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A Discussion on Waste Generation and Management Trends in South Africa

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***Abstract*—**This paper, a continuation and expansion of the work of Muzenda et al, 2012 [1] looks at the management trends in South Africa. It focuses on waste classification, hierarchy, generation and management. The waste tyre problem in South Africa is also briefly discussed. Solid waste management is a growing environmental problem in developing countries such as South Africa. The increasing standard of living and economic growth results in challenges in the management of both general and hazardous waste. Landfill sites life spans have been reduced and hence the need for waste minimization, utilization and alternative disposal methods. Waste tyre management is challenge as they are non compactable and non-biodegradable. The REDISA Integrated Industry Waste Tyre Management Plan (IIWTMP) approved by Environmental Affairs Minister, Edna Molewa, and published in the Government Gazette [No. 35927] in November 2012 support and promote tyre recycling, providing the collection and depot infrastructure required to collect waste tyres from across the entire country and deliver them to approved recyclers. The objectives of this paper were achieved through a literature review and analysis.

***Keywords*—**Environmental, Recycling, REDISA, Waste Hierarchy, Waste Management

I. Introduction

IN generic terms, waste can be defined as "an unavoidable by-product of most human activity". Economic development and rising living standards have increased in the quantity and complexity of generated waste. Moreover, industrial diversification and the provision of expanded health-care facilities have added substantial quantities of industrial hazardous waste and biomedical waste into the waste stream with potentially severe environmental and human health consequences. There are two fundamental waste classes, namely, general waste (municipal waste) and hazardous waste (health care risk waste and certain industrial waste). Waste tyres fall under the general waste category which gives rise to land filling, health and environmental challenges. Waste tyres can be characterised as polymers which are non-biodegradable because of their complex mixture consisting of several rubbers, carbon black, steel cord and other organic and inorganic components.

In South Africa, it is estimated that around 60 million legacy waste tyres are lying in dumps and stockpiles or scattered across the country in residential, industrial and rural areas. In addition, almost 11 million waste tyres are added to this number every year. The disposal of waste tyres is a growing environmental problem for the modern society, especially in developing countries. The major concerns are (i) tyre stockpiles provide breeding ground for mosquitoes and vermin, this in turn, causes serious diseases, thus affecting human health, (ii) fire hazards in large stockpiles that could consequently cause uncontrollable burning and air pollution, (iii) the current ''conservation of natural resource concept'', precisely, the reuse (retread) first, then reuse of rubber prior disposal, does not accommodate the ever increasing dumping of tyres, (iv) due to the high cost of legal disposal for tyres, illegal dumping may increase, (v) disposal of tyres is becoming more expensive, while this trend is likely to continue as landfill space becomes more scarce. Tyres require large quantities of air space because their volume and non compactability [2]. Through the REDISA Waste Tyre Management Plan, tyres will now be recycled into useful products instead of polluting the environment. Different recycling processes are being practiced such as reclaiming, incineration, retreading, grinding etc. but these have weaknesses and drawbacks [3].

II. Classification of Waste

A. Waste Classes

Waste classification systems are vastly documented in South Africa; these include waste regulations and laws such as the minimum requirements for the handling, classification and disposal of general and hazardous waste [4] as well as the waste classification and management regulations, which is in accordance with the Waste Act (Act No. 59, 2008) [5]. Some of the laws that have been amended on this act include, Act No. 73 of 1989 (Environmental Conservation Act, 1989) whereby certain sections have been amended or repealed as well as the repulsion of sections 8 and 9 of the environmental conservation amendment Act, 1992 (Act No. 79 of 1992).

The waste classification system is based on the concept of risk [4]. It is accepted that there is no waste that is truly "non-hazardous", since nothing is entirely safe or ideally non-hazardous. No matter how remote the risk posed to man and the environment by a particular waste, it nonetheless exists. However, it is possible to assess the severity of the risk, and to make informed decisions on that basis. The classification system therefore distinguishes between waste of extreme

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hazard, which requires the utmost precaution during disposal, and waste of limited risk, requiring less attention during disposal. Thus waste is divided into two main classes, namely general and hazardous waste, which are further sub classified into smaller categories. General waste is sub classified into domestic, industrial and institutional waste, while hazardous waste class is further classified into explosives, flammable liquids and solids as well as corrosives. The waste classification system is in accordance with the risk waste poses, hence, general waste poses little risk to the environment while hazardous waste poses significant risk. For waste to be properly managed, its properties and its risk potential must be fully understood.

- *General Waste*

General waste does not pose a significant threat to public health or the environment if properly managed [4]. Examples would include domestic, commercial, certain industrial wastes and builder's rubble. General waste may be disposed of at any duly authorized waste disposal facility permitted in terms of the Environment Conservation Act (73 of 1989). Domestic waste is classified as general waste even though it may contain hazardous components. This is because the quantities and qualities of hazardous substances in domestic waste are sufficiently minor to be a potential risk. In addition, the Minimum Requirements for Waste Disposal by Landfill require leachate control at certain general waste disposal sites.

TABLE 1
SOURCES AND TYPES OF GENERAL WASTE

Source	Typical waste generator	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. bulky items, consumer electronics, batteries oil, tyres) and house hold hazardous wastes
Industrial	Light and heavy manufacturing, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Industrial	Stores, hotels, restaurants, markets	Paper, cardboard, plastics, wood, food wastes, glass, special wastes, metals, hazardous wastes
Institutional	Schools, hospitals, prisons, government centres	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.

- *Hazardous Waste*

Hazardous waste is defined as waste that has the potential, even in low concentrations, to have a significant adverse effect on public health and the environment because of its inherent toxicological, chemical and physical characteristics [4]. Hazardous waste requires stringent control and management, to prevent harm or damage and hence liabilities. It may only be disposed of on hazardous waste landfills (Section 3, *Minimum Requirements for Waste Disposal by Landfill*) [4] Hazardous waste can further be classified by its hazardous rating which simply differentiates between a hazardous waste that is moderately hazardous and one that is extremely hazardous. The 9 sub classes of hazardous waste as listed in Table II are classified and treated under the South African Bureau of Standards (SABS) Code 0228, namely, the identification and classification of dangerous goods and substances. Applying the precautionary principle, waste must always be regarded as hazardous where there is any doubt about the potential danger of the waste stream to human beings or the environment. Waste management in South Africa is regulated by legislation such as the National Environmental Management Act, 1998 (Act 107 of 1998), Environment Conservation Act (Act 73 of 1989) Section 20, National Water Act (Act 36 of 1998), Health Act (Act 63 of 1977), Air Quality Act (Act 39 of 2004), Hazardous Substances Act (Act 15 of 1973), Nuclear Energy Act (Act 131 of 1993) Section 45 & 46 Authority, Medicines and Related Substances Act, 1965 (Act 101 of 1965) Section 27, and the Occupational Health and Safety Act (Act 85 of 1993).

The definition and regulation of waste has been redefined and amended over the past years in South Africa. However, the Environmental Conservation Act (ECA) was the first piece of legislation formally regulating waste management in South Africa. The ECA came into operation on the 9th of June 1989 and underwent many amendments, and it was later repealed in its entirety, save for a few provisions by National Environmental Management Waste Act (NEMWA) [6] The significant changes that were made in the ECA which are now catered for by the NEMWA, 1998 (Act No. 107 of 1998) where the redefining and addition of important terms, the provision for temporary waste storage and other waste related aspects that came into effect after 1997 are included. Many large industries in South Africa dispose of industrial waste on-site, but since this hazardous waste does not enter the formal waste stream, there is also often little reported data available [7].

TABLE II
HAZARDOUS WASTE SUB CLASSES

Class No.	Class type
Class 1	Explosives
Class 2	Gases
Class 3	Flammable liquids
Class 4	Flammable solids
Class 5	Oxidising substances and organic peroxides
Class 6	Toxic and infectious substances
Class 7	Radioactive substances
Class 8	Corrosives
Class 9	Other miscellaneous substances.

This regulatory system includes:

- The issuing of waste disposal site permits.
- A manifest system for the transportation of hazardous waste.
- The registration of hazardous waste generators and transporters.

The aim is to protect the environment (Environment is used in the holistic sense and includes cultural, social, soil, biotic, atmospheric, surface and ground water aspect) and the public from the harmful effects of unsafe waste disposal practices. Before a waste disposal site permit is issued, minimum procedures, actions and information is required from the permit applicant. These are termed "Minimum Requirements". The minimum requirements provide the applicable waste management standards or specifications that must be met in the absence of any valid motivation to the contrary. They also provide a point of departure against which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices.

The objectives of setting minimum requirements are to [4]:

- Prevent water pollution and ensure sustained fitness for use of South Africa's water resources.
- Attain and maintain minimum waste management standards in South Africa, so as to protect human health and the environment from possible harmful effects caused by the handling, treatment, storage and disposal of waste.
- Effectively administer and provide a systematic and nationally uniform approach to the waste disposal process.
- Endeavour to make South African waste management practices internationally acceptable.

III. The General Waste Hierarchy

The conceptual approach to waste management is underpinned in the waste hierarchy, which was introduced into South African waste management policy through the White Paper on Integrated Pollution and Waste Management [7]. It was a hallmark of the 1999 National Waste Management Strategy (NWMS) [4], as represented in Fig. 1, with Fig. 2 representing the amended 2011 waste hierarchy. The essence of the approach is to group waste management measures across the entire value chain in a series of steps, which are applied in descending order of priority. The foundation of the hierarchy, and the first choice of the measures in the management of waste, is waste avoidance and reduction. Where waste cannot be avoided, it should be recovered, reused, recycled and treated. Waste should only be disposed of as a last resort.

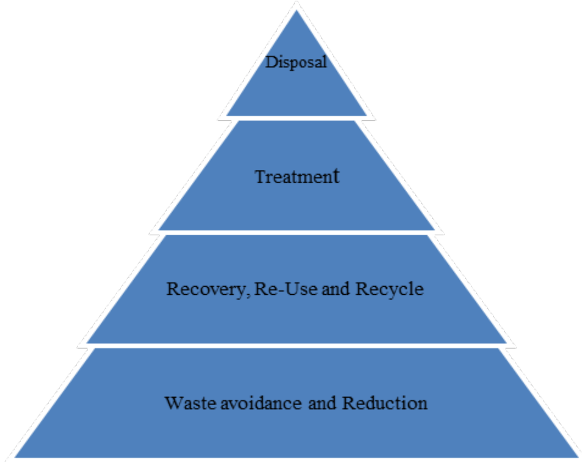

Fig. 1 Waste Hierarchy, NWMS 1999 [4].

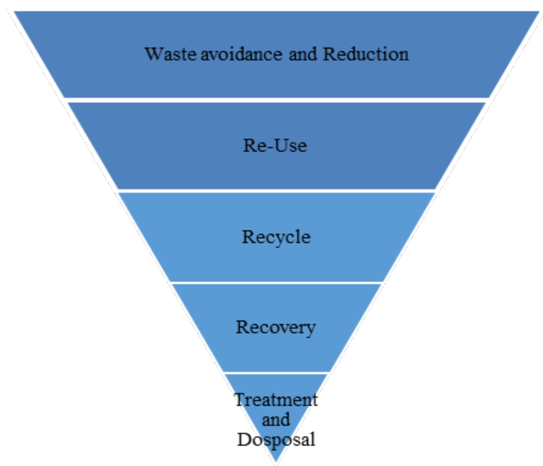

Fig. 2 Waste Hierarchy, NWMS 2010 [4].

The Waste Act provides the legal mandate for the successful implementation of the waste hierarchy, through the provision of additional measures for the remediation of contaminated land to protect human health and secure the wellbeing of the environment. Implementation of the waste hierarchy promotes extended producer responsibility with respect to the design, composition or production of a product and packaging. These requirements include clean product measures, the composition and volume of packaging to be restricted as well as the responsibility of the producer to ensure that packaging be designed in such a way that it can be reduced, re-used, recycled or recovered, thus giving effect to the concept of ‘cradle-to-cradle’ waste management. This is an important advance from the previous “cradle to grave” approach, which mainly took into account producer responsibility for the entire lifecycle of a product until its final disposal. Cradle to cradle management ensures that once a product reaches the end of its life span, its component parts are recovered, reused or recycled, thereby becoming inputs for new products and materials and this cycle repeats itself until the least possible portion of the original product is eventually disposed as shown in Fig. 3

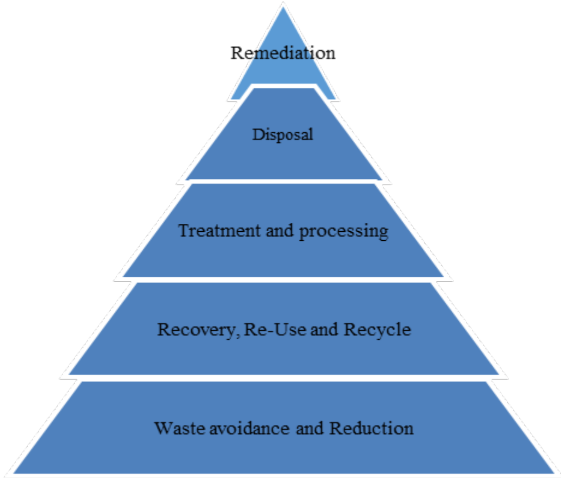

Fig. 3 Waste Hierarchy, 2010 [4].

A. Waste Avoidance and Reduction

Waste avoidance and reduction is the foundation of the waste hierarchy and is the most preferred waste management option. The aim of waste avoidance and reduction is to achieve waste minimization and thus reducing the amount of waste entering the waste stream. This is particularly relevant for waste streams where recycling, recovery, treatment or disposal of the waste is problematic. While waste minimization is difficult to quantify, available figures indicate that waste generation across all provinces has been on a rise per kilogram per year, as supported by the 2011 figures and prior, given in Fig. 4 and Table III [6]. Waste minimisation occurs largely as a result of competitive pressures, economic incentives, and through producer responsibility initiatives implemented by industries. To date the most notable of the national government initiatives with respect to waste minimization has been the plastic bag levy initiative. The agreement came into effect on the 9th of May 2003, accompanied by a standardization of the following bag sizes 8-litres, 12-litres and 24-litres, with the 24-litres dominating retail markets [8]. Knowler [9] reported that plastic bag consumption significantly dropped from 90% to 70%, the fee was first introduced at a rate of 46 cent per bag in 2003. However, due to pressure from plastic bag manufacturing industries the rate has decreased by 44% in 2005[10]. A survey carried out by one of the major retail supermarkets reported that, due to the lower price of plastic bags, majority of people tend to not reuse the plastic bags for shopping purposes as was intended by the acts. Consumers might also perceive the carrying of plastic bags for shopping as an inconvenience, leading to the absorption of the price of plastic bags into consumer’s grocery list because of their low price. Nevertheless, the plastic bag levy has slightly decreased the consumption of plastic bags in South Africa. This is a tax instrument being used to effect change in behavior at both consumer and industry level. Furthermore, there is also a proposed levy for the management of end of life tyres entering the waste stream.

B. Recovery, Re-use and Recycling

Recovery, re-use and recycling make the second step in the waste hierarchy. These are very different physical processes, but have the same aim of reclaiming material from the waste stream and reducing the volume of waste generated that moves up the waste hierarchy. Recycling rates in South Africa are relatively well established (shown by Fig 2.4 and 2.5). These are primarily driven by industry-led, voluntary initiatives with funds managed independently of government via non-profit organizations, which oversee the recovery or recycling processes and facilities.

C. Treatment and Disposal

Section 2 (a) (iv) of the Waste Act clearly indicates that the treatment and disposal of waste is a “last resort” within the hierarchy of waste management measures. In terms of waste treatment and processing, the Department of Environmental Affairs (DEA) supports the development of alternatives to land filling such as incineration, gasification, and pyrolysis [11] of general waste and waste tyres. While there are cost implications for the adaptation of the incineration process as a waste processing technology, the option requires attention considering the rising costs of landfilling. It is anticipated that appropriate incineration, gasification and pyrolysis facilities as well as other alternative technologies will increase over time and ultimately replacing landfills as the primary waste disposal mechanism [11].

D. Remediation

Remediation is the final step in the waste hierarchy. There is a lack of data on the number and extent of contaminated sites (which include un- managed waste dumps) in South Africa due to the various mining activities in the country plus the historical under-regulation of such areas.

TABLE III
PROVINCIAL WASTE GENERATION IN SOUTH AFRICA [6]

Province	Kg/capital / Annum	Waste generated as % of total waste
Western Cape	675	20
Eastern Cape	113	4
Northern Cape	547	3
Free State	199	3
KwaZulu Natal	158	9
North West	68	1
Gauteng	761	45
Mpumalanga	518	10
Limpopo	103	3

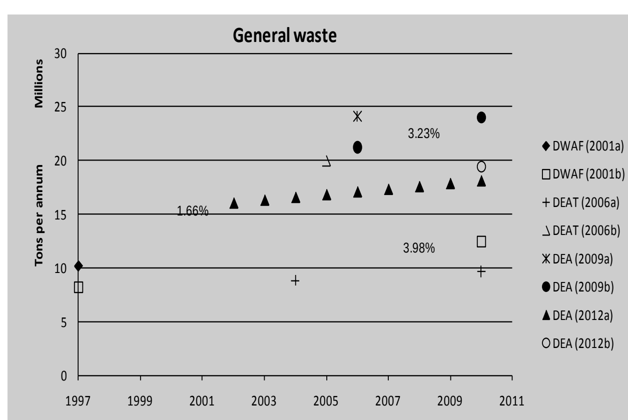

Fig. 4 Municipal general waste data in South Africa [7].

IV. Waste Generation

Over 42 million cubic metres of general waste is generated every year in South Africa, with Gauteng Province contributing 42% [8]. In addition, more than 5 million cubic metres of hazardous waste is produced yearly, mostly in Mpumalanga and KwaZulu-Natal. This is a result of the concentration of mining activities and fertilizer production in the two provinces. The average amount of waste generated per person per day in South Africa is 0.9 kg [9]. This is closer to the average waste produced in developed countries (0.73 kg in the UK and 0.87 kg in Singapore), compared to the average in developing countries such as 0.3 kg in Nepal [18]. By far the biggest contributor to the solid waste stream is mining waste (72.3%), followed by pulverized fuel ash (6.7%), agricultural waste (6.1%), urban waste (4.5%) and sewage sludge (3.6%) [10].

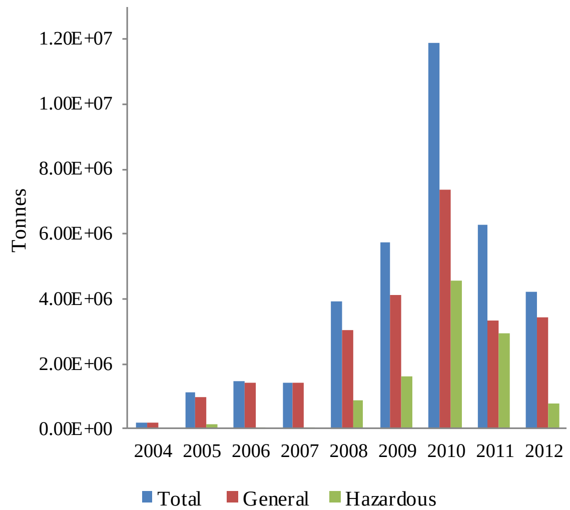

Fig. 5 General and hazardous waste disposal [21]

South Africa has been implementing the "end on pipe" approach in the management of solid waste, including waste tyres. Disposal at landfills has been the most predominantly utilized method; hence the main focus was on acquiring land space for landfilling. According to the South African Waste Information Centre (SAWIC) data bank which was established in 2004, waste disposal has been increasing since then due to the betterment of the living standards for most South Africans, thus resulting in an increased number of disposal sites. Domestic environmental laws of most countries, including South Africa, have been profoundly influenced by international laws. Most environmental problems transcend political boundaries and global trends as well as pressures have driven the development of national laws. In South Africa, environmental assessment was practised on a voluntary basis since the early 1980s, but become part of legislation because of the incorporation of an environmental right in the Bill of Rights [12]. As a result countries such as South Africa adopted new waste reduction management strategies and systems. Fig. 5 was generated from the SAWIC databank.

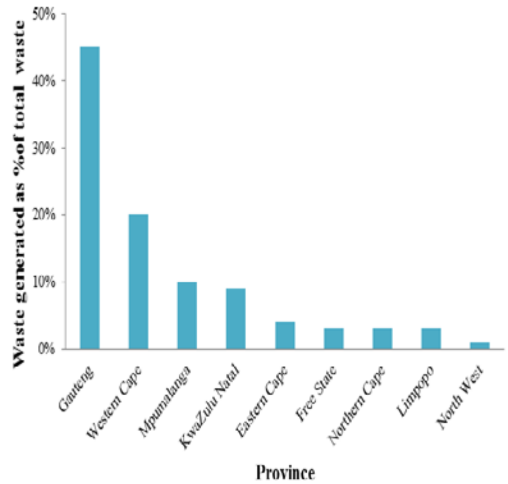

Fig. 6 Provincial municipal waste contribution in South Africa, 2011 [19].

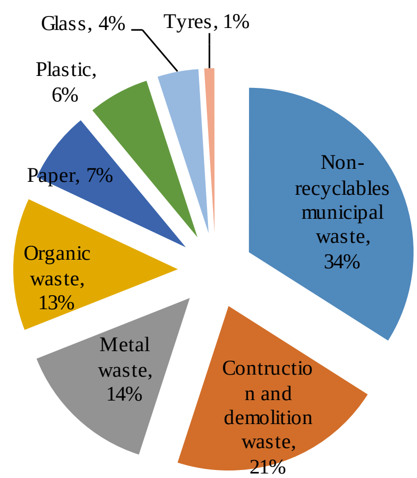

Fig. 7 General waste composition, 2011 [9].

Fig. 6 shows the provincial waste contribution in 2011 and the general waste composition is shown in Fig 7. Gauteng, the economic hub of South Africa with a population of 11.3 x 10^6 in 2011 [13] contributes 42% to the waste stream. Fiehn & Ball (2005) [14] suggested a current growth rate envelope of between 2-3% per annum from a starting tonnage of ±15m t/a, while DEAT (2012) suggested a generation rate of 1.57% [7].

Waste tyres made up 1% of landfilled general waste in 2011 [7], Fig 2.3. The disposal of waste tyres at landfill sites is environmentally unfavourable compared relatively to their size as well their health and environmental implications, accompanied by low recycling and alternative treatment rates in South Africa. As a result they are often illegally dumped or burnt to recover steel for recycling. In 2009, regulations were promulgated requiring tyre producers and importers to develop an integrated industry waste plan for waste tyre management and funding.

V. Waste Management

This section centres on the current waste management practices in urban communities. Plans exist for waste management as economically and safely as possible. Waste produced by urban communities may, if left uncontrolled, not only be an aesthetic problem, but also pose serious health risks. This can be aggravated by the presence of hazardous material in the waste stream. Thus waste must be collected from all sources as efficiently as possible, and disposed of in controlled disposal facilities [15]. Various options are available for the treatment of either whole general waste or of materials separated from it for recovery/recycling or pre-treatment prior to disposal. After waste prevention and re-use, the waste management hierarchy accords the highest preference to recycling over energy recovery and disposal options.

A. Mobilisation

A common feature among the waste management options is the need for collection, sorting, processing and transportation from source to the waste treatment or disposal facilities and markets for recovered materials. A formal waste collection system was first established around 1786 though the utilization of animal-drawn carts until the use of mechanical transportation took over in the1920's. This transition bought about significant cost savings as well as the advantage of easier supervision [16]. Waste collection and transportation has had to be critically thought out in South Africa to accommodate rapid urbanisation, population growth, improvements in community health demands as well as better service. The best approach for South Africa is to be able to integrate existing and new technological systems to maximize economic advantage [16]. The same approach is also required for waste tyres which is reliable and well managed in the collection and transportation. For simplicity and easy management, a single a national plan is the preferred approach.

B. Recycling

Rapid economic growth in South Africa's developed commercial and industrial areas, particularly in the larger cities, reflects an increasing demand on the individual's life style and leisure preferences. These demands have changed consumption needs resulting in increased discarded goods and packaging material. Recycling diverts components of the waste stream for reuse. The success of recycling is largely dependent on the market availability for both the raw and re-manufactured products. Economically, recycled products should be priced at a rate that covers the cost of their recovery less any subsidies. The price commanded by recycled materials is highly dependent on their quality. Clean, well-sorted and contaminant-free secondary material attracts a higher price than mixed, low quality or sordid material. Low quality recycled products have no market and must be disposed of at cost [17]. Figs. 2.4 and 2.5 show the recycling rates for common general waste in 2007 and 2009 respectively. Generally, there is an increase in recyclable material from 2007 to 2009, with the exception of beverage cans. This can be attributed to environmental awareness and recycling initiatives by both private and public sectors. On the contrary, the recycling of beverage cans dropped slightly during that period, this might have been attributed to the recession that was experienced in South Africa during the first quarter of 2009. This resulted in big cooperate companies not being able to properly fund and sustain their environmental initiatives and projects. Numerous waste tyre processing plants are in operation across South Africa. The plants which are currently in operation are involved in the shredding, granulation and pulverising of waste tyres which found use in various applications. South Africa requires technology that can process waste tyres with job creation potential with also the ability to reduce the health and environmental risks. Some of the waste tyres companies and initiatives in South Africa are: (a) The East Rand-based Vredestein SA Recycling Company found in the 1950s and was burnt down in 2008. The facility produced rubber-chip products sold to a leading international manufacturer of artificial grass systems for pitches and sports fields. Waste steel and nylon flock were also reclaimed and sold to other recyclers consents [18]. (b) Innovative Recycling converted waste rubber and plastic to fuel. The products were steel wire, oil and carbon black and these were sold to scrap metal traders, transport companies and the ink and paint industry. The plant closed down due to its failure to meet environmental standards. (c) South African (SA) Tyre Recyclers, formed in late 2005 at Atlantis, Cape Town, to steer South Africa's newest and most advanced technology in tyre recycling. The company works closely with local authorities and government in waste tyre recycling and other waste tyre environmental related matters. Scrap tyres are processed into a range of rubber granules and fine powders. Rubber products produced are shreds (used in matting, sport surfaces, turf and playgrounds); granules and chips (used in athletic tracks, playgrounds, horse arenas and asphalt); crumbs and powders (used in new tyres, brake pads, road sealing, adhesives and paints); and large shred tyre chips (used in civil engineering and fuel derivatives).

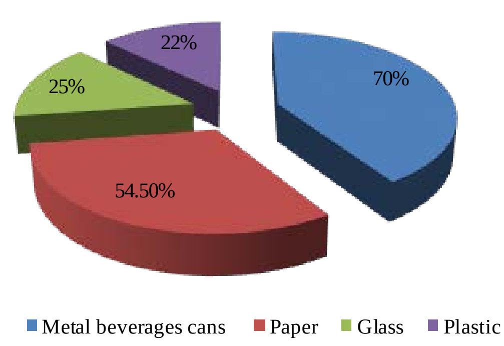

Fig. 8 Recycling rates in South Africa in 2007 [19]

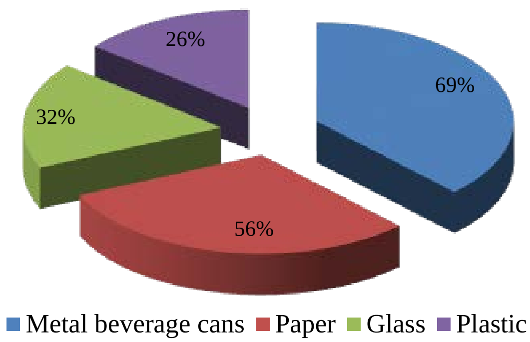

Fig. 9 Recycling rates in South Africa in 2009 [19]

C. Land filling

Land filling involves the managed disposal of waste on engineered sites with little or no pre-treatment. Thus, landfilling is different from dumping which is characterized by the absence of design, construction, control of the disposal operations and management of dump sites. Land filling is the most common, cheapest and cost-effective method of disposing waste [20].Waste dumping still occurs in less-developed communities in South Africa but this is gradually declining [20]. The volume and content of the waste to be disposed of will dictate the size and classification of the landfill, and necessary requirements for licensing purposes. Some of the major problems associated with landfilling include (i) wind dispersing debris (ii) rodent, insect and bird infestation (sometimes disease-carrying) (iii) pollution of ground and surface water (iv) spontaneous combustion hazard, and (v) foul odours. Nation-wide, there are over 2 000 waste handling facilities, of which 530 are permitted, yet only four of the nine provinces have hazardous waste facilities [21]. There is an undersupply of landfill airspace, and the currently available airspace is being rapidly depleted. This is propelled by the low levels of waste minimization and reuse, recovery and recycling [21]. Landfill sites are not allowed to accept waste tyres into their sites in line with the proposed REDISA plan.

D. Incineration

The demand for land and the need to protect the limited groundwater resources in South Africa dictates that alternative solutions to landfilling need to be explored. Incineration as an alternative has been considered as a waste management strategy with the potential for job creation. The purpose of thermal treatment of waste (which in the narrow sense usually means combustion in incinerators) is to reduce waste bulkiness before disposal as inert inorganic ash residue. Modern incinerators are designed to recover the energy released from the combustion process and this can replace electricity and/or heat from other sources [6]. Large-scale incineration is capital-intensive, but has the advantage of; (i) reducing the volume of waste requiring landfilling (ii) combating the spread of disease (iii) providing a potential energy source.

E. Pyrolysis and Gasification

Along with the combustion technology outlined above, there is increasing interest in the advanced thermal conversion technologies of pyrolysis and gasification. These technologies differ from combustion in that the waste is first heated either in the absence of air or with a very restricted quantity of air. Organic matter is thermally broken down to give a mixture of gaseous and/or liquid products that are then used as secondary fuels. The secondary fuels are used to provide heat input for the process, thus promoting self sustainability. Some processes may also produce solid coke residues which may be used as a coal substitute. Fig. 7 shows the schematic waste cycle.

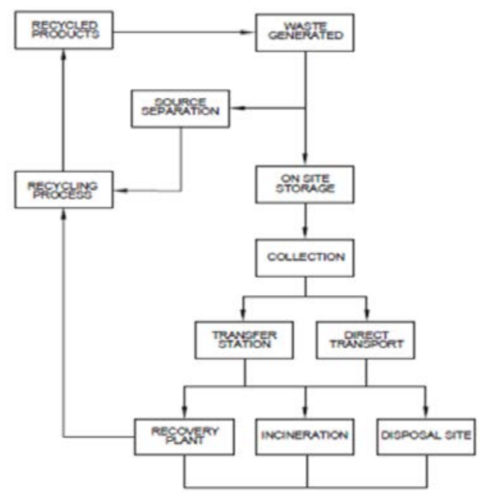

Fig. 10 The waste cycle

VI. Conclusion

The South African economy and the standard of living have been growing at a significant rate resulting in more waste generation. However due to international pressures to save and protect the environment, South Africa is required to adopt safe and ecologically waste disposal methods. This can be through recycling, re-use as well as energy and material recovery. The REDISA Plan is expected to address the waste tyre problem. Also, Waste is not waste: recycling creates an opportunity for resource sustainability

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