

DOI: <https://doi.org/10.38027/iccaua2023en0108>

## The 3Rs(Reduce, Reuse, Recycle) of Waste Management – An effective and Sustainable Approach for Managing Municipal Solid Waste in Developing Countries

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### Abstract

As the population of the world increases, more and more places are becoming urbanized; production and consumption rates are on a speedy rise. The inevitable consequence of high consumption rate around the world is the high volume of solid waste generated, thus, there is urgent need to properly manage generated wastes. The developing countries are at high risk of environmental degradation because of the way their solid waste is been handled due to lack of waste management infrastructures, policy framework and orientation. This results into severe health and environment. Thus, there is need for urgent awareness; tangible framework and orientation as to how municipal solid waste can be well manage in a sustainable way through the 3Rs(Reduce, Reuse Recycle) of waste management.

This research is based on a comprehensive review of relevant scholarly written literatures for an in-depth understanding of the concept of waste, it sources, composition, treatment, disposal, and general management of MSW (municipal solid waste) in places around the world. In addition, this research investigates the current culture of waste management in developing countries and re-emphasizes the impact of waste on the environment. Hence, to mitigate the ongoing damaging effects of wastes in developing countries, this study introduces the 3Rs of waste management as a tangible approach to sustainability in terms of solid waste coming from both urban and rural municipalities in developing countries. In a more specific way by answering the WH(What and how) question on common and everyday items used and easily dispose of by individual. With the approach and framework brought forward by this study, it aims to meet economic and environmental obligations of the ecosystem.

**Keywords:** Waste management; Sustainability; 3Rs(Reduce, Reuse Recycle); Municipal solid waste; Developing countries.

### Introduction

Granted, wastes are indispensable and the rapid change of lifestyle, increase in population especially in urban municipality, Economic development and rising living standards, advancement in many aspect of human life such as technology and production unprecedentedly increases the quantity and complexity of generated wastes (Amen, 2021, Aziz Amen, 2022, Amen et al., 2023, Amen & Nia, 2020)

. The often nonchalant attitude and incorrect disposal of wastes by individual and co-operate entities often results in extreme ecological pollution, mainly based on the emission of harmful gases that contribute to the greenhouse effect, such as methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) (Dek Vimean et al 2022). The worldwide waste market has become a lucrative economic sector, it is estimated that the waste market value is at USD 410 billion per year, from collection stage through to recycling— nevertheless, only about one-third of the world's municipal solid waste is managed properly, and much of the unmanaged wastes are increasingly hazardous. All sorts of litters, such as plastics, feaces, and microplastics are now found in all oceans, at all levels (UNEP 2021). Thus, to avert the potential severe environmental and human health consequences of generated waste, there is need for a sustainable and tangible approach to manage the large volume of non-stop waste generated in every human settlement.

Within the scope of Municipal solid waste in developing country, the general source of Municipal wastes are from homes, markets, businesses, institutions, offices, restaurants and hospitals and they consist of everyday items such as food waste, paper, plastic, rags, metal and glass that are utilized and discarded by the public in a geographical location (John D 2020). To manage this generated waste that comes from different sources, the concept of waste management was developed and implemented through frame works and strategies that spans through many professions, industries and down to individual (White et al., 1995). Many developed countries have unique and peculiar ways they treat and manage their MSW. In some well developed countries, such as Australia, China, Japan, Republic of Korea, Hong Kong, and Singapore, progress has been made on procedures for detoxification of hazardous waste and recycling by turning them into bricks and other usable materials. Purpose-built sanitary landfills have been developed to receive hazardous waste (Brunner 2014)

Generally in urban areas of developing countries, Municipal solid wastes (MSW<sup>1</sup>) are disposed by mixing with plastic, glass, textile, paper, and other fractions without source separation. It is then collected and disposed in dumps,

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<sup>1</sup> MSW will be used in this research as abbreviation for Municipal Solid Waste

landfills, or incineration as the simplest, most convenient, least expensive, and requiring no technologically method. In retrospect, this causes more environmental damage and poses a health risk. (Saleh 2019). More also, it is observed by Godfrey, (2019) that the problem of waste management in developing countries is compounded by rapid urbanization, dumping of used items by the developed world into developing countries, lack of awareness and orientation, corruption and lack of resources/finance.

This research qualitatively and comprehensively discusses the generation, composition, treatment, disposal, and general management of MSW. This study further evaluates the factors influencing the improper disposal of solid waste in the developing world. Hence, adopting the most holistic, proven, feasible strategy - the 3Rs<sup>2</sup> strategy specifically for urban municipality of developing country who are more prone or vulnerable to environmental and health hazards due to their lack of proper orientation and needed resources to deal with the volume of waste generated. The 3Rs principle contribute to sustainable living in the most significant way by making individuals consider the effects of their consumption and trash creation can motivate us to change our lifestyles in order to produce less waste and have a smaller negative impact on the environment. This study aim to put the spotlight and bring awareness to the urgent need to deal with the ongoing damaging effects of all sorts of wastes in the environment. Hence, promptly mitigate these effects in a sustainable way.

### **1.1 Methodology**

This paper which is a review of literatures relied heavily on secondary data, existing information are used for analysis and to draw vital conclusions. Some of the sources of data for the study include books, journal articles, unpublished papers, government reports, organizational and private webpages and personal experiences. This paper utilized this approach to evaluate what different researchers have written on wastes, its classification and management. Below is a well detailed explanation of the research systematic review operandi

- (i) Search strategy: A systematic literature search was carried out between November 2022 and January 2023. In skimming through relevant literatures for discuss, polemics and in-depth writings about waste and types of waste, environmental impact of waste and waste management methods. Through online databases such as Google scholar, MIT, PUBMED, research gate, science direct and other connected web platform and in line with the drafted table of contents, research was performed using a combination of specific and related keywords: “waste”, “waste management”, waste pollution, waste management in developing countries, waste disposal, reduce, re-use, recycle of waste, impact of waste, environmental impact of improper waste disposal, e-waste, hazardous and non-hazardous waste etc. Furthermore, references found in writings were checked for additional articles eligible for this research. Questions considered for screening the relevancy of literatures are: what are the objective of the study, what is the tool and methodology used in this study? What is the overall aim? What aspects of waste were considered? What is novelty of the research? How reliable and compressive is this research? Answers to those analytical questions help proceed to next stage – Article selection
- (ii) Article selection: subsequent screening of all Titles, abstracts, and full articles in picking the most related writings. A further in-depth reading of each selected articles/Journal/thesis was done and highlighting relevant and useful statement for this study. Words and structure were extracted from the writings in giving wide and accurate knowledge about the topic. From the genuine online databases, a total of 120 references or literature were clicked during the course of the research, 92 very relevant titles of the literatures was selected out of the 120. Moreover, after reading through the abstract for more clarification, a total of 89 literatures were selected. A filter for duplicate of ideas was done and 69 literatures were selected. An in-depth reading of the 69 literatures brought the selection of literature to 60 literatures. In addition, snow baling method of the 60 literatures, added 6 very relevant literatures to the references, bringing the references systematically reviewed to a total of 67.

### **1.2 Novelty of Research**

There are numerous research, report, polemic and recommendation about waste and it management in different context and places around the world, which therefore gives insight and broader understanding about this research area. Through the extensive search for previously written scholarly literature and a review them, there are literatures that have touched on the 3Rs of waste management, some have added two more Rs (Refuse, Repurpose) to the waste management strategies and re-emphasize on the global issue of uncontrolled and improper disposal of waste in our world. However, during the course of review of literatures, it is observed that many researchers generally mentions the pathetic situation of waste disposal in developing countries without pin pointing a proper and specific strategy that fits into the context and meet the standard of sustainability. Therefore, this research took a new spin by focusing on the main 3Rs of waste management

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<sup>2</sup> 3Rs means Reduce, Reuse, and Recycle

proposed by authoritarian standards and come up with a specific and direct strategy to apply in the managing of waste in the developing countries. This research aim to contribute to the already known knowledge in this area of study as well as bring more awareness, proposed a new tangible and sustainable approach to waste management in an often neglected geographical location – the developing countries.

## 2. Waste – An Overview

The scope of the waste definition encompasses all types of ‘substances’ and ‘matter’ including solid, liquid and gaseous waste. In defining waste, definition of common waste materials, such as mixed household waste, is clear and obvious. For other materials, it may be more complicated and in some cases and some instances, the status of a material can change as a result it processing or other activities (Saleh 2019). Waste is a broad theme that encompasses different aspect of human activities. As shown in figure 1 below, wastes are generated by various human activities.



**Fig 1:** showing the various sources, origin of waste and what it consist. (source: <https://sisu.ut.ee/waste/book/11-definition-and-classification-waste>)

Thus, for a broader understanding of waste, these section expatiate and review the concept of waste, it numerous definitions both objectively and subjectively, then touch on the impact of waste on the environment and it inhabitants, hence, emphasizing the need for a proper, tangible and sustainable waste management.

### 2.1 Defining the concept of waste

Almost all activities of humans generates waste (Brunner and Rechberger, 2014), thus, waste is an inevitable product of human activities. There are many definitions of waste by individuals and well known organizations. One common thread among these definitions is the concept that waste is a material that is unwanted by its owner or producer. Waste as a concept is largely subjective in the sense that a substance or material labeled waste by an individual may be regarded as essential resources by another. In other sense, any product or material that as lost its original purpose from the perspective of the owner or consumer can be regarded as waste (Ebikapade Amasuomo et al 2016). For example, a yesterday newspaper or one that has been read, a package or a can that has been opened and emptied of its content or an apple with a little bite and left because of its undesirable taste can be said to be subjective definition of waste.

According to the criteria set out by United Kingdom Department for Environment, Food and Rural Affairs (2012), to define waste, here are the questions and criteria for assessment in determining if an item or product is waste:

Table 1: A table adapted from the “Guidance on the legal definition of waste and its application” done by United Kingdom Department for Environment, Food and Rural Affairs (Source: <http://www.defra.gov.uk/environment/waste/legislation/eu-framework-directive/>)

No	Question/Criteria
1	Is the aim of production of the mass or substance is to be used once or is it being re-used for the same purpose for which it was originally produced?
2	Is the object or matter a by-product that comes out of a production process?
3	Does the substance or object need to be disposed of?
4	Has the substance or object been transferred to a disposal or recovery operation?
5	As regards economic value, is the value very low?
6	Is it hazardous or polluting?
7	Is it or are they still suitable for its original purpose?
8	Is the matter being transferred on as second hand goods?

The above table suggests that whether a material or mass is a waste and to be discarded, it has to be decided on a case-by-case basis, taking account of all the circumstances. In other words, some criteria have to be met and question answered and on its own merits....

### 2.1.1 Definition of waste

The definition of waste is imperative because the classification of substances as waste forms the basis for the conceptualization and plan of waste management policy and the enforcement of regulatory controls to protect the environment and human health. There are many numerous definition of waste by individual and organizations. Oluwatuyi, et al. (2020) defines waste as:

*“Waste: any discarded, rejected, unwanted, surplus or abandoned matter; discarded, rejected, unwanted, surplus or abandoned matter intended for recycling, re-processing, recovery, re-use, or purification by a separate operation from that which produced the matter, or for sale, whether of any value or not” (Oluwatuyi, et al. (2020)*

Table below collated by Pongrácz, Phillips and Keiski (2004) gives definitions of waste from reliable organization and verified researchers:

Table 2: showing different definitions of waste by reliable organizations and verified researchers

No	Organization/academia	Definitions
1	European Union(1991)	Waste shall mean any substance or object which the holders dispose or is required to be disposed.
2	The Organization for Economic Cooperation and Development (OECD 1997)	Waste refers to materials that are not main products produced for the market, or which the manufacturer has no further use in terms of his/her own production purposes, transformation or consumption, and of which he/she wants to discard.
3	The United Nations Environment Programme (UNEP 1989)	Wastes are substances or objects, which are disposed of or are intended and required to be disposed of by the provisions of national law.
4	Lox (1994)	Waste is either an output with no tangible economic market value from a manufacturing system or any matter or object that has been used and served its deliberate production purpose and function by the consumer and will not be re-used
5	McKinney(1986)	Waste is the unnecessary costs that result from inefficient practices, controls or systems
6	Baran (1959)	Waste is the residual obtained when all productive factors were allocated to their highest uses under rational social order. The difference between the level of output of useful goods and services that can be gained.
7	Hollander(1998)	Waste is something that needs to be disposed/expelled in order that the system continues to function
8	Elwood & Patashik (1993)	Waste is subjective like beauty, is in the eyes of the beholder
9	Gourlay (1992)	Waste is what we fail to use or do not want
10	Pongrácz (1997, 1998)	10 Waste is an unwanted, but inevitable output, whence its creation was inevitable either because it was impossible, or

	because it unavoidable. Waste can said to be a man-made or substance or thing that has no purpose; or is unable to perform with respect to its purpose.
12 Bontoux (1997)	Waste is a man-made thing that is, in a particular instance, in its actual structure and state, it become useless to its owner, or an output that has no owner.

### 2.1.2 Classification of Waste

Just as Waste comes in many different form, its classification and characterization can be classified in many forms. Common attributes used in the classification of waste includes: physical properties, reusable potentials, the physical states, line of production, biodegradable potentials, and its impact on the environment (Demirbas, 2011; Dixon & Jones, 2005; White et al., 1995). There are 5 main based classification of waste that encompasses many characteristics of waste: source-based, hazard based, source based, composition based, and type based classification.

#### Physical state-based classification

Waste falls under 3 main state, which are Solid, Liquid and gaseous.

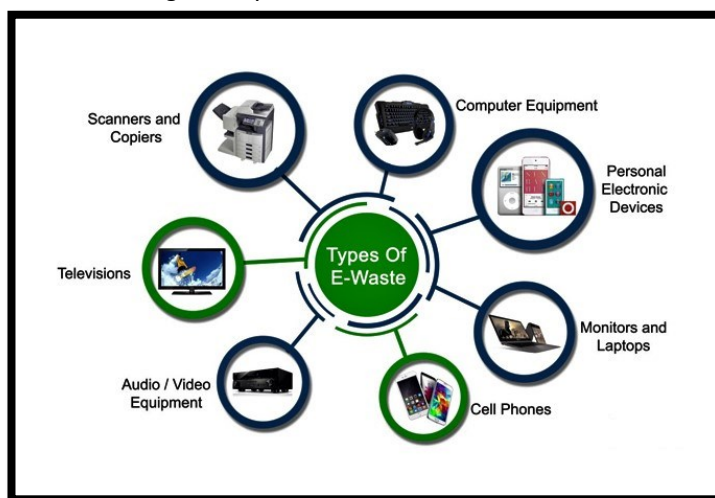
- (i) Solid waste: Solid wastes are hard or semi-solid object or substances that are produced as a result of numerous activities (McMurdie 2014). More also Xiong et.al (2019) define Solid waste as all rotting and non-rotting waste in hard or semi-solid form, including but not limited, trash, ash or incinerator remains, waste on the street, dead animals, demolition and construction waste, sanitation, commercial and industrial waste (Xiong et.al 2019 cited from Hosam, 2021) Solid waste can be classified into two major types: Agricultural and animal waste, Municipal waste.
- (ii) Liquid waste: Any liquid material that are generated from a home, community and industries, that is discarded or intended to be discarded as a result of human or industrial activity is referred to as liquid waste (Esayas Alemayehu 2004). Sewage, agricultural runoff, industrial process waste, and storm water runoff are examples of such materials. The composition of liquid waste varies greatly depending on the source, but it may contain a mixture of dissolved and suspended materials such as organic matter, nutrients, heavy metals, and other contaminants (Esayas Alemayehu 2004). Liquid waste also includes wastewater or sewage from toilet, bath, laundry, lavatory, and kitchen-sink wastes, and surface run off. Because of their ability to enter watersheds, pollute ground and drinking water, and cause diseases such as cholera, plague, tuberculosis, hepatitis B, and diphtheria, liquid waste poses a serious threat to health and the environment. (Priyanka 2021)
- (iii) Gaseous Waste: These are the wastes emitted as gases by automobiles, factories, or the combustion of fossil fuels such as petroleum. Human activity is the primary source of gaseous waste. Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), chlorofluorocarbons (CFC), oxides of nitrogen (NO<sub>x</sub>), carbon monoxide (CO), and other gaseous wastes are examples. They mix with other gases in the atmosphere, causing smog and acid rain on occasion. Gaseous wastes can be offensively odorous or toxic. Some of them are linked to global warming, ozone depletion, and smog (Guillermo et.al 2015)

#### By hazard level

NSW Environment Protection Authority (EPA 2014) states that waste can be classified by its potential to cause harm to human health or the environment. This might include categories such as non-hazardous waste, low-hazard waste, moderate-hazard waste, and high-hazard waste. The two major categories discussed below are non-hazardous and hazardous.

- (i) Non-hazardous Waste: All waste that has not been labeled as hazardous is considered non-hazardous or solid waste, including paper, plastic, glass, metal, and beverage cans. Solid wastes are not necessarily dangerous, but when not properly collected and processed, it can have damaging effects on the environment and human health. Although it is theoretically possible to reuse or recycle a sizable amount of solid waste, selective waste collection, which is required for reuse and recycling, presents one of the major waste management issues. (Dixon & Jones, 2005)
- (ii) Hazardous Waste: Any trash that could be dangerous or detrimental to the environment or to human health is considered hazardous waste. This can contain things like chemicals, batteries, electrical equipment, and other kinds of industrial waste in addition to medical waste (Bacinschi et.al 2010). Due to the possibility that it may be combustible, corrosive, poisonous, or radioactive.

Flammability, corrosiveness, toxicity, explosiveness are the main characteristics of hazardous waste (White et.al 1995). Most hazardous waste originates from industrial production. Special types of hazardous waste include: E-waste, which is waste generated by electric and electronic equipment such as obsolete computers, phones, and home appliances (Fig 2). Because it contains toxic components, e-waste is generally classified as hazardous.



**Fig 2:** various sources of e-waste causing environmental hazard due to hazardous chemical it contain and improper disposal (Source: <https://meticulousblog.org/top-10-companies-in-e-waste-management-market/>)

Due to consumer demand, and rapid technological changes, among other factors, electrical and electronic waste is one of the fastest-growing waste streams (Perkins 2014). Globally, 53.6 million tonnes (Mt) were produced in 2019, an increase of 9.2 Mt since 2014, and this figure is expected to rise to 74.7 Mt by 2030. (Halim et.al 2020). The problem of e-waste pollution acutely affects developing countries, where electronic devices are frequently disposed of in an environmentally hazardous manner, often complicated by the fact that source of e-wastes are not all domestically generated as many developed countries dump their obsolete electric waste into the developing countries. The negative health effects of these toxins on humans include brain, heart, liver, kidney and skeletal system damage (Pekins et al 2014)

#### Source-based classification

In classifying waste, identifying the source they emanate from plays a key role in understanding how to best manage them. Below are the different sources of waste and what consist, as collated by Ebikapade and Jim (2016)

- (i) Residential: This are wastes from dwellings and apartments and comprises of leftover food, vegetable, plastic, clothes, ashes, etc.
- (ii) Commercial: This refers to wastes consisting of leftover food from resturants, glasses, and metals, ashes, generated from stores, markets, hotels, motels, auto-repair, shops, and medical facilities.
- (iii) Institutional: Theses are generated from administrative, educational and public buildings such as colleges, schools, offices, prisons etc. predominantly comprises of paper, plastic, glasses,
- (iv) Hospital/Health waste – These are waste generated within health-care facilities. In addition, it includes the same types of waste from minor and scattered sources, including waste produced during health care undertaken at home (WHO 2014)
- (iv) Municipal sanitation: These are generated from various governmental municipal activities like construction and demolition, street cleaning, landscaping, other recreational area and sludge. They consist of dust, leafy matter, building debris, treatment plant residual sludge, etc.
- (v) Industrial: wastes generated from different industrial activities this mainly consists of process wastes, ashes, demolition and construction wastes or C&D (More specifically, the term is defined as the waste generated from construction, demolition, excavation, site clearance, roadwork, and building renovation) Ngoc & Schnitzer, (2009) described industrial wastes as waste produced as a result of the processing of raw materials for the production of new products.

(vi) Agricultural: Williams (2005) stated that agricultural waste materials include animal manure, various crop remains and silage outflow or emission. This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, generated from fields, orchards, vineyards, farms, etc.

## 2.2 Impact of improper Waste Management on the Environment and its inhabitants

On a global scale, the world is currently facing three major environmental crises: global warming, dwindling of resources, and unprecedented destruction of our ecosystem. These crises are interrelated and connected to waste and waste management. (Tanaka, 2010). Any type of waste which is not properly disposed or unattended to, thus lying around attracts flies, rodents, mosquitoes and other creatures that in turn spread disease. Furthermore, improper disposal generates serious heavy metals pollution occurring in the water, soil, and plants (Vongdala et al 2019). For example, open burning causes the emission of CO, CO<sub>2</sub>, SO, NO, PM<sub>10</sub> and other pollutant emissions that affect the ozone layer and the atmosphere in general (Wiedinmyer et al 2014)

The ever increasing amount of waste produced in the society today has an ongoing significant impact on human health and environment. Many of the materials disposed either in the general waste bin or around, can last in the environment anywhere from hundreds to thousands of years. In developing countries, due to urban sprawl and developments in major cities, environmental and sanitary conditions are becoming very complex due to many factors such as lack of awareness and low income sources, dwellers are not aware of the danger of improper waste disposal and they are forced to live with unhealthy and unhygienic conditions. OECD (2010) report states that Global municipal waste generation in 2030 will be 900 million tones in just the OECD.

- (i) Increased Greenhouse Gas Emission: The greenhouse gases or greenhouse effect is natural phenomenon in which certain gases such as carbon dioxide, methane, and water vapor in the Earth's atmosphere trap heat from the sun, allow the sun's energy to pass through the Earth's atmosphere, reflected back from the surface of the Earth. This trapped heat warms the surface of the Earth and the lower atmosphere, helping to keep the planet at a temperature that is suitable for life. (Julie E. Doll et al 2011). Human activities such as improper waste disposal into landfilled, deforestation and incineration are now increasing the amount of greenhouse gases in the atmosphere, which leads to extreme climate changes, more frequent and severe heat waves, droughts, and storms, as well as rising sea levels due to the melting of polar ice caps. Hence, these changes are affecting many aspect of human life (Wiedinmyer et al 2014). From wastes and waste management activities, such as thermal treatment, landfill, incineration, mechanical biological treatment, transportation means and no treatment at all releases huge amount of harmful gas into the atmosphere (Darkwah et al 2018).
- (ii) Pollution: Environmental pollution from waste is a very common practice ranging from individual, small scale businesses and big industries. Improper waste disposal, pollute the air, water and land. This pollution from waste and it inadequate treatment give rise to environmental and health hazard such as erosion, bad air quality, contamination and diseases. For example, in a report by the First Nations of Quebec and Labrador Sustainable Development Institute (2008 ed. Daniel Dicke) Yearly, about 24,000 metric tons of plastic end up in the ocean; improper waste disposal into the sea often result into sea living creatures strangled, infested, suffocated or have their intestines blocked by plastic bags. In 2018, Global plastic production was 359 million tonnes and it expected to double by 2050, with about 8 million tonnes of it ending up in the oceans (UNEP 2021). Moreover, there is a toxic pollutant known as leachate that can escape into the surrounding groundwater causing environmental problems for plants and animals living downstream, if a landfill site is not properly sealed. Leachate is a liquid pollutant that is produced when wastes start to break down and it contains high levels of heavy metals, chemical compounds, pesticides and solvents which filter down into the bottom of a landfill site (Jr Richards 2013). The foul smell pollutes the air and can cause respiratory issues for the inhabitants. More also, when waste is buried, it lacks oxygen, thus it decomposes and biogas is formed. Biogas can spread to the nearby basements of building and when in contact with a flame or ignition, it can explode, causing destruction to life and properties and more polluting chemical is release into the atmosphere. When Waste decomposes, its volume decreases, and this causes sagging in the occupied area, so that in these places, buildings or other facilities cannot be erected (SubhasishDas et al 2019)
- (iii) Loss of Biodiversity: Biodiversity, from the word "Bio" which means life and "diversity" means variety, Biodiversity is the variability of living thing or different forms of life on earth, including the different plants, animals, micro-organisms, their innate genes and the ecosystem they form. It can also refer to variation in genetics and ecosystem, variation of species within an area (Rawat et.al



2015). Sadly, these variations are going into extinction due to humans selfish activities. Waste plays a key role in the loss of Biodiversity of our ecosystem. According to the research done by the Montreal Secretariat of the Convention on Biological Diversity (2012) it states that pressures on biodiversity can be traced to increases in population, economic activity, consumption increase, production patterns and huge amount of wastes that inevitably result from it. Waste management pressures such as the demand for new landfill sites results alterations to the natural environment by clearing of large amounts of vegetation and killing the living organism in the area. Over time, this practice of land clearing can result in the displacement of plant and animals or something worse - extinction of many of these species, and a significant loss of biodiversity. According to the Worldwide Home Environmentalists' Network (2012), 120,000 pieces of plastic of all sizes float on each km<sup>2</sup> of the oceans. Turtles, dolphins and whales are tricked into thinking plastic bags floating in the ocean with jellyfish. When they swallow bags, these animals can choke and die since the plastic blocks their digestive system. According to press release by United Nations Environment Programme in the Minamata Convention (2021), Pollution from wastes impacts biodiversity of our world in many obvious and continuous ways. Effects ranging from the choking of life in our rivers and oceans by plastic waste or pesticides, to neurotoxicity and endocrine disruption in humans and wildlife caused by the accumulation of industrial chemicals wastes, consistence leakage of harmful chemical into the soil, hereby poisoning our soils and living organisms in them, wastes through dumping or open burning of waste, unsound management of waste places a burden on biodiversity across the globe. Furthermore, in the developing world and in the world poorest countries, very few landfill or other waste management that meets environmental standard are visible, and with limited budgets and resources, it is unlikely that waste management sites are thoroughly evaluated prior to use in the quest to protect the biodiversity in the area.

### **2.3 Defining Waste Management**

Waste management can be simply put as a form of systematic administration of activities that make provisions for the collection, source separation, storage, transportation, transfer, processing, treatment and disposal of solid waste. (Vongdala et al 2019) Waste management refers to the collection, transport, processing, recycling or disposal of waste materials. The goal of waste management is to reduce the amount of waste produced and to minimize the negative impacts of waste on the environment and human health. There are several ways to manage waste; including recycling, composting, and incineration (Bacinski et al 2010) Landfills are also used to store waste, although this is generally considered to be the least desirable option due to the potential for environmental damage. Proper waste management is important for protecting the environment and public health, and it can also have economic benefits by reducing the costs associated with waste disposal and creating new products from recycled materials (Achillas et al 2013).

#### **2.3.1 Different methods of Waste management in developed and developing countries**

Due to the obvious environmental impact of all types of waste, many countries put as much effort as they possibly can to control, reduce and mitigate these impacts. Some of the most common waste management methods are briefly discussed below:

- (i) Incineration: Waste incineration involves burning waste at high temperatures for an extended period, resulting in a significant reduction in waste volume and the effective elimination of harmful biological organisms. Concerns about incineration mainly revolve around the by-products released into the atmosphere during the combustion process. By incinerating waste with energy recovery, it is possible to reduce the amount of disposed waste by up to 90%. However, such high volume reductions are only achievable when the waste contains substantial amounts of packaging materials, paper, cardboard, plastics, and horticultural waste. It is generally considered preferable to recover the energy value from waste before disposing of it in landfills, as long as pollution control measures and costs are adequately addressed. Incineration without energy recovery, or the need to constantly add fuel (non-autogenic combustion), is not a favored option due to its high costs and pollution. Open burning of waste, particularly at low temperatures, is strongly discouraged due to the severe air pollution it causes. In Africa and Latin America, more than 90% of the waste collected falls into this category.
- (ii) Bioremediation: This is a process that uses microorganisms, such as bacteria and fungi, to remove or neutralize pollutants from the environment. These microorganisms can break down or transform harmful substances into less toxic forms, making them less hazardous to human health and the environment. Bioremediation can be applied to a variety of different types of pollution, including oil spills, chemical contamination, and agricultural waste (Saini, S., & Dhanial, G. 2020).



- (iii) Landfill: Is the practice of disposing of solid waste materials by placing them in a designated area, or "landfill," and covering them with soil. This method is commonly used for disposing of household and commercial waste, construction debris, and other types of solid waste. The materials in a landfill are typically compacted and then covered with soil, clay, or other materials to prevent the release of pollutants and odors, and to deter scavengers (Ahmad et al, 2018). Landfills are typically lined with materials such as plastic to prevent pollutants from leaching into groundwater and surrounding soil. Landfills are a common final disposal site for waste and should be engineered and operated to protect the environment and public health (USEPA 2014). Proper landfilling is often lacking, especially in developing countries. Landfilling usually progresses from open-dumping, controlled dumping, controlled landfilling, to sanitary landfilling. Landfills continue to emit air pollution for many years after the last waste is deposited (United State Environmental Protection Agency USEPA, 2012)
- (iv) Waste-to-energy (WtE): Waste-to-energy (WtE) encompasses a diverse set of methods for processing waste into valuable resources such as electricity, heat, fuel, or other usable substances. It also involves handling various byproducts such as fly ash, sludge, slag, boiler ash, wastewater, and emissions, including greenhouse gases. (Vijayalakshmi 2020). Based on its energy conversion processes of MSW, technologies such as pyrolysis, gasification, incineration, and bio-methanation. Waste-to-energy (WtE) can be categorized into four main types: thermal, mechanical and thermal, thermo-chemical, and biochemical. In terms of waste management hierarchy, it can also be classified as disposal, other forms of recovery, or recycling operations, based on the energy products generated and the level of recovery achieved. UNEP (2019).
- (v) Waste collection: Many countries boast of an effective waste collection as the best way of managing municipal solid waste. This process involves the collection of solid waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal. Municipal solid waste is collected in several ways as proposed by Carlos-Alberola et al (2021):
- House-to-House: Garbage is collected by waste collectors who go from house to house. Typically, the user is charged for this service.
  - Community Bins: People use community bins, which are positioned at set locations around a neighborhood or town, to dispose of their trash. According to a predetermined timetable, MSW is picked up by the municipality or a Curbside.
  - Pick-Up: In accordance with a rubbish pick-up schedule arranged with the local authorities, users leave their trash outside of their homes representative of it
  - Self-Delivered: Generators either transport their own garbage to disposal facilities or transfer stations, or they contract with outside operators to do so (or the municipality).
  - Contracted or Delegated Service: Organizations contract other waste organizations to coordinate collection schedules and fees on their behalf.
- (vi) Open dumping: is the practice of disposing of solid waste materials by simply leaving them in an open area, rather than placing them in a designated landfill. This method of disposal is often used in areas where there is limited infrastructure for waste management or where proper disposal facilities do not exist (Ukpong and Agunwamba (2011). The waste materials are typically not covered or compacted in any way, and are left to accumulate over time. Open dumping poses a serious environmental and public health hazard, as the waste can contaminate air and water, attract pests, and create unpleasant odors. Additionally, open dump sites can create hazards for people who live or work near them, such as the risk of injury from sharp objects and the presence of dangerous chemicals or pathogens in the waste (Srigirisetty et al., 2017) it is obvious that many hazardous wastes and other wastes are not being managed in an environmentally friendly way. Open dumping is the most popular technique of hazardous waste disposal in developing countries. Toxic wastes, including e-waste, build up in these dumps. Roughly 33% of the solid waste produced worldwide is dumped in open landfills. Around 64 million people's daily lives are impacted by 48 of the world's 50 largest active dumpsites, which are located in developing nations and constitute a major threat to the environment and human health (Biro et al. 2013)
- (vii) Open burning: This a practice done by gathering and piling all type of waste together and burning them in an open place or dump site. This practice is common in many low-income and developing countries and releases large amounts of hazardous substances to the environment, making open burning a major global source of some hazardous substances such as dioxins and furans and mercury. The impact of fire on soil has been examined in certain literatures. For instance, Guenon et al. (2013) and Leon et al. (2014) studied and demonstrated that fire alters the quality of soil. The chemical and biological makeup

of the soil can change in a hot environment. For example, in a research carried out by David and Olatunji (2018) in Ogun state Nigeria, They reported that almost all of cassava processors (90.5%) dump their cassava waste at a dump site, 4.2% of respondents burn cassava solid waste generated near the factory, that practice becomes the main source of environmental pollution. Moreover, 97.3% of those who use cassava residue use it for animal feed or give it to those who use it for animal feed. However, Just 1.6% of those who use cassava residue do so as fertilizer. This is a peculiar way of handling most types of waste by individual and small scale businesses that endangered the environment and human health.

- (viii) A mechanical-biological treatment MBT: is a type of waste treatment process that combines mechanical processes such as sorting and size reduction with biological processes such as composting and anaerobic digestion to reduce the volume and toxicity of municipal solid waste (MSW). It is a form of transition from generic waste disposal to resource management of residual waste from other waste management strategies like recovery and recycles. An MBT's goal is to recover valuable resources from the waste stream, such as recyclable materials and biogas, and to reduce the amount of waste that must be landfilled (Velis et al 2010)

### 3 The 3Rs of waste Management

The 3Rs is a hierarchy of waste management and they stand for reduce, reuse, and recycle. These are the most preferred and three key principles of waste management that aim to minimize the amount of waste that is produced and to make better use of the resources that are contained in waste materials. Consistently incorporating this methodology into MSW waste reduction and recycling efforts will minimize landfill waste and a major strategy in reducing greenhouse gas emission (Wahied et al 2022) The waste refers to the "3 Rs" classifies waste management strategies according to their desirability in terms of zero waste goal or at least a significant minimization of it as shown(FIG 2) by the chart drawn by United Nation Center for Regional Development (UNCRD

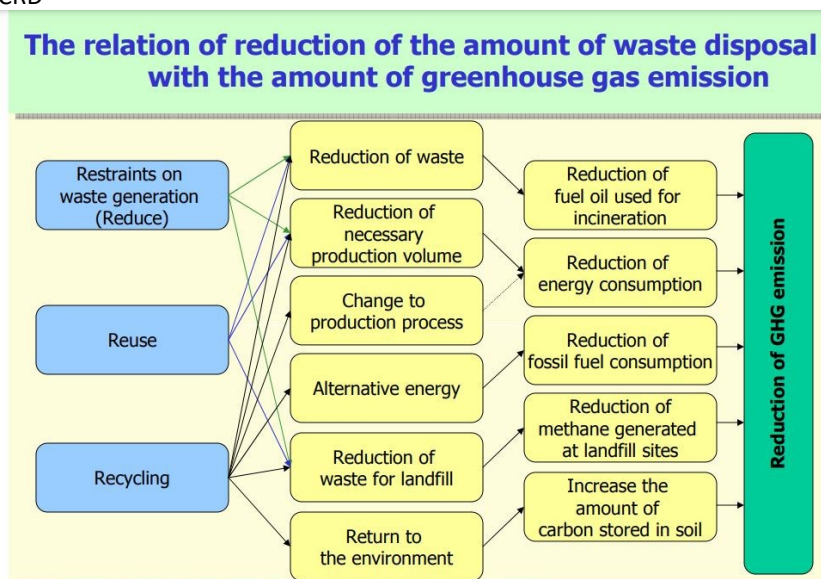


Fig 2: If the 3Rs of waste management are properly applied, the main threat (GHG emission) to our environment from improper waste disposal can be significantly reduced (Source: UNCRD 2017).

In addition, Dijkema et al (2000) advises that: the all waste management infrastructure must not be treated independently from the system that creates the waste. Rather from the start, the two must be fused in the concept of material cycles so as to effectively achieve the goal of zero waste. The 3Rs hierarchy of waste management briefly discussed below is an upstream strategy to reduce the environmental and economic impacts of waste, and conserve resources.

- (i) Reduce: Simply means to avoid waste because the efficient way to avoid waste is to avoid creating it in the first place. Reduce in the 3Rs also means to use less, whether that means to use fewer resources in the first place or to use them more efficiently (Fahzy 2014). This can include things like using reusable shopping bags instead of disposable ones, turning off lights when leaving a room, and repairing rather than replacing items. Waste source reduction initiatives (including prevention, reducing, and reuse) aim to reduce waste at its source by redesigning products or changing production and consumption patterns (Adedipe et. al, 2005). Reduced waste generation

has two main benefits in terms of lowering GHG. First, the emissions accompanied with material and product manufacture is avoided. The second is eliminating the emissions associated with the avoided waste management activities (Daniel, 2003)

- (ii) Reuse: Re-use means any system of operation by which object or components that are not waste are used again for the same purpose for which they were conceived and produced for. Reuse in waste management can also refer to recovery activities, which examine, clean, or repair products or parts of products that have become waste so they can be reused without further preprocessing (Ismail and Lino, 2012. Many countries have established reuse centers have. By repairing the products and selling them for a reasonable price, these facilities hope to end the short product-to-waste cycle. People who have trouble entering the labor market or are experiencing long-term unemployment can use the reuse centers to help them find jobs. Company clusters have been created in Japan and other industrialized nations, where the perceived waste of one industry is the useful resource of another (N.O. Adedipe et al, 2005) However, Reuse after a recovery operation should be distinguished from reuse as a waste prevention operation the difference between the two is that the former is an activity that does not involve waste, whilst the latter is an activity that does. A milk bottle is a nice illustration of packaging in this context. In another case, the item is discarded but is later recovered in some manner, allowing it to be used for the original intent once more.
- (iii) Recycle: The popular meaning of 'recycling' in most developed countries refers to the extensive collection and repurpose of everyday waste materials such as empty beverage containers (Jasem, 2005). The recycling process are usually in this chain; Collection – Sorting – Cleaning - Crushing or Grinding - Melting and forming - Reprocessing into a new product. Word bank (2009) defines recycle Recovery operations involve the reprocessing of waste materials into products, materials, or substances, whether for their original purpose or for other uses. This encompasses the reprocessing of organic materials as well. Hoornweg et al (2005) states that recycling can only ever be carried out on substances or objects that are classified as waste and the main advantages of recycling and recovery are: reduced quantities of disposed waste and the return of materials into the economy. In many developing countries, individual waste pickers informally pick and sort at municipal collection points and disposal sites to recover a significant portion of discarded objects. No doubt, recycling generates revenue, creates jobs and protects the eco-system.

#### **4 Specific application of the 3Rs to MSW in developing countries – Answering the “W. H” Questions**

Attention should be paid in developing and transition countries, where the unsustainable management of MSW is common with no visible hope slowing down the health and environmental impact. The goals with the proposed 3Rs are: to incentivize producers to modify the design of their products and leverage manufacturers' expertise in managing products once they reach the end of their life cycle. Additionally, it involves devising methods for gradually transitioning the responsibility and associated costs of managing used products from municipalities to manufacturers. To give needed training and involve households and individual on how to rip the benefits of achieving zero waste in their own little way. Studies conducted in many developing countries shows that many citizens and organizations are willing to apply the 3Rs but do not know how.

Thus, as the novelty of this research states, the new spin is proposing environmental and requiring little or no budget ways to manage waste. To specifically and directly point out what do with some major items, object or substances that are commonly and uncontrollably used improperly disposed in developing countries, causing environmental and health hazard in an unprecedented way.

##### **4.1 What and How to Reduce MSW**

Waste production must be reduced at the source, a prevention-based approach. This means reducing the quantity of waste during production, distribution, purchasing, use and elimination. Practical examples on how to do that in an upstream way include:

- Product redesign and packaging optimization to reduce materials and toxicity
- Implementing responsibility policies, where producers are held responsible for the waste generated by their products
- Implementing green policies in all organizations
- “implementing producer take-back schemes, where manufacturers take back used products for recycling or proper disposal”
- Promote clean and sustainable Production

These are some of the specific items causing huge environmental impact in developing countries that needs to be reduced.

Cell phones: it is of a common knowledge that when a new cell phone is introduced to the market, the older one becomes obsolete and often lies around until it discarded as part of MSW (Umair et al., 2015). Studies shows that 35–40% hazardous metallic elements are present in an average size phone, a single battery of a mobile phone can spoil 600,000L of water (Wu et al., 2008) In developing countries it an acute case due to lack of legislation, illegal markets, used phone markets and lack of processing technologies makes mobile phone waste management process more critical in developing countries (Vyshnavi and Gayani 2016) on how to apply the first R (reduce) on cell phone in developing countries is to always trade in, donate, or recycle your old phones. The local, state and federal government should effectively create or work with E-waste management group in other to reduce the amount of cell phones produced, imported, and discarded.

Plastic bags: Plastic bags are made primarily of petroleum and is estimated that 12 million barrels of petroleum are required to make 100 billion plastic bags. A plastic bag takes 200-450 years to decompose. Apparently, fossil fuel contain in just nine plastic bags can make a car run for a kilometer. Plastic bags are among the 10 most frequently found items on beaches; Plastic bags blocked the sewer system in many developing countries and caused major flooding. Each year, over one million sea birds, 100,000 marine mammals, and an immeasurable quantity of fish experience poisoning, entanglement, infestation, suffocation, or intestinal blockage caused by plastic bags. (Moore, 2012) In addition, buying local or home-made products can reduce waste generated because, local product usually have less packaging and besides helping the local economy, it also means we can reduce negative impact of environmental pollution from transportation and less things to dispose.

#### **4.3 What and How to Reuse**

1. Reuse shopping bags: Keep a few reusable shopping bags in your car or purse so you always have them with you when you go to the store.
2. Use old t-shirts as cleaning cloths: Cut up old t-shirts into small squares and use them as cleaning cloths around the house.
3. Reuse empty glass jars and bottles as containers for storing food, liquids, or other household items.
4. Old newspapers can be reuse as packing material: when moving or shipping
5. Use old containers for storage: Wash out old food containers and use them to store dry goods or other items.
6. Turn old clothes into rags: Cut up old clothes into small squares and use them as rags for cleaning or as dust cloths.
7. Reuse gift wrapping: Save gift bags, wrapping paper, and bows to use again next year
8. Donate items you no longer need: Instead of throwing away items that you no longer need or use, consider donating them to a thrift store or other charitable organization.

#### **4.4 What can be Recycled and How**

Many everyday items can be recycled, including paper, plastic, and glass.

Agricultural wastes are very common in developing countries and they can be recycled:

There are several ways to recycle agricultural waste, including:

1. Composting: Organic waste such as crop residues, animal manure, and green waste can be composted to produce a nutrient-rich soil through it use as fertilizer.
2. Anaerobic digestion: Organic waste can be broken down by microorganisms in the absence of oxygen to produce biogas, which can be used as a fuel source.
3. Incineration: Agricultural waste can be burned to generate energy.
4. Pelletizing: Agricultural waste such as straw, corn stover, and sugarcane bagasse can be made into pellets and used as a fuel source.
5. Livestock bedding: Agricultural waste such as straw can be used as bedding for livestock, helping to keep them clean and comfortable.
6. Industrial raw material: Agricultural waste can be used to produce raw materials for industry, such as paper and packaging, textiles, biofuels, and chemicals.
7. Biorefining: converting agricultural waste into useful products like biofuels, bioplastics, and chemical.

Household wastes:

Household waste can be recycled in several ways, including:

1. Curbside recycling: Many cities and towns offer curbside recycling services where residents can place recyclable materials such as paper, cardboard, glass, plastic, and metal in designated bins for collection.

2. Drop-off recycling centers: There may be recycling centers located in your community where you can drop off recyclable materials such as electronics, hazardous waste, batteries, and certain plastics.
3. Composting: Organic waste such as food scraps and yard waste can be composted to create a nutrient-rich soil amendment for gardening.
4. Reuse: Many items can be reused, such as clothes, furniture, appliances and more, by donating them to charity organizations or second-hand stores
5. E-waste: Electronic waste should be recycled through special program, as it often contains hazardous materials, it should not be mixed with regular waste or it might harm the environment. Government or organization can come up with a pick-up program where used or intended to be disposed mobile phone waste is collected at homes or offices with a little incentive.
6. Glass items: A form of glass-to-glass recycling process is done by crushing and melting the glass, it is then reshaped and cooled to make new glass products. Another way to recycle glass is by Cullet usage: which is crushed glass that can be used in the manufacturing of new glass products, as it then reduces the amount of raw materials needed, as well as energy consumption during the manufacturing process.

## 5 Conclusion and recommendation

The problem of waste management in developing countries is compounded by rapid urbanization, dumping of used items by the developed world into developing countries, lack of awareness and orientation, corruption and lack of resources/finance. Regardless, this research have been able to shield more light on the current situation and bad impact of uncontrolled waste disposal in developing countries and proposed and alternative and sustainable approach to gradually achieve a good measure waste reduction. The 3Rs principle of Reduce, Reuse and Recycle is a holistic approach that can easily be applied by every individual and to everyday items we use that can generate waste.

However, there is a need for environmental education, which is crucial since it teaches both young and adult valuable lessons about waste management through the application of the 3Rs, which encourage ethical and sustainable environmental practices. And spread awareness of the advantages of trash reduction, reuse, and recycling throughout the entire community.

Along with increasing our awareness and caution in all of our acts, we should also work to incorporate recycling, reducing, and reusing techniques into our daily lives and routines so that they become the standard rather than an option.

By offering financial incentives to homeowners that can boost participation and recycling rates and by promoting the idea that people pay less if they recycle, local governments should do more to encourage the implementation of the 3R principle by establishing Drop-off programs for collection through the use of containers on street and organizing waste management events and rallies.

In retrospect, every individual, organizations and industries can contribute to the sustainable development goal of achieving zero waste and save the planet by answering the What and How questions as regards daily activities and practically applying the 3Rs waste prevention strategy.

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