisoning/poisoning/hydrocarbon-poisoning#:~:text=Swallowing%20or%20inhaling%20hydrocarbons%20can,particularly%20after%20exertion%20or%20stress (Accessed: 18 February 2022).

Omwoma, S, Lalah, JO, Kueppers, S, *et al*. 2017. Technological tools for sustainable development in developing countries: The example of Africa, a review. Sustainable Chemistry and Pharmacy 6: 67–81. (Accessed: 09 February 2022).

Oneale L. 2016. South Africa Oil Dumping an Environmental Disaster. Available: http://athermal.co.za/south-africa-oil-dumping-an-environmental-disaster/ (Accessed: 19 February 2022).

Oricol Environmental Services. 2021. WASTE TO ENERGY. Available: https://www.oricoles.co.za/services/waste-to-energy/ (Accessed: 28 February 2022).

Orisakwe, Frazzoli, Ilo and Oritsemuelebi. 2020. Public health burden of e-waste in Africa. Available: Public Health Burden of E-waste in Africa (amazonaws.com) (Accessed: 25 August 2022).

Owusu P and Asumadu-Sarkodie S. 2016. A review of renewable energy sources, sustainability issues and climate change mitigation.

Available: http://dx.doi.org/10.1080/23311916.2016.1167990 (Accessed: 22 April 2022).

Panasonic Group. 2020. Berlin's First Smart City Quarter Powered by Panasonic. Available: https://news.panasonic.com/global/topics/2020/79631.html (Accessed: 18 July 2023).

Pandey, K. 2019. South Africa bans dumping of liquid waste in landfills. Available: https://www.downtoearth.org.in/news/waste/south-africa-bans-dumping-of-liquid-waste-in-landfills-66390 (Accessed: 27 February 2022).

Parajuly, K., Kuehr, R., Awasthi, A.K., Fitzpatrick, C., Lepawsky, J., Smith, E., Widmer, R. and Zeng, X. (2019) Future E-Waste Scenarios. Available: http://www.step-initiative.org/files/_documents/publications/FUTURE%20E-WASTE%20SCENARIOS_UNU_190829_low_screen.pdf (Accessed: 04 April 2022).

Park, J. K., Hoerning L., Watry S, Burgett T and Matthias, S. 2017. Effects of Electronic Waste on Developing Countries. Available: https://www.hilarispublisher.com/open-access/effects-of-electronic-waste-on-developing-countries-2475-7675-1000128.pdf (Accessed: 23 August 2022).

Patel, M. 2019. Exploring Research Methodology: Review Article. Available: https://www.ijrrjournal.com/IJRR_Vol.6_Issue.3_March2019/IJRR0011.pdf (Accessed: 18 July 2022).

Paz, A., Carballo, J., Perez, M.J. and Dominguez, J.M. (2017). Biological treatment of model dyes and textile wastewaters. Chemosphere, 181 (2017), pp. 168-177. Available: https://reader.elsevier.com/reader/sd/pii/S0045653517305696?token=005150

8931708A4FFDDBC59663F6CD89C48A8192E5BDA50BC735811924CBEDBB4ADEC99980DD55D400B410A6DDD6CAA6&originRegion=eu-west-1&originCreation=20220126114658 (Accessed: 26 January 2022).

Pensupa N., Leu S.-Y., Hu Y., Du C., Liu H., Jing H., Wang H., Carol Sze Ki Lin, Yunzi S.L. and Chenyu H. 2017. Recent trends in sustainable textile waste recycling methods: current situation and future prospects. Top. Curr. Chem., 375 (2017), pp. 189-228. Available: https://doi.org/10.1007/978-3-319-90653-9 (Accessed: 24 March 2022).

PET Resin Association. 2015. An Introduction to PET. Available: http://www.petresin.org/news_introtoPET.asp#:~:text=PET%20(also%20abbreviated%20PETE)%20is,soft%20drinks%2C%20juices%20and%20water. (Accessed: 21 June 2022).

PETCO. 2016. A registered producer responsibility organisation (PRO) for PET. Available: https://petco.co.za/who-we-are/ (Accessed: 31 August 2022).

Pettipas, S., Bernier, M. and Walker, T.R. 2016. A Canadian policy framework to mitigate plastic marine pollution. Available: https://reader.elsevier.com/reader/sd/pii/S0308597X16302779?token=5F88F88E3716DEF43F286B5903D038E0F971870231BDD75FD49587CE5626B9A7BA0483CA3A7413CCA760EE376897F778&originRegion=eu-west-1&originCreation=20220907223341 (Accessed: 08 September 2022).

Pillay S.N., Brent A., Musango J. and van Geems F. 2020. Using a system dynamic modelling process to determine the impact of eCar, eBus and eTruck market penetration on carbon emissions in South Africa. Available: http://dx.doi.org/10.3390/en13030575 (Accessed: 12 April 2022).

Pinto, I., Zachariah, M., Wolski, P., Landman, S., Phakula, V., Maluleke, W., Bopape, M., Engelbrecht, C., Jack, C., McClure, A., Bonnet, R., Vautard, R., Philip, S., Kew, S., Heinrich, D., Vahlberg, M., Singh, R., Arrighi, J., Thalheimer, L., van Aalst, M., Li, S., Sun, J., Vecchi, G., Yang, W., Tradowsky, J., Otto, F. E. I. and Dipura, R. 2022. Climate change exacerbated rainfall causing devastating flooding in Eastern South Africa. Available: https://www.worldweatherattribution.org/wp-content/uploads/WWA-KZN-floods-scientific-report.pdf (Accessed: 14 June 2022).

Plastics SA. 2021. Plastic Industry releases recycling figures. Available: https://www.plasticsinfo.co.za/wp-content/uploads/2021/11/2020-Plastics-recycling-figures_Final-PR-1.pdf (Accessed: 18 August 2022).

Pourfakhraei, E., Badraghi, J., Mamashli, F., Nazari, M. and Saboury, A.A., 2018. Biodegradation of asphaltene and petroleum compounds by a highly potent Daedaleopsis sp. J. Basic Microbiol. 58, 609–622. (Accessed: 18 February 2022).

Pulselli, F.M. and Zuo, J. 2022. Cleaner Waste Systems. Available: https://www.journals.elsevier.com/cleaner-waste-systems (Accessed: 15 February 2022).

QMS International. 2022. ISO Standards for the Manufacturing Industry. Available: https://www.qmsuk.com/iso-by-industry/manufacturing (Accessed: 21 June 2022).

Ralph Lauren Corporation. 2021. Ralph Lauren Revolutionizes How the Fashion Industry Dyes Cotton. Available:

https://corporate.ralphlauren.com/pr_210322_ColorOnDemand.html (Accessed: 04 January 2024).

Ramakrishna, S.; Ngowi, A.; De Jager, H. and Awuzie, B.O. 2020. Emerging Industrial Revolution: Symbiosis of Industry 4.0 and Circular Economy: The Role of Universities. Available: https://journals.sagepub.com/doi/10.1177/0971721820912918 (Accessed: 22 March 2022).

Rao, P and Karkie, U. 2023. Techno-economic analysis of the water, energy, and greenhouse gas emissions impacts from the adoption of water efficiency practices in the U.S. manufacturing sector. Available: https://doi.org/10.1016/j.resconrec.2023.107054 (Accessed: 05 July 2023).

Rao, P.; Sholes, D. and Cresko, J. 2019. Evaluation of U.S. manufacturing subsectors at risk of physical water shortage. Available: 10.1021/acs.est.8b04896 (Accessed: 05 July 2023).

Raquel, M. Balanaya, R.M., Varela, R. P. and Halog A.B. 2021. Circular economy for the sustainability of the wood-based industry: The case of Caraga Region, Philippines. Available: https://www.sciencedirect.com/science/article/pii/B9780128216644000169#! (Accessed: 27 February 2022).

Rees N. and Fuller. R. 2020. The toxic truth: Children's exposure to lead pollution undermines a generation of future potential. Available: https://www.unicef.org/reports/toxic-truth-childrens-exposure-to-lead-pollution-2020 (Accessed: 07 September 2022).

Rehman, F.U., Islam, M.M., Ullah, M., Khan, S. and Rehman, M.Z. 2023. Information digitalization and renewable electricity generation: Evidence from South Asian countries. Available: main.pdf (sciencedirectassets.com) (Accessed: 18 July 2023).

Research and Markets. 2022. Pharmaceutical Industry in South Africa 2022 and the Government's Cannabis Masterplan. Available: https://www.globenewswire.com/en/news-release/2022/04/15/2423226/28124/en/Pharmaceutical-Industry-in-South-Africa-2022-and-the-Government-s-Cannabis-Masterplan.html (Accessed: 04 September 2022).

Reuters Events. 2021. Move Ambition to Action. Transform USA Post Conference Report: 15. (Accessed: 04 July 2023).

Rhee, S. 2020. Management of used personal protective equipment and wastes related to COVID-19 in South Korea. pp. 820-824 Available: 10.1177/0734242X20933343 (Accessed: 07 April 2022).

Ribeiro, J. P. and Barbosa-Povoa, A. 2018. Supply Chain Resilience: Definitions and Quantitative Modelling Approaches – A Literature Review. Available: https://doi.org/10.1016/j.cie.2017.11.006 (Accessed: 04 July 2023).

Ritchie, H. and Roser, M. 2018. Plastic pollution. Our World in Data. Available: https://ourworldindata,org/plastic-pollution (Accessed: 12 February 2022).

Roblek, V., Thorpe, O., Bach, M. P., Jerman, A. and Meško, M. 2020. The Fourth Industrial Revolution and the Sustainability Practices: A Comparative Automated Content Analysis Approach of Theory and Practice. Sustainability, 12 (20). (Accessed: 04 July 2023).

Rondganger, L. 2014. Activists question ‘dumping’ toxins. Available: https://www.iol.co.za/news/activists-question-dumping-toxins-1749818 (Accessed: 25 February 2022).

Rubin, A. and Bellamy, J. 2012. Practitioner's guide to using research for evidence-based practice. New Jersey: John Wiley and Sons. (Accessed: 04 July 2023).

Safeopedia. 2018. Post-Consumer Waste. Available: https://www.safeopedia.com/definition/2347/post-consumer-waste (Accessed: 27 February 2022).

Salau, M. a. G. A. 2021. The race to net zero; How construction is modernising their materials and construction methods ahead of 2050. Available: https://beale-law.com/article/the-race-to-net-zero-how-construction-is-modernising-their-materials-and-construction-methods-ahead-of-2050/ (Accessed: 21 September 2021).

Salau, M. and G. A. 2021. The race to net zero; How construction is modernising their materials and construction methods ahead of 2050. Available: https://beale-law.com/article/the-race-to-net-zero-how-construction-is-modernising-their-materials-and-construction-methods-ahead-of-2050/ (Accessed: 21 September 2021).

Saleh, M. 2022. CO2 emissions in Africa 2020, by country. Available: https://www.statista.com/statistics/1268395/production-based-co2-emissions-in-africa-by-country/ (Accessed: 22 June 2022).

Sandanayake, M., Bouras, Y., Haigh, R. and Vrcelj, Z. 2020. Current Sustainable Trends of Using Waste Materials in Concrete—A Decade Review. Sustainability, 12 (22). (Accessed 21 September 2021).

Satapathy, S. 2017. An analysis of barriers for plastic recycling in the Indian plastic industry. Benchmarking: An International Journal, 24 (2): 415-430. (Accessed: 12 February 2022).

Schountz T. and Prescott J. 2014. Hantavirus Immunology of Rodent Reservoirs: Current Status and Future Directions. Available: https://www.mdpi.com/1999-4915/6/3/1317 (Accessed: 12 April 2022).

Science for Environmental Policy (SEP). 2011. Plastic Waste: Ecological and human health impact. Available: https://ec.europa.eu/environment/integration/research/newsalert/pdf/IR1_en.pdf (Accessed: 08 September 2022).

Scott, T.-M., Phillips, P. J., Kolpin, D. W., Colella, K. M., Furlong, E. T., Foreman, W. T. and Gray, J. L. 2018. Pharmaceutical manufacturing facility discharges can substantially increase the pharmaceutical load to U.S. wastewaters. Science of the Total Environment, 636: 69-79. (Accessed: 02 August 2021).

Scott, T.-M., Phillips, P. J., Kolpin, D. W., Colella, K. M., Furlong, E. T., Foreman, W. T. and Gray, J. L. 2018. Pharmaceutical manufacturing facility discharges can substantially increase the pharmaceutical load to U.S. wastewaters. Science of the Total Environment, 636: 69-79. (Accessed: 22 August 2021).

Scrivener, K. L., John, V. M. and Gartner, E. M. 2018. Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry. Cement and Concrete Research, 114: 2-26. (Accessed: 02 August 2021).

Shaaban H, Alghamdi H, Alhamed N, Alziadi A. and Mostafa A. 2018. Environmental Contamination by Pharmaceutical Waste: Assessing Patterns of Disposing

Unwanted Medications and Investigating the Factors Influencing Personal Disposal Choices. 2018. (Accessed: 25 January 2022).

Shah, R. Harding, J. Brown, J and Mckinlay C. 2020. Sourcing personal protective equipment during the COVID-19 pandemic. p. 1912. Available: 10.1159/000492859 (Accessed: 07 April 2022).

Shahabuddin, M., Uddin, M. N., Chowdhury, J. I., Ahmed, S, F., Uddin, M, N., Mofijur, M. and Uddin, M. A. 2022. A review of the recent development, challenges, and opportunities of electronic waste (e-waste). Available: https://link.springer.com/article/10.1007/s13762-022-04274-w (Accessed: 07 September 2022).

Shan, H.Y. and Yang, J.L. 2020. Promoting the implementation of extended producer responsibility systems in China: A behavioural game perspective. Available: https://doi.org/10.1016/j.jclepro.2019.119446 (Accessed: 25 June 2023).

Sharma, M., Joshi, S. and Govindan, K. 2023. Overcoming barriers to implement digital technologies to achieve sustainable production and consumption in the food sector: A circular economy perspective. Available: https://doi.org/10.1016/j.spc.2023.04.002 (Accessed: 17 July 2023).

Shenzhen Valley Ventures (SVV). 2021. What are the three types of manufacturing? Available: https://svv.io/what-are-the-three-types-of-manufacturing/ (Accessed: 10 April 2022).

Shirvanimoghaddam K., Motamed B., Ramakrishna S and Naebe M. 2020. Death by waste: fashion and textile circular economy case. Available: 10.1016/j.scitotenv.2020.137317 (Accessed: 24 March 2022).

Shroff, J. 2016. How Green Manufacturing is Improving the Environment. Available: https://jaishroff.wordpress.com/2016/12/01/how-green-manufacturing-is-improving-the-environment/ (Accessed: 24 June 2021).

Silverstein, K. 2019. For Southern Africa, Climate Change Is Real as Prolonged Droughts Are Creating Food Shortages. Available: https://www.forbes.com/sites/kensilverstein/2019/11/07/for-southern-africa-climate-change-is-real-as-prolonged-droughts-are-creating-food-shortages/?sh=703e3f5b43f7 (Accessed: 07 September 2022).

Simatele, D. M., Dlamini, S. and Kubanza, N. S. 2017. "From Informality to Formality: Perspectives on the Challenges of Integrating Solid Waste Management into the Urban Development and Planning Policy in Johannesburg, SouthAfrica." Available: https://doi.org/10.1016/j.habitatint.2017.03.018 (Accessed: 21 June 2023).

Simatele, D., and C. L. Etambakonga. 2015. "Scavenging for Solid Waste in Kinshasa: A Livelihood Strategy for the Urban Poor in the Democratic Republic of Congo." Available. https://doi.org/10.1016/j.habitatint.2015.05.029 (Accessed: 21 June 2021).

Slevitch, L. 2011. "Qualitative and quantitative method ologies compared: Ontological and epistemological perspectives." Journal of Quality Assurance in Hospitality andTourism (Accessed: 24 May 2022).

SLO Active. 2021. How to make more ethical and conscious fashion choices. Available: https://sloactive.com/slow-fashion-guide/ (Accessed: 14 August 2021).

Sojinu, S. O. S. and Ejeromedoghene, O. 2018. Environmental Challenges Associated with Processing of Heavy Crude Oils. Available: https://www.intechopen.com/chapters/64885 (Accessed: 22 June 2022).

Solving the E-waste Problem (StEP). 2019. What is e Waste? Available: https://www.step-initiative.org/e-waste-challenge.html(Accessed: 17 January 2022).

Solving the e-waste problem. 2013/2014. Annual Report. Available: http://collections.unu.edu/eserv/UNU:6138/step_annual_report_2013_2014.pdf (Accessed: 09 September 2022).

Song Q, Wang Z, Li J, Duan H, Yu D and Zeng X. 2017. Characterizing the transboundary movements of UEEE/WEEE: is Macau a regional transfer center? Available: https://doi-org.proxy.lib.ul.ie/10.1016/j.jclepro.2017.04.149 (Accessed: 10 April 2022).

South African Development Community. 2019. Status of Integration in the Southern African Development Community. Available: https://www.sadc.int/files/9915/9154/2991/Status_of_Integration_in_the_SADC_Region_Report.pdf (Accessed: 12 April 2022).

South African Legal Information Institute. 2019. Environmental Regulations for Workplaces. Available: https://www.saflii.org/za/legis/consol_reg/erfw428/ (Accessed: 03 January 2024).

South African Government News Agency. 2018. SA's manufacturing sector must modernize. Available: https://www.sanews.gov.za/south-africa/sas-manufacturing-sector-must-modernise (Accessed: 08 September 2022).

South African Government News Agency. 2022. KZN aims to accommodate over 4 000 displaced families. Available: https://www.sanews.gov.za/south-africa/kzn-aims-accommodate-over-4-000-displaced-families (Accessed: 14 June 2022).

South African Sugar Association, 2022. Natural Resources, Renewable Energy and Policy Liaison. Available: https://sasa.org.za/natural-resources-renewable-energy-and-policy-liaison/ (Accessed: 21 June 2022).

Statistics Canada. 2015. Data Collection, Capture and Coding. Available: https://www150.statcan.gc.ca/n1/pub/12-539-x/2009001/collection-collecte-eng.htm (Accessed: 23 October 2022).

Statistics South Africa (StatsSA). (2017). Mid-year population estimates (statistical release P0302), Statistics South Africa. Pretoria: RSA. Accessed: 18 February 2022.

Steenmans, Taylor and Steenmans. 2021. Blockchain Technology for Governance of Plastic Waste Management: Where Are We? Available: https://www.mdpi.com/2076-0760/10/11/434/htm (Accessed: 01 September 2021).

StopWaste. 2022. The Impact of Paper Waste. Available: https://www.stopwaste.org/at-work/reduce-and-reuse/reduce-paper-use/the-impact-of-paper-waste#1 (Accessed: 27 February 2022).

Sukamolson, S. (2007). Fundamentals of quantitative research. Language Institute Chulalongkorn University, 1-20. (Accessed: 08 May 2022).

Suleman Y., Tagoe E. and Agyemang-Duah W. 2015. Solid waste disposal and community health implications in Ghana: Evidence from Sawaba, Asokore

Mampong Municipal Assembly. Available: Doi:10.4172/2165-784X.1000202 (Accessed: 19 June 2022).

Sultana, S and Tiba, T. I. 2011. Data editing and coding in quantitative and qualitative research. Available: https://www.academia.edu/11882335/Data_editing_and_coding_in_quantitative_and_qualitative_research (Accessed: 02 May 2022).

Sunitha, R., 2017. Bengaluru gets first e-waste bin on roadside. Available: https://timesofindia.indiatimes.com/city/bengaluru/bengaluru-gets-first-e-waste-bin-on-roadside/articleshow/61706915.cms (Accessed: 24 August 2022).

Suraj, M. and Khan, A. 2015. Environmental Impact of Paper Industry. Available: https://www.ijert.org/research/environmental-impact-of-paper-industry-IJERTCONV3IS20096.pdf (Accessed: 03 January 2024).

Svanes, E., Vold, M., Møller, H., Pettersen, M. K., Larsen, H. and Hanssen, O, J. 2010. Sustainable packaging design: A holistic methodology for packaging design. Available: http://dx.doi.org/10.1002/pts.887 (Accessed: 31 July 2023).

Taherdoost, H. 2019. What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale. Available: https://hal.archives-ouvertes.fr/hal-02557308/document (Accessed: 18 July 2022).

Taherdoost, H. 2022. Validity and Reliability of the Research Instrument. Available: https://encyclopedia.pub/entry/20511 (Accessed: 24 October 2022).

Tandon, A. 2022. The extreme rainfall that triggered one of South Africa's deadliest disasters of this century was made more intense and more likely because of climate change, a new “rapid-attribution” study finds. Available: https://www.carbonbrief.org/climate-change-made-extreme-rains-in-2022-south-africa-floods-twice-as-likely/ (Accessed: 14 June 2022).

Tavakol, M. and Dennick, R. 2011. Making sense of Cronbach's alpha. International journal of medical education, 2, 53. (Accessed: 02 August 2021).

Tavakol, M. and Dennick, R. 2011. Making sense of Cronbach's alpha. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4205511/#:~:text=What%20is%20Cronbach%20alpha%3F,number%20between%200%20and%201. (Accessed: 19 June 2023).

Taylor, S. 2023. Central Tendency. Available: https://corporatefinanceinstitute.com/resources/data-science/central-tendency/ (Accessed: 23 March 2023).

Technavia. 2020. Top 10 Largest Beer Companies and Their Beer Brands in the Global Beer Market 2020. Available: https://www.therichest.com/entertainment/top-five-largest-beer-brewing-companies-in-the-world/#:~:text=The%20Anheuser-Busch%20InBev%20company%20is%20the%20world%27s%20largest,Busch%20went%20under%20substantial%20restructuring%20and%20cost%20cutting (Accessed: 14 August 2021).

Thakur, H. K. 2021. Research Design. Available: https://www.researchgate.net/publication/353430802_Research_Design#fullTextFileContent (Accessed: 05 January 2024).

The Coca Cola Company. 2021. Coca-Cola Collaborates with Tech Partners to Create Bottle Prototype Made from 100% Plant-Based Sources. Available:

https://www.coca-colacompany.com/news/100-per cent-plant-based-plastic-bottle (Accessed: 21 June 2022).

The Coca-Cola Company. 2018. Moving Toward a Circular Economy. Available: https://www.coca-colacompany.com/news/moving-toward-a-circular-economy (Accessed: 28 February 2022).

The Department of Trade and Industry, 2019. Facts and Figures on Skills in Manufacturing. Available: http://www.thedtic.gov.za/wp-content/uploads/publication-Facts-and-Figures.pdf (Accessed: 08 September 2022).

The Global Manufacturing and Industrialization Summit. 2020. GMIS2020 Virtual Summit. Available: https://www.unido.org/sites/default/files/files/2020-11/GMIS2020%20Virtual%20Summit%20Outcomes%20PDF%20Version.pdf (Accessed: 07 September 2021).

The world counts. 2022. Tons of hazardous waste thrown out. Available: https://www.theworldcounts.com/challenges/waste/hazardous-waste-statistics (Accessed: 29 August 2022).

Thompson, R. C. 2017. Future of the Sea: Plastic Pollution. Government Office for Science. (Accessed: 12 February 2022).

Tiseo, I. 2021. Leading countries based on generation of electronic waste worldwide in 2019. Available: https://www.statista.com/statistics/499952/ewaste-generation-worldwide-by-major-country/#:~:text=China%20is%20the%20largest%20producer,metric%20tons%20worth%20in%202019. (Accessed: 23 June 2022).

Tollefson, J. 2022. Nature. Available: https://www.nature.com/articles/d41586-022-00585-7 (Accessed: 25 May 2022).

Tomita A., Smith C.M., Lessells R.J., Pym A., Grant A.D., de Oliveira T. and Tanser F. 2019. Space-time clustering of recently diagnosed tuberculosis and impact of ART scale-up: Evidence from an HIV hyper-endemic rural South African population. Available: https://www.nature.com/articles/s41598-019-46455-7#citeas (Accessed: 12 April 2022).

Tomita, Cuadros, Burns, Tanser and Slotow, 2020. Exposure to waste sites and their impact on health: a panel and geospatial analysis of nationally representative data from South Africa, 2008–2015. Available: http://dx.doi.org/10.1016/S2542-5196(20)30101-7 (Accessed: 12 April 2022).

Tongwane, M. I. and Moeletsi, E. M 2021. Status of electric vehicles in South Africa and their carbon mitigation potential. Available: Status of electric vehicles in South Africa and their carbon mitigation potential | Elsevier Enhanced Reader (Accessed: 22 August 2022).

Trading Economics. 2022. South Africa - Manufacturing, Value Added (% Of GDP). Available: https://tradingeconomics.com/south-africa/manufacturing-value-added-per cent-of-gdp-wb-data.html#:~:text=Manufacturing%2C%20value%20added%20(%25%20of%20GDP)%20in%20South%20Africa%20was,compiled%20from%20officially%20recognized%20sources. (Accessed: 02 September 2022).

Turner, S. 2022. Chi-Square Test of Independence | Formula, Guide & Examples. Available: https://www.scribbr.com/statistics/chi-square-test-of-independence/ (Accessed: 02 June 2022).

UN Environmental Programme. 1972-2022. GOAL 12_ Sustainable consumption and production _ UNEP - UN Environment Programme.pdf. Available: https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-12 (Accessed 18 August 2021).

United Nations Environment Programme (UNEP) and The Basel Convention. 2020. Waste management an essential public service in the fight to beat COVID-19. Available: http://www.basel.int/Implementation/PublicAwareness/PressReleases/WastemanagementandCOVID19/tabid/8376/Default.aspx (Accessed: 07 April 2022).

United Nations Environment Programme (UNEP). Global Waste Management Outlook. 2015. Available: http://web.unep.org/ourplanet/september-2015/unep-publications/global-waste-management-outlook (Accessed: 07 April 2022).

United Nations Environment Programme (UNEP). Waste Investing in energy and resource efficiency. Green Economy. Online report; 2011. http://sawic.environment.gov.za/documents/3636.PDF (Accessed: 27 February 2022).

United Nations Industrial Development Organisation. 2022. Green Industry initiative. Available: https://www.unido.org/our-focus-cross-cutting-services-green-industry/green-industry-initiative (Accessed 06 September 2021).

United Nations. 2015. Transforming our World: The 2030 agenda for sustainable development. New York. Available: https://sustainabledevelopment.un.org/post2015/transformingourworld (Accessed: 16 June 2022).

United States Environmental Protection Act. 2020. What are the trends in greenhouse gas emissions and concentrations and their impacts on human health and the environment. Available: https://www.epa.gov/report-environment/greenhouse-gases (Accessed: 22 June 2022).

United States Environmental Protection Act. 2021. Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. Available: https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy (Accessed: 27 February 2022).

United States Environmental Protection Agency. 2011. Lean, Energy and Climate Toolkit, Achieving Process Excellence Through Energy Efficiency and Greenhouse Gas Reduction.pdf. Available: https://www.epa.gov/sites/default/files/2013-10/documents/lean-energy-climate-toolkit.pdf (Accessed: 03 September 2020).

US Waste and recycling. 2018. A look at industrial solid waste . Available: https://www.southernwasteandrecycling.com/blog/2017/01/a-look-at-industrial-solid-waste/#:~:text=Some%20of%20the%20most%20common,infectious%20wastes%2C%20and%20confidential%20documents. (Accessed: 30 August 2022).

Ventureburn. 2021. Why the circular economy is fertile ground for South African entrepreneurs. Available: https://ventureburn.com/2021/12/why-the-circular-economy-is-fertile-ground-for-south-african-entrepreneurs/ (Accessed: 28 February 2022).

Vijayvargy, Thakkar and Agarwal. 2017. Drivers of and barriers to green manufacturing in South Africa. Available: https://journals.co.za/doi/pdf/10.35683/jcm20141.147 (Accessed: 09 September 2022).

Vikrant, K., Giri, B.S., Raza, N. Roy, K., Kim, K.-H., Rai, B.N. and Singh, R.S. (2018). Recent advancements in bioremediation of dye: current status and challenges. Bioresource. Technol., 253 (2018), pp. 355-367. Available: https://www.sciencedirect.com/science/article/pii/S2452072119300413 (Accessed: 25 January 2022).

Visvanathan, C., Parasnis, M. and Janesiripanich, A. 1998. Multimedia environmental audit in a rice cracker factory in Thailand: A model case study. Availabe: https://doi.org/10.1016/S0959-6526(97)00056-5 (Accessed: 23 June 2023).

Wachpanich, N. and Coca, N. 2022. As waste-to-energy incinerators spread in Southeast Asia, so do concerns. Available: https://news.mongabay.com/2022/12/as-waste-to-energy-incinerators-spread-in-southeast-asia-so-do-concerns/ (Accessed: 18 July 2023).

Wang, X.; Jiang, J.; Gao, W. 2022. Reviewing textile wastewater produced by industries: Characteristics, environmental impacts, and treatment strategies. Available: https://doi.org/10.2166/wst.2022.088 Accessed: 29 June 2023.

Wanjohi, A. M. and Syokau, P. 2021. How to conduct Likert scale analysis. Available: https://www.kenpro.org/how-to-conduct-likert-scale-analysis/ (Accessed: 14 June 2023).

Wansia, E., D'Ansa, P., Gondaa, L., Segatoa T. and Degreza, M. 2018. Waste management of discarded cell phones and proposal of material recovery techniques. Available: Waste Management of Discarded Cell Phones and Proposal of Material Recovery Techniques - ScienceDirect (Accessed: 05 July 2023).

White, P. R., Franke, M., and Hindle, P. (1995). Integrated Solid Waste Management: A Lifecycle Inventory. (Accessed: 20 June 2022).

Williams, C. (2011). Research methods. Journal of Business and Economics Research (JBER), 5(3) (Accessed: 08 May 2022).

Wood, D., Lane, L., Gillespie, W., Baker, S. and Rowbottom, C. (2014), "The implementation of a PDR 3d-guided gynaecological brachytherapy service in a UK centre", Journal of Radiotherapy in Practice, Vol. 13 No. 3, pp. 322-331. (Accessed: 22 March 2022).

World Economic Forum. 2019. A New Circular Vision for Electronics. Available: https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf (Accessed: 03 January 2024).

World Bank. (2019). What a waste 2.0: A global snapshot of solid waste management to 2050. Retrieved 4 July 2019 from: http://datatopics.worldbank.org/whatwaste/trends_in_solid_waste_management.html (Accessed: 18 February 2022).

World Health Organisation. 2023. Climate change and health. Available: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health (Accessed: 03 January 2024).

World Health Organisation. 2023. Dioxins and their effects on human health. Available: https://www.who.int/news-room/fact-sheets/detail/dioxins-and-their-effects-on-human-health (Accessed: 03 January 2024).

World Wildlife Fund (WWF) South Africa. 2018. WWF Plastic File #1: living in a plastic age. Available from: http://www.wwf.org.za/?26021/plastic-file-01 (Accessed: 08 September 2022).

Wright, M. (2021). How pilot testing can dramatically improve your user research. Available: https://www.widerfunnel.com/blog/pilot-testing-user-research/ (Accessed: 21 June 2021).

Wu, F., Liu, X. and Qu, G., 2022. High value-added resource utilization of solid waste: review of prospects for supercritical CO2 extraction of valuable metals. Available: http://dx.doi.org/10.1016/j.jclepro.2022.133813 (Accessed: 10 July 2023).

Xolo N. 2020. 'We're suffocating': Caught between Covid-19 and polluted air. Available: https://www.news24.com/citypress/news/were-suffocating-caught-between-covid-19-and-polluted-air-20200902 Accessed: 19 February 2022.

Yan, Y., Zhang, X., Zhang, J. and Li, K. 2020. Emissions trading system (ETS) implementation and its collaborative governance effects on air pollution: The China story. Available: https://doi.org/10.1016/j.enpol.2020.111282 (Accessed: 07 July 2023).

Yang, B., Xu, H., Yang, S., Bi, S., Li, F., Shen, C., Ma, C., Tian, Q., Liu, J., Song, X., Sand, W. and Liu, Y. 2018. Treatment of industrial dyeing wastewater with a pilot-scale strengthened circulation anaerobic reactor. Bioresource Technology, 264: 154-162.

Yaqub, M. and Lee, W. 2019. Zero-liquid discharge (ZLD) technology for resource recovery from wastewater: A review. Available: https://doi.org/10.1016/j.scitotenv.2019.05.062 (Accessed: 29 June 2023).

Yatmar, H., Ramli, M. I., Pasra, M and Ikbal M. 2022. The Relationship Between Socio-Demographic Environment and Trip Preferences Towards Relaxation Facilities in Urban Area (Case Study: Modern Café in Makassar). Available: https://iopscience.iop.org/article/10.1088/1755-1315/1000/1/012016/pdf (Accessed: 27 May 2023).

Yin, H. and Schmeidler, P. J. (2008) 'Why Do Standardized ISO 14001 Environmental Management Systems Lead to Heterogeneous Environmental Outcomes? Available: https://ideas.repec.org/a/bla/bstrat/v18y2009i7p469-486.html (Accessed: 21 June 2022).

Yonli A.H. and Godfrey L. 2018. Appropriate solutions for Africa. Africa Waste Management Outlook. Nairobi, Kenya: UNEP; 2018. pp. 119-150. Available from: https://t.co/BYjYbHpwwz (Accessed: 06 April 2022).

Youcai, Z. 2018. Pollution Control Technology for Leachate from Municipal Solid Waste. Available: Summary (sciencedirectassets.com) (Accessed: 10 July 2023).

Youmatter. 2019. Greenwashing definition – What is greenwashing? Available: https://youmatter.world/en/definition/definitions-greenwashing-definition-what-is-greenwashing/ (Accessed: 03 September 2021).

Younis, Sundarakani, H., Mahony O. and Barry, G. 2019. Green Supply Chain Management and Corporate Performance: Developing a Roadmap for Future

Research Using a Mixed Method Approach. Available: https://dspace.adu.ac.ae/handle/1/2107 (Accessed: 09 September 2022).

Zafar, S. (2019) Medical waste management in developing countries. Thomé-Kozmiensky Verlag GmbH-Neuruppin. Available at: https://www.vivis.de/wp-content/uploads/WM9/2019_WM_351-358_Zafar.pdf (Accessed: 04 February 2022).

Zali, M. 2021. Disposable masks are the latest pollution problem. Available: https://mg.co.za/environment/2021-12-06-disposable-masks-are-the-latest-pollution-problem/ (Accessed: 28 February 2022).

Zamboni, J. 2018. Difference Between Conceptual and Theoretical Framework. Available: https://classroom.synonym.com/theoretical-orientation-research-articles-7798312.html (Accessed: 12 October 2023).

Zhang, W., Li, G., Uddin, M.K. and Guo, S. 2020. Environmental regulation, foreign investment behavior, and carbon emissions for 30 provinces in China. Available: https://doi.org/10.1016/j.jclepro.2019.119208 (Accessed: 08 July 2023).

Ziraba AK, Haregu TN, Mberu B. 2016. A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. Archives of Public Health. 2016;74(55):1-11. Available: https://archpublichealth.biomedcentral.com/track/pdf/10.1186/s13690-016-0166-4 (Accessed: 07 April 2022).

Zolnikov, da Silva, Tuesta, Marques and Cruvinel. 2018. Ineffective waste site closures in Brazil: A systematic review on continuing health conditions and occupational hazards of waste collectors. Available: Ineffective waste site closures in Brazil:

A systematic review on continuing health conditions and occupational hazards of waste collectors - ScienceDirect (Accessed: 29 August 2022).

Zondo, S. G. 2019. Production and Characterization of Polyhydroxyalkanoates (PHA) from Corn Silage using Thermus thermophilus HB8. Available: ZONDOSG_2019.pdf (dut.ac.za) (Accessed: 04 July 2023).

Zubair, M. and Adrees, A. 2019. Dioxins and Furans: Emerging Contaminants of Air. Available: (PDF) Dioxins and Furans: Emerging Contaminants of Air (researchgate.net) (Accessed: 22 August 2022).

APPENDICES

APPENDIX A: RESEARCH QUESTIONNAIRE

Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

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Good day

As a Master's student at the Durban University of Technology, I, Everlane Reddy, a KwaDukuza resident, am conducting research on waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal. In this regard, I sincerely request your participation in this survey by completing the short questionnaire below.

Please note that as you are not required to reveal your name or the name of your organisation, your confidentiality and anonymity are guaranteed.

By completing the survey, it is implied that you consent to participate in the study. (Ethical Clearance number: 149/22). Should you have any questions or concerns, kindly contact me at 21751874@dut4life.ac.za or my research supervisor, Prof. R.W.D. Zondo, at DumisaniZ@dut.ac.za. **Thank you!**

Start time: __________ Finish time: ___________

Kindly indicate your response (in all sections) by marking the appropriate box with a cross (X)

SECTION A: DEMOGRAPHIC DETAILS

---

1. Personal Details

1.1 Position in the organisation

1.1.1	Proprietor		1.1.2	General Manager		1.1.3	Production Manager		1.1.4	Head of Department /Supervisor		1.1.5	Other	

1.2 Age

1.2.1	18-34 Years		1.2.2	35-59 Years		1.2.3	60 Years and older	

1.3 Highest Educational Qualification

1.3.1	Grade 12		1.3.2	Diploma / Degree		1.3.3	Postgraduate Degree		1.3.4	Other	

2. Organisational Details

2.1 Which category of raw materials, semi-finished products or finished products does your organisation manufacture?

2.1.1	Furniture manufacturing		2.1.2	Paper and printing products		2.1.3	Electrical machinery and apparatus	
2.1.4	Textiles, clothing and leather goods		2.1.5	Food, beverages and tobacco		2.1.6	Metals, metal products, machinery and equipment	
2.1.7	Petroleum and chemicals products		2.1.8	Plastic and rubber products		2.1.9	Automotive component	
2.10	Other (please state)							

2.2 Number of full-time employees?

2.2.1	1 - 10 employees		2.2.2	11 - 50 employees		2.2.3	51 – 250 employees		2.2.4	More than 250 employees	

2.3 How long has your organisation been in operation?

2.3.1	Less than 1 year		2.3.2	1 – 5 years		2.3.3	5 – 10 years		2.3.4	Older than 10 years	

2.4 Form of ownership

2.4.1	Sole proprietorship		2.4.2	Partnership		2.4.3	Close Corporation (CC)	
2.4.4	Private company (Pty) (Ltd)		2.4.5	Public Company (Ltd)				

SECTION B

---

3. Select the types of waste generated by your organisation

3.1	Toxic Waste		3.2	Used Lubricants		3.3	Chemical Waste	
3.4	Plastic Waste		3.5	Solid Waste		3.6	Laboratory Waste	
3.7	Wood & Paper		3.8	Electronic Waste		3.9	Radioactive Wastes	
3.10	Food Processing Waste		3.11	Metals		3.12	Other	

Please indicate the extent to which you agree or disagree with the statements below by placing a cross "X" in the appropriate column

Rating Scale	1	2	3	4	5
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

4. Waste management/disposal method		Rating				
4.1	Our waste is recycled in-house	1	2	3	4	5
4.2	Our waste is reused to manufacture other-products	1	2	3	4	5
4.3	Plasma Gasification	1	2	3	4	5
4.4	Composting	1	2	3	4	5
4.5	Incineration	1	2	3	4	5
4.6	Sanitary-landfills	1	2	3	4	5
4.7	Stored Indefinitely	1	2	3	4	5
4.8	Dilution	1	2	3	4	5
4.9	Collected by the municipality	1	2	3	4	5
4.10	Fermentation	1	2	3	4	5

SECTION C

5. Please indicate the extent to which you agree or disagree with the statements below by placing a cross "X" in the appropriate column

Rating Scale	1	2	3	4	5
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

5. Measures used to manage waste		Rating				
5.1	Our organisation has a policy for managing waste generated during production	1	2	3	4	5
5.2	Our organisation has the necessary resources to design green / eco-friendly products.	1	2	3	4	5
5.3	The technology employed in our organisation is current and adequate for enabling clean production processes.	1	2	3	4	5
5.4	Our organisation often makes fundamental changes to product design & processes to reduce pollution, waste, and toxic emissions.	1	2	3	4	5
5.5	Our organisation uses biodegradable and/or compostable raw materials.	1	2	3	4	5
5.6	Our organisation effectively reduces the carbon emission and hazardous substances or waste into the environment.	1	2	3	4	5
5.7	Our organisation incorporates recycled materials in certain product formulations.	1	2	3	4	5
5.8	Our organisation considers constant environmental auditing as an internal waste management strategy.	1	2	3	4	5
5.9	Our organisation complies with the application of environmental management systems (for example, Eco-management and Audit Scheme (EMAS) or to SABS ISO for example, 14001, ISO14021)	1	2	3	4	5
5.10	Our organisation has reduced the consumption of water in its production processes.	1	2	3	4	5

5.11	Our organisation has reduced the consumption of electricity in its production processes.	1	2	3	4	5
5.12	Our products are packaged in reusable packaging.	1	2	3	4	5
5.13	Our organisation provides adequate training to its employees on how to dispose of toxic waste	1	2	3	4	5
5.14	Our organisation uses waste treatment techniques to reduce the volume of toxicity prior disposal	1	2	3	4	5
5.15	Our organisation has collection points for post-consumer waste, products/packaging.	1	2	3	4	5
5.16	Our organisation employs “Waste pickers” to collect our post-consumer waste	1	2	3	4	5
5.17	To what extent do you agree or disagree with the statement that “obsolete/redundant waste contains no value”?	1	2	3	4	5
5.18	To what extent do you agree or disagree with the statement that “there is a serious waste management problem in iLembe”?	1	2	3	4	5

SECTION D

Please indicate the extent to which you agree or disagree with the statements below by placing a cross “X” in the appropriate column

Rating Scale	1	2	3	4	5
	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

6. Factors influencing waste management practices in your organisation		**Rating**				
6.1	Our organisation complies with Government Environmental Regulations.	1	2	3	4	5
6.2	Our organisation receives government grants or other financial incentives to support innovative and high-impact green initiatives.	1	2	3	4	5
6.3	Our organisation experiences pressure from non-governmental organisations (NGOs) and the local community with regards to waste management.	1	2	3	4	5
6.4	Our organisation employs digitalised technology to reduce energy/electricity consumption during production	1	2	3	4	5
6.5	Our organisation employs digitalised technology to reduce water consumption during production	1	2	3	4	5
6.6	Our organisation has realised cost reductions due to the adoption of cleaner production processes and green initiatives.	1	2	3	4	5
6.7	Other					

7. Barriers to adopting sustainable waste management practices in your organisation		**Rating**				
7.1	Lack of capital to invest in new technologies and processes to reduce waste.	1	2	3	4	5
7.2	Employee reluctance to adopt new technologies and cleaner industrial processes	1	2	3	4	5
7.3	Insufficient supply of biodegradable raw materials in our area	1	2	3	4	5
7.4	Our organisation lacks effective waste management solutions	1	2	3	4	5
7.5	Other					

8. Would your organisation consider supporting a waste recycling plant in iLembe?

8.1	Yes		8.2	No		8.3	Unsure	

If you wish to receive a copy of the research results, please state your e-mail address below:

Thank you for taking the time to complete this questionnaire and for your contribution to this study.

APPENDIX B: LETTER OF INFORMATION

Faculty of Management Sciences
Department of Entrepreneurial Studies and Management
Date: 12 August 2021

Dear Participant

LETTER OF INFORMATION

Title of the Research Study: (Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal)

Principal Investigator/s/researcher: Everlane Reddy, (Bachelor of Technology in Management)

Co-Investigator/s/supervisor/s: Professor R.W.D. Zondo, (D. Com)

Brief Introduction and Purpose of the Study: Operating a firm in the context of current environmental concerns necessitates a transition away from a management strategy that is merely focused on achieving economic goals. The chronic issues associated with environmental exploitation and pollution, as well as the constant shrinkage of available natural resources makes environmental challenges an extremely crucial corporate imperative. In this context, sustainable business practices, particularly those that are innovative, are gaining traction. These green initiatives allow for the mitigation and/or reduction of environmental pollution while, at the same time, generating certain measurable benefits for the companies implementing them. Considering the above, this investigation aims to assess the use of sustainable waste management practices among manufacturing organisations in the iLembe Municipal District, KwaZulu-Natal (KZN).

Greeting: (Good day, how are you).

Introduce yourself to the participant: I am a 2nd year student at DUT doing research for my Master of Management Sciences Degree (Business Administration).

Invitation to the potential participant: I would like to invite you to participate in the research.

What is Research: Research can be described as the organized generation of new information and/or the creative application of existing information to generate novel ideas, approaches, and comprehensions. You are free to ask as many questions as you wish because it is important that you fully understand the study. You are permitted to discuss the study with your family and friends and are under no obligation to commit at this stage. For this purpose, a copy of the Letter of Information document will be issued to you to take home.

Outline of the Procedures: Data for this study will be gathered by means of a survey consisting of structured questions. The questionnaire should take between 20-25 minutes to complete. Please complete the questionnaire within 2 weeks of receipt and kindly return to eve.r644@gmail.com. The data will then be analysed, and the results used to provide recommendations. Should you wish to receive a copy of the results of this study, kindly provide your contact details at the end of the questionnaire.

Risks or Discomforts to the Participant: It is unlikely that you will face any physical, psychological, or social risks. However, if you feel uncomfortable or have any problems because of your participation in this study, you may withdraw at any time, without prejudice.

Explain to the participant the reasons he/she may withdraw from the Study:

The research may be terminated early in particular circumstances viz. Non-compliance, illness, adverse reactions, etc. If you feel uncomfortable or have any problems due to of your participation in this study, you may feel free to refuse of withdraw at any time, without any penalty or prejudice. You may provide the research team with a reason for leaving the study but is not obligatory to do so.

Benefits: Your involvement in this study may not provide you with any immediate benefits. However, the results of this study may be useful to future students, you, your organisation, and the business and academic communities. It is also vital to note that the researcher will receive no benefits other than the satisfaction of doing the research for academic purposes.

Remuneration: Your participation in this study is entirely voluntary, and you will not be compensated in any way for your participation in this research

Costs of the Study: You will not incur any costs, nor will you receive any reimbursements for your participation in this study.

Confidentiality: Participation in this study is strictly confidential, and the questionnaire does not require you to reveal your identity and the identity of your business. Completed questionnaires will be electronically stored in a password protected folder. I will be the only person that has access to this information.

Results: (Explain how the researcher plans to disseminate the results of the research. Explain if any significant new results developed during the course of the research how it will be conveyed to the participant).

Research-related Injury: Your participation in this study is entirely voluntary, and you will not be compensated in any way for your participation in this research.

Storage of all electronic and hard copies including tape recordings: The data will be stored electronically in a password-protected folder and will be held for a period of 5 years, then deleted.

Persons to contact in the Event of Any Problems or Queries: (Supervisor and details) Please contact the researcher Everlane Reddy (0826431848), my supervisor Prof. R.W.D. Zondo on 031 373 6831 or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

APPENDIX C: LETTER OF CONSENT

Full Title of the Study: Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

Names of Researcher/s: Everlane Reddy

Statement of Agreement to Participate in the Research Study:

□ I hereby confirm that I have been informed by the researcher,_____ (name of
researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance
Number: ____,

□ I have also received, read and understood the above written information (Participant Letter of
Information) regarding the study.

□ I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

□ In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.

□ I may, at any stage, without prejudice, withdraw my consent and participation in the study.

□ I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

□ I understand that significant new results developed during the course of this research which may
relate to my participation will be made available to me.

______________________	__________	______	___________________________
Full Name of Participant	**Date**	**Time**	**Signature / Right Thumbprint**

I, Everlane Reddy (name of researcher) Herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Everlane Reddy

Full Name of Researcher **Date** **Signature**

Full Name of Witness (If applicable) **Date** **Signature**

Full Name of Legal Guardian (If applicable) **Date** **Signature**

APPENDIX D: LETTER OF ETHICAL CLEARANCE FROM IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY

INSTITUTIONAL RESEARCH ETHICS COMMITTEE

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

26 June 2023

Mrs E Reddy
88 Geranium Street
Stanger Manor
KwaDukuza
4449

Dear Mrs Reddy

Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal
Ethical Clearance number IREC 149/22

The DUT-Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

Yours Sincerely

Prof J K Adam
Chairperson: DUT-IREC

APPENDIX E: LETTER OF STATISTICAL SUPPORT

ANALYTICS CONSULTINA
Data-driven solutions

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CLEARANCE

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Sample size, Data Collection Tools, Capturing, Cleaning, Analysis, Interpretation, Report Writing & Training (Workshops / Webinars)

TO WHOM IT MAY CONCERN — REFERENCE

COMPANY	Durban University of Technology	CLEARANCE №	23 1121 0730
FACULTY/DEPT	Management Sciences	DATE ISSUED	Tue, 21-Nov-2023
ATTENTION	The Chairperson		
COUNTRY	South Africa	TOTAL APPROVED:	2 of 2

ITEM	SERVICE	CLEARED	IN PROGRESS	PENDING	N/A
1	Sample Size Calculations (Power Analysis)	☐	☐	☐	☑
2	Data Collection Instrument(s)	☐	☐	☐	☑
3	Statistical Analysis Plan	☑	☐	☐	☐
4	Data Analysis Results	☑	☐	☐	☐

LETTER OF STATISTICAL SUPPORT

This letter serves to confirm that I am professional (Bio)Statistician and have carefully studied the research protocol of:

Reddy, Everlane (21751874)

Title

Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

I have been consulted on the above-listed items which I deemed as statistically sound for the statistical analysis of the data generated from the project. I also hereby confirm that I was responsible for guiding and performing all the required data analysis including the selection of the most appropriate statistical techniques according to the research objectives.

Should you require any further details, please do not hesitate to contact us.

SINCERELY YOURS — SUMMARY

The Analytics Team

(Bio)Statistician: P. Tinarwo, PhD (UKZN) | Engineering Technologist (DUT)
+27(0)61 006 9432
statistician@analytics-consultina.com
www.analytics-consultina.com

CLEARED	2
IN PROGRESS	0
PENDING	0
NOT APPLICABLE	2
REQUESTED	2

NOTES

CLEARED	- Declared as either statistically sound or the appropriate advise has been given.
PENDING	- The service will be required at a later stage.
N/A	- Not applicable. It is either the service was sourced elsewhere or not required

Quality and efficiency are priority in delivering all our services — Thank you for choosing Analytics

APPENDIX F: TURNITIN SIMILARITY REPORT

Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

ORIGINALITY REPORT

18%	15%	9%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Durban University of Technology Student Paper	2%
2	ir.dut.ac.za Internet Source	1%
3	www.researchgate.net Internet Source	1%
4	www.mdpi.com Internet Source	1%
5	www.dut.ac.za Internet Source	1%
6	ujcontent.uj.ac.za Internet Source	<1%
7	openscholar.dut.ac.za Internet Source	<1%
8	vdoc.pub Internet Source	<1%

Prof RWD Zondo (Supervisor)

APPENDIX G: LETTER FROM THE EDITOR

EDITOR'S LETTER

Researchers Beyond-Borders (PTY) LTD
Umhlanga, Durban
South Africa
1 January 2024

To whom it may concern

Editing of Master's dissertation: Everlane Reddy (Student number - 21751874)

Title: Waste management practices among manufacturing organisations in the iLembe Municipal District in KwaZulu-Natal

This letter serves as confirmation that the aforementioned dissertation has been language edited.

Any queries may be directed to the author of this letter.

RESEARCHERS
BEYOND BORDERS

Regards

Maleni Pillay
Researchers Beyond-Borders
consult@researchersbeyondborders.com
www.researchersbeyondborders.com