A Review of the Effectiveness of the Integrated Solid Waste Management System in Institutional Solid Waste Management in Zimbabwe

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Abstract

Abstract The review focuses on the effectiveness of the integrated institutional solid waste management system in Zimbabwe, utilising already published literature. Zimbabwean institutional solid waste is produced from schools, tertiary learning institutions, barracks, prisons, police camps and medical facilities. Institutional solid waste consist of plastics, papers, metals, textiles, rubber, food waste, glass and wood. Construction and demolition waste such as broken bricks, concrete, sand, stones are also produced from institutions. Medical institutions are sources of sharps, pathological, infectious, pharmaceutical, radioactive and cytotoxic solid waste. Institutions also discard electric and electronic waste such as computers and cell phones. Institutional solid waste management approaches in Zimbabwe are characterised by illegal dumping, co-storage of waste, inefficiency collection and transportation as well as co-disposal in poorly constructed landfills, open pits and incinerators. However, open combustion and burying of solid waste is done at onsite to minimise environmental eyesore. These strategies cause water, land and air pollution while flora and fauna are not spared. People are affected by gastrointestinal diseases, work related risks and psychological problems. These problems are fuelled by management approaches and legal framework which neglect integrated institutional solid waste management. However, integrated approach have potential to reduce environmental health problems, accelerate economic development and support social life of Zimbabweans. Therefore, integrated model which consist of various stages and processes of institutional solid waste management, numerous aspects and all stakeholders was developed.

Introduction

Nedziwe and Murairwa (2022) noted that solid substances generated from residential areas, industrial, commercial and institutions which are regarded useless and disposed is solid waste. Rapid urbanisation, population growth, need for peace, education and better education has led to expansion of various institutions in Zimbabwe. Institutions are regarded as minor communities, however they pose significant effects to environment health due to solid waste they generate (Jerie, 2006; Moqbel, 2018). In Zimbabwe institutions that produce solid waste encompass learning, health, churches, police stations, prisons and barracks. In the Zimbabwean context, approximately 60 percent of solid waste is organic (Kwenda, *et al.,* 2022) and institutional solid waste is encompassed. However, Mandevere and Jerie (2018) postulated that of all solid waste generated including from institutions 90 percent is discarded while the remaining percentage is recycled. This simply depict that a large volume of institutional solid waste is dumped utilising various strategies, since about 10 percent is recycled. Solid waste in Zimbabwe is disposed through landfills, open dumps, opens pits, open burning (Tsiko and Togarepi, 2012; Chapungu *et al.*, 2015). However, Mafume *et al.* (2016) noted that burying of solid waste in open spaces and backyard is also practiced, but at minimum rate. This suggest that institutional solid waste is destined in various noted strategies, since Mangizvo and Chinamasa (2008) and Kwenda *et al*., (2022) studies revealed that in Zimbabwe solid waste segregation is at miniature stage. Nevertheless, disposal approaches used in Zimbabwe may cause aggressive consequences to the environment and humanity is not spared

(Makwara and Magudu, 2013; Munyai and Nunu, 2020; Nedziwe and Murairwa, 2022). This implies that institutional solid waste can also be a threat to terrestrial and aquatic ecosystem since they also utilise crude disposal strategies.

In Zimbabwe proper management is attributed to misuse and misallocation of funds, weakly formulated and implemented policies alongside low enforcement of solid waste legal framework (Mandevere, 2015; Mandevere and Jerie 2018). This means municipalities responsible for all forms of waste including waste from various institutions is running devoid of resources and support from policy makers. Chapungu (2015) and Sinthumule and Mkumbuzi, (2019) revealed that passive participation of various stakeholders including citizens exacerbate improper solid waste management practices. This non participation approach accelerate negative attitudes and perceptions of the public concerning solid waste (Mafume *et al.* 2016), hindering proper segregation and storage. Tanyanyiwa (2015) and Nhubu and Muzenda (2019) coincide that owing to public resistance (Not In My Backyard) acquiring of solid waste disposal land is now difficult. Consequently, effectual strategies which minimise institutions' traditional norm of collection, transfer and disposal are required.

Sinthumule and Mkumbuzi (2019) and Nhubu *et al.*, (2020) laments that inefficiency collection and disposal of solid waste is attributed to lack of link between solid waste generation rate and municipalities' capacities coupled by slacking of political sector. However, countries' institutions generate diverse solid waste (Jerie, 2006), adding burden to incapacitated municipalities (Menikpura *et al.,* 2013). This implies that barriers of solid waste management including from institutions emanate from different angles. However, the existing scenario demonstrate that integration of various management approaches in monitoring institutional solid waste is lagging behind in Zimbabwe (Jerie, 2006; Mwanza and Phiri, 2013). Therefore, jointing of numerous organisations, stakeholders, technology, legal framework and treatment as well as discarding approaches is required. This suggest that integrated institutional solid waste management can be a panacea to the challenges. Hence, the main objective of this paper is to review the effectiveness of the integrated solid waste management system in institutional solid waste management. However, it shall be buttressed by specific goals namely analysis of institutional solid waste composition, examination of current management approaches. Assessment of benefits associated with integrated institutional solid waste in Zimbabwe will be considered. Also proffering of an integrated model for sustainable management of institutional solid waste in Zimbabwe was done basing on the existing management approaches. The model demonstrated what should be considered to achieve sustainable solid waste management in Zimbabwe.

Study Area

The study was carried out in Zimbabwe, a land locked country which covers approximately 390. 757km^2 in Africa (ZNCCRS, 2015). The country is located between latitudes 15-23^0 S and longitudes 25-34^0 E and shares natural and political boundaries with Zambia, Mozambique, South Africa as well as Botswana (World Bank, 2021). Zimbabwe is characterised by Sub-tropical climate with 4 seasons namely winter, summer, Autum and Spring however, summer and winter are the major seasons (Mugandani *et al.*, 2012;

Bradley *et al.*, 2020; RCRC, 2021). Manyeruke *et al.*, (2013) postulated that the country is divided into 5 ecological regions according to precipitation and temperature, with region 1receiving high rainfall while the least is experienced in region 5 (Manyeruke *et al.*, 2013). Zimbabwe's average yearly precipitation received from November to March is about 670mm while the country's average temperature is between 15^0C and 25^0C (Mugandani *et al.*, 2012; Manyeruke *et al.*, 2013; Brazier, 2018). Large part of Zimbabwe is covered by soil derived from weathering of granite rocks and Kalahari sands which support vegetation species like *Terminalia, Baikiaea, Brachystegia, Julbernadia and Colophospermum mopane* (Nyamapfene, 1991; Nyamapfene, 1992; World Bank, 2021). According to ZIMSTAT (2022) the country's population is approximately 15.1 million. The population is served by various institutions namely schools, universities, colleges, police centres, barracks, medical facilities, prisons. This means various types of solid waste is generated from these institutions. However, institutional solid waste is given little attention in the Zimbabwean context (Jerie, 2006). Therefore, the review focused on effectiveness of integrated solid waste management approach in institutional solid waste management in Zimbabwe.

Methodology

A systematic review of existing literature was carried out to gather information used for the study. Systematic review promote identification, analysis and interpretation of literature related to the topic (de Almeida Biolchini, 2007; Maphosa and Maphosa, 2020). Therefore, systematic review methodology assist in mapping of institutional solid waste literature. However, Zimbabwean solid waste literature with aspects of institutional solid waste was included since literature on institutional solid waste per se is at miniature stage. In order to increase validity and reliability of the review paper, literature published in English was used, in-text and end-text citation was done as well as utilisation of international literature. Also, articles, journals, abstracts, thesis and online books were retrieved from African Journals Online, Google Scholar, PubMed, Sage Publications, Springer, Science Direct, Scopus and Web of Science Publications. During literature review institutional solid waste, solid waste, integrated solid waste management, Zimbabwe and environmental health problems were typed as key terms on search engines. In terms of timeframe literature published from the past dates up to 2022 was considered. Development of the review paper was guided by reviewing of the effectiveness of integrated solid waste management systems in institutional solid waste management as overarching objective. Nevertheless, reviewing was specifically based on analysis of institutional solid waste composition, examination of existing institutional solid waste management practices and potential benefits of integrated institutional solid management. Additionally, proffering of integrated institutional solid waste management model was based on institutional solid waste and solid waste management approaches in Zimbabwe. Moreover, a number of published literature focused on rounding up papers with recommendations. Hence this review neglect recommendations and focus on development of a model which narrow the gap to achieve sustainable management of institutional solid waste.

Physical Composition of Institutional Solid Waste Generated In Zimbabwe.

In the Zimbabwean context, solid waste generation per individual is estimated to be between 0.36kg to 0.48kg (Pawandiwa, 2013; Kharlamova *et al*., 2016; Nemadire *et al*., 2017). Hence, institutions like universities which accommodate large populations have potential to generate various types of solid waste in large quantities. Zimbabwean institutional solid waste is generated by universities, colleges, primary and secondary schools, polytechnics, public and private medical facilities and prisons (Jerie, 2006; Chatira-Muchopa and Tarisayi, 2019). As a result institutional solid waste in Zimbabwe consist of both hazardous and non-hazardous waste. This congruent with the fact that medical facilities in Zimbabwe generate approximately 85% high risk waste and about 15% general waste (Taru and Kuvarega, 2005; EMA; 2007; Mangizvo and Chinamasa, 2008). Chatira-Muchopa and Tarisayi (2019) postulated that learning institutions produce plastics, papers, metal and glass as part municipal solid waste in urban areas. This implies that a certain fraction of solid waste from institutions is recyclable and combustible. In Zimbabwe, timber and wood waste have been given little attention (Charis *et al.,* 2019), specifically from 2011 to 2017 (Makarichi *et al,* 2018). However, training centres and polytechnics in Zimbabwe generate wood waste from wood work departments, which can be burned to generate heat energy. Kharamova *et al*., (2016) and Kwenda *et al*., (2022) coincide that Zimbabwean cities produce about 50% to 62% biodegradable solid waste including from institutions. Therefore, biodegradable solid waste from institutions can be composted and go through biomethanation (anaerobic digestion) to produce fertilizer and biogas respectively. Chijarira, (2013) and Chitotombe, (2013) agree that dumpsites in Zimbabwe are characterised by cartridges, batteries, non-functioning cell phones and computers. Consequently, institutional solid waste consist of electronic waste since learning institutions are homes of technological equipment.

Additionally, Mazhandu *et al*., (2020) postulated that plastic waste accounts for 13% of disposed solid waste in Sub-Saharan region. This entails that plastic food wrappers, straws, beverage bottles, disposable plates, cups and cutlery from Zimbabwe's institution add a proportion to the region's plastic waste. However, plastics biodegradable rate is slow (Jerie, 2013), since plastic bottles and Styrofoam cups decompose after 450 and 50 years respectively (Mazhandu *et al*., 2020). Taking this account, plastics from institutions speed exhaustion of dumpsites since they degrade slowly. According to Chatira-Muchopa and Tarisayi (2019) institutional dining halls and kitchen generate 20% cans, 10% stationary and 61% food waste. This means a tangible quantity of solid waste which decompose quickly at dumpsites come from learning institutions and hospitals in Zimbabwe. Also, production of paper waste is approximately 60% at institutional classes while offices generate 50.5 % (Chatira-Muchopa and Tarisayi, 2019). High generation of solid waste in form of papers denotes that adoption of information communication technology is still evolving at institutions in Zimbabwe. In Zimbabwean cities construction and demolition waste is also part of collected municipal solid waste (Jerie, 2013; Moyo and Chigara, 2021), and accounts for an average of 30.6% to 39.6% in suburbs like Monomutapa and Shamrock Park (Jerie, 2016). As a result institutions renovation and construction activities generate pieces of iron sheets, asbestos, builder's rubble and broken bricks which are collected by municipalities.

Table 1: Physical composition of institutional solid waste in Zimbabwe

Type of Solid waste	Description of waste	References
Medical	Pathological, pharmaceuticals, sharps, radioactive, chemical waste, infectious waste, cytotoxic waste and general waste.	Taru and Kuvarega (2005); Mangizvo and Chinamasa (2008); Jerie and Musasa (2022).
Construction and demolition	Piles of sand, builders' rubble, broken bricks, few small and large stones, broken metals and glasses	Jerie (2013); Moyo and Chigara (2021).
Papers	Books, newspapers, book covers, stickers, flyers, files and card boxes.	Jerie (2006); Chatira-Muchopa and Tarisayi (2019); Maqhuzu *et al*., (2019).
Plastics	Beverage containers, cups, windscreen wipers, pen, plates, food takeaways, book covers, food wrappers, containers of cosmetics, lotions, disinfectants and chemicals and packaging materials.	Jerie (2016); Tsiko and Togarepi (2012); Mazhandu *et al*., (2020)
Textiles	Piece of cloth, tattered clothes and fabrics	Jerie (2013); Chikobvu and Makarati (2011);
Rubber	Shoes, belts, hand bags/purses and tyre pieces.	Jerie (2013); Jerie and Tevera (2014);
Wood	Broken furniture (Chairs and desks), doors, trusses, pencils and timber.	Charis *et al.,* (2019); Makarichi *et al,* (2018).
Metals	Empty containers of paint, nails, oil, polish, thinners or chemicals, scrap metal, car shells, sharpeners, aluminium and ferrous and non-ferrous metals.	Jerie (2016); Maqhuzu *et al*., (2019)
Food waste	Fruits, vegetables, maize cobs, bones, sadza and rice remains and chicken waste.	Kharamova *et al*.,(2016); Kwenda et al., (2022)
Eletronic and electric waste	Printers, cartridges, electric (cables, plugs, and adaptors), computers, cell phones, batteries, televisions, air conditioners, refrigerators and appliances like iron, heater and electric Jar.	Chijarira, (2013); Gweme *et al*., (2016); Makarichi *et al.,* (2018);
Glass	Broken and old glass plates, cups, jars, bottles, window pens and screens.	Jerie (2016); Makarrichi *et al.,* (2018)

Current Institutional Solid Waste Management Practices

Storage and collection

Institutional solid waste storage encompass a situation where produced waste is stored in bins and other suitable plastic or metal receptacles (Mwanza and Phiri, 2013). Temporal storage of solid waste is carried out at onsite waste site at hospitals and learning institutions awaiting for collection. Mafume *et al.,* (2016) and Jerie (2016) concur that in Zimbabwe solid waste from various sources is collected to official

dumpsites by municipality's waste management section. This points out that participation of institutions in solid waste collection is low, since it is regarded as responsibility of municipalities. Nevertheless, individuals and private companies also play a role in collecting solid waste to designated discarding sites (Mandevere, 2015; Jerie and Mandevere, 2018). This is evidenced by existing of institutions like universities and colleges who engage private collectors or collect their own waste to dumpsites. Also, health institutions in rural areas of Zimbabwe collect their own waste to waste sites.

Mangizvo, (2010) and Muhamba (2015) agree that non segregated waste is found in solid waste receptacles and disposal sites in Zimbabwe. This suggest that indiscriminately stored institutional solid waste is transported together by municipalities. Institutional solid waste collection from prisons and learning institutions is done through the curbside approach (Mwanza and Phiri, 2013; Jerie and Mandevere, 2018). Currently, different municipalities are unable to offer efficient waste collection services in various cities (Makwara and Magudu, 2013; Muhamba 2015; Tanyanyiwa, 2015). Consequently, a number of institutions for instance hospitals and churches sink into pools of solid waste due to erratic collection practices. Nhubu *et al*., (2019) and Kwenda *et al*., (2022) concur that collection rate of institutional solid waste as part of municipal solid waste is about 60% in Zimbabwe. Inefficient solid waste collection from institution is attributed to municipality improper planning and operating without enough waste trucks, staff, fuel due to limited finance (Chikobvu and Makarati, 2011; Nyatsanza and Kudzai, 2016). Though, the public including institutional authorities blame municipalities for financial misallocation (Mandevere and Jerie, 2018). However, Mwanza and Phiri (2013) noted that some areas are inaccessible so collection of solid waste is difficult. In Zimbabwe some schools are located in peripheries of cities with poor roads, therefore municipalities fail to access them. However, it depends with the route taken by the waste trucks to reach the institution. Therefore, inadequate collection of institutional solid waste remain inevitable in Zimbabwe. Nyatsanza and Kudzai (2016) and Munyai and Nunu (2020) stated that solid waste including waste from institutions is collected once a week. However, Taru and Kuvarega (2005) and Jerie and Tevera (2014) hospital solid waste should be collected to designated sites on daily basis in order to conform with World Health Organisation standards.

Moreover, Zimbabwe is in the Sub-tropics hence solid waste needs to be collected at least twice per 7 days (Munyai and Nunu, 2020). Therefore, collection of solid waste from health institutions and colleges contradicts the recommended collection standards since is done once a week. According to Chikobvu and Makarati (2011) and Mandevere, (2015) the condition is worsened deployment of waste collection trucks without offering specific directions to drivers. This suggest that some institutions like colleges and polytechnics may be skipped by this haphazard approach and solid waste continue to accumulate at onsite waste sites. Also, frequency of solid waste collection is high in low density suburbs as compared high density residential areas (Mandevere and Jerie, 2018). This entails that solid waste generated by health and learning institutions in high density suburbs are given less attention, hence continue to accumulate and decompose. In Zimbabwe postponement in solid waste collection result in application of rudimentary and illegal disposal approaches like open burning, open pit dumping, burying and open

dumping (Pawandiwa, 2013; Munyai and Nunu, 2020). This suggest that institutions also adopt illegal and non-environmental friendly during waste discarding to free space for newly generated waste.

Institutional solid waste disposal

Mandevere (2015) and Mandevere and Jerie (2018) coincide that roughly 90% of solid waste collected by Zimbabwe's municipalities is destined in dumpsites. This concur by Nemadire *et al.*, (2017) and Kwenda *et al.*, (2022) that the estimated discarding rate is between 270 000 and 500 000 kilograms per day in Zimbabwean cities. This demonstrate that large volume institutional solid waste is also disposed in designated dumpsites, since it is part of municipal solid waste. However, in Zimbabwe disposal of solid waste in improperly engineered official dumpsites is practised as evidenced by Golden Quarry dumpsite (Kharlamova *et al.*, 2016, Makarichi *et al.*, 2018; Munyai and Nunu, 2020). This simply means institutional solid waste in destined in landfills devoid of gas and leachates control structures. Solid waste destined in landfills is spread and compacted, then covered by soil or remain open (Nemadire *et al.,* 2017), however dumped waste can be openly burned or incinerated (Kwenda *et al.*, 2022). Considering this institutional solid is disposed in landfills which are operated as open dumpsites, since combustion processes are applied.

According to Makarichi *et al.*, (2018) approximately 37.6% of various types of solid waste from numerous sources is destroyed through combustion at generation points. As a result hospitals, colleges and universities are part of those who apply onsite burning and incineration. This congruent with Jerie and Musasa (2022) that solid waste from health institutions is always disposed through incineration. In the Zimbabwean context incineration is applied to reduce the volume of disposed solid waste (Taru and Kuvarega, 2005), hence solid waste from institutions also went through the process. However, in Zimbabwe incineration process is inefficiency since incinerators are not build to standard (Mangizvo and Chinamasa, 2008), and non-separated waste is overloaded into incinerators (Nhubu and Muzenda, 2019). Consequently, incomplete combustion of institutional solid waste result in production of partially burned electronic waste from learning institutions and sharps from hospitals.

Furthermore, in Zimbabwe both legal and illegal discarding sites are utilised (Mwanza and Phiri, 2013). A view in line with Nhubu *et al.*, (2019a) of all solid waste generated in Zimbabwean cities 40% is disposed through illegal methods. Considering this account institutional solid is disposed into open spaces, drainage systems, street corners, road sides and buildings under construction. Illegal disposal of institutional solid waste is exacerbated by inefficiency collection, absence of awareness and commitment among institutions' authorities. This coincide with Jerie (2016) and Munyai and Nunu (2020) that delays in waste collection result in cropping of illegal or informal dumpsites in Zimbabwe. Institutions like prisons, police stations, hospitals also resort to waste burying due to infrequent waste collection. However, Mafume *et al.*, (2016) noted that the strategy is used at low rate. Jerie (2016) and Makarichi *et al.*, (2018) correspond that in Zimbabwe open pits to dispose solid waste are dug at open spaces. This means institutions also use open pits as final destinations of solid waste, although they are always not lined hence result in various environmental problems.

As a result of consciousness of environmental problems associated with continuous disposal of solid waste, institutions adopt waste reduction alternatives. In Zimbabwe 10% to 13.6% generated solid waste including from institutions is either recycled, reused, composted or recovered (Kharlamova *et al.,* 2016; Nhubu *et al;* 2019b). This suggest that recycling and reuse strategies are applied by institutions like universities to reduce volume of disposed waste. However, solid waste reduction approaches are used at lower rate by institutions since less than 14% is diverted from reaching dumpsites. In Zimbabwe, recovering of solid waste from dumpsites by informal waste pickers falls in the rage of 6 to 10% (Nemadire *et al*., 2017; Kwenda *et al*., 2022). Therefore, a minor percentage of institutional solid waste such as textiles, electronic gadgets, plastics, rubber among others is recovered from dumpsites. However, a large percentage is disposed through legally or utilising approaches which contradicts legislation in Zimbabwe.

Institutional Solid Waste Management and the Legal Framework.

The Environmental Management Act [Chapter 20:27].

The Act was endorsed in 2002 as the supreme environmental law which safeguard the environment in Zimbabwe. The Act addresses management of various types of solid waste from different sources. This means management of institutional solid waste is guided by Environmental management Act. Environmental principles and rights are enshrined Section 4 of the Act, where it is stated that humans should reside in an environment is not deleterious to health (Environmental Management Agency, 2007). Failure to conform to the requirements of the Act, means the Environmental Management Agency will apply the Polluter pays principle. This means institutions in Zimbabwe must conform to section 4 to prevent environmental pollution and uphold human rights which are also enshrined in the 2013 Constitution of Zimbabwe Amendment (Number, 20) section 73 (Parliament of Zimbabwe, 2013). Section 10 of the Act demonstrate that management of solid waste from generation to disposal should be done according to the formulated standards. Therefore, institutional solid waste from learning institutions, hospitals and prisons management methods should comply with Act. Also, inspection of solid waste management applied by various institutions is carried by Environmental Management Agency. This is done to assess conformity of institutions to environmental protection regulations and practices. In Section 70 of the Act it is clearly articulated that no one is allowed to discard waste using a strategy that cause negative environmental health impacts. Similarly, littering is prohibited in Section 83 of the Act. Therefore, if institutions contravenes Section 70 and 83 will be considered guilty and liable to fine or polluter pays principle.

The Public Health Act [Chapter 15:09]

The 1996, Public Health Act is a legislation that deals with solid waste including institutional solid refuse at local authority as well as Central Government level. Section 83 stipulate that it is the accountability of local authorities to ensure that areas under their jurisdiction are in a clean environment in order to protect humanity. This suggest that institutions in Zimbabwe should be kept clean by frequent collection of waste to prevent accumulation of solid waste which result in outbreak of diseases. In Section 85 of the

Act, it is noted that local authorities should provide solid waste receptacles or containers to generators of solid waste while maintaining and monitoring of dumping areas is regarded as duty of local authorities. This implies that institutions as generators of solid waste should receive storage containers from municipalities. Also, institutional solid waste is collected and disposed in dumpsites managed by local authorities. However, institutional solid waste can be collected by private operators to minimise continuous accumulation of solid waste at generation points. Penalties to be imposed to those who discard waste in a manner which is hazardous to human health and breach the environmental standards are shown in Section 87 and 88. This denotes that if institutional solid waste management approaches are against the Public Health Act, Chapter 15:05, institutions became vulnerable to fines and penalties.

The Urban Council Act [Chapter 29:15]

The Act regulates management of waste in areas regarded as urban (Jerie, 2013). This clearly means institutional solid waste from institutions in cities and towns is managed by councils. Ministry of Local Government and Public Works (2021) stated that the Act's Statutory Instrument 68 of 2021 Subsection 1 of Section 4 articulate that councils are accountable for solid waste collection and conveyance to disposal areas in Urban areas. This also demonstrated in Section 235 [3] that solid waste collection services should be provided to urban centres by municipalities. This means institutions in urban areas are beneficiaries of the Act, while schools, hospitals and police stations in rural areas shoulder the burden of solid waste management without enough resources. Urban Councils Act offers municipalities opportunity to craft solid waste related by-laws which are approved by the Minister of Local Government as shown in Section 229. The by-laws encompass solid waste collection charges per month. Consequently, charges paid by institutions for solid waste removal are guided by the by-laws.

Water Act [Chapter 20:24]

Section [68]1 of the Act include information which is related to solid waste. Water Act articulate that disposal of any type of waste into water sources is prohibited (Jerie, 2013). This entails that discarding of solid waste from institutions like schools, universities and colleges should conform to the Act's requirements. According to this Act dumpsites must be properly located and engineered to safeguard aquatic ecosystem in Zimbabwe. This denotes that, in the Zimbabwean context water act regulates disposal of institutional solid waste management. Therefore, if institutions apply rudimentary solid waste disposal approaches they shall be liable to polluter pays principle to decontaminate polluted water.

Hazardous Substances and Articles Act [Chapter 15:17]

Management of hazardous solid waste is guided by the Hazardous Substances and Articles Act. According to Environmental Management Act (2007) stated that hazardous solid include corrosive, flammable, toxic and radioactive waste. However, Jerie (2016) goes on to say ingectivity, irritability, mutagenicity, tetragenicity and carcinogenicity are also characteristics of hazardous solid waste. This means solid medical waste, electronic waste, chemical waste containers as well as pressurised containers among others from various institutions are managed as hazardous solid waste. According to

the Act producers of hazardous solid waste should apply sustainable management approaches to prevent environmental pollution and safeguard humanity. This simply point out the Act offer guidelines for hazardous solid waste management to institutions in Zimbabwe. In Section 72 of the Act, it is stated that collection and conveyance of hazardous waste should be carried out using designated vehicles. Henceforth, transportation of institutional hazardous waste from clinics, universities, colleges and prisons is done according to the Act's standard.

The Factories and Workers Act [Chapter 14:08]

The Act was enacted in 1996 to address issues related to workers protection and accident prevention at workplaces. The Act is implemented following the occupational health and safety legislations like the Statutory Instrument 68 of 68 0f 1990. According to the Act employers must provide enough personal protective equipment/clothing to employees. This means waste workers involved in management of institutional solid waste should be equipped with adequate safety gear to minimise work related risks. Also, solid waste workers must receive enough training to prevent workplace injuries. Therefore, compliance to requirements should be done by local authorities and institutions to protect workers.

The Environmental Impact Assessment Policy

The utilization of Environmental Impact Assessment (EIA) tool is also applied in the management of institutional solid waste, especially treatment and disposal stages. In Zimbabwe, municipalities are urged to carry out EIA process before locating disposal areas and constructing solid waste treatment plants. This means institutional solid waste landfills and incinerators' location in relation to residential areas and water sources are according to standards after EIA. This facilitates conformity to standards such as a distance of 500 meters from residential areas (Jerie and Zulu, 2017; EPA, 2020). EIA enable municipalities and institutions to implement precautionary measures which protect humans and the environment from institutional solid waste.

Analysis of Institutional Solid Waste Legal Framework

Paramount of legal framework in solid waste management from different sources including institutions has been recognised in Zimbabwe (Tevera, 1991). A view upheld by Jerie (2013) that comprehensive legislation exist, however there is discrepancies between legal framework demands and what is occurring practically. This clearly demonstrate that legislation and policies remain paper work while they fail to serve their major purpose. According to Jerie (2013) the legal framework fail to consider solid waste reduction strategies like recycling, recovery. Hence, large volumes of solid waste finds its way into disposal sites and exerting pressure to already burdened environment. Similarly, issues of integrated solid waste management are overlooked, hence management of institutional solid waste remain problematic. Additionally, environmental rights put much emphasis on human beings while ignoring other living and non-living species, therefore non included species are threatened by institutional solid waste. According to Tevera *et al*., (2002) despite existence of detailed pieces of environmental legislation in Zimbabwe, solid waste management standards are deteriorating. This congruent with Muheirwe *et al.,* (2022) that

solid waste legislation and policies in Sub-Saharan region fail to yield anticipated results. Therefore, detrimental impacts of institutional solid waste to humanity, aquatic and terrestrial ecosystem is inevitable.

Environmental Health Risks Associated With Institutional Solid Waste.

Public health risks

Residential areas located at a distance less than 500 meters from dumping sites are likely to be affected by pollutants (Jerie and Zulu, 2017, EPA, 2020). This congruent with Ziraba *et al.*, (2016) that people who reside in proximity to waste sites are affected by persistent coughing and headaches due to fumes and odours from decomposing and burning waste. Incomplete combustion and incineration produce smoke, toxic gases, fumes and bio-aerosols (Mangizvo, 2010; Jerie, 2013), which result in bronchitis, asthma and eye irritation and other various respiratory problems (Chikobvu and Makarati, 2011). This implies that proper siting of waste sites may be a panacea to respiratory ailments associated with institutional solid waste. Jerie (2016) and Zubar and Andrees (2019) coincide that exposure to heavy metals, furans, radiation and dioxins from combustion of solid waste pose skin rushes, burns, cancer, genetic mutation, neurological alterations and reproductive complications. This denotes that workers who operate incinerators used to dispose institutional solid waste are affected unknowingly. Similarly, women are more vulnerable since heavy metals and radiation affect pregnant mothers by reducing weight of babies as well as development which result in existence of down syndromes (Ncube *et al.*, 2016; Munyai and Nunu, 2020). As a result institutional solid waste affect females than males in proximity to waste sites, therefore proper management is required to safeguard present and future generation.

Improperly dumped institutional solid waste offer breeding sites for flies, rodents, mosquitoes, rats and cockroaches which facilitates spread of various ailments (Tsiko and Togarepi, 2012). According to Nyatsanza and Kudzai (2016) and Chanza et al., (2017) outbreak of malaria and gastrointestinal diseases like typhoid, cholera, dysentery, stomach cramps is attributed to improper dumping of waste and utilisation of contaminated water. However, intestinal problems are highly experienced by those who retrieve food from dumpsites (Mangizvo, 2010). This implies that mismanagement of institutional solid waste pose diseases and even death in Zimbabwe. A view supported by Chirisa *et al.,* (2015) and Chigudu *et al.*, (2020) that outbreak of 2008 cholera in Zimbabwe was a result of poorly disposed solid waste, including from institutions. Kwenda *et al.*, (2022) goes on to say in Dzivarasekwa, Harare 500 cases of health problems associated with solid waste are recorded annually while 23 people lost their lives annually. Consequently, institutional solid waste also needs attention since it can potentially speed the spread of diseases in Zimbabwe.

Children and waste scavengers who visit dumpsites without safety gear are vulnerable to injuries, thereby affected by infectious diseases (Mangizvo and Chinamsa, 2008; Chikobvu and Makarati, 2011). This revealed that institutional solid waste have potential to accelerate the spread of tetanus, HIV and AIDS, tuberculosis, Hepatitis B,C as well as Covid 19 in Zimbabwe. Abidoye *et al.*, (2016) indicated that 30% of Hepatitis B, C and 2.5% HIV new cases are attributed to cuts and pricks from sharp waste in Sub-Saharan

Africa. Jerie (2012; 2016) concur that solid waste workers affected by musculoskeletal disorders due to perpetual manual loading and offloading of solid waste. This entails that institutional solid waste workers encounter shoulder, hand, wrist problems as well as chest and back pain while necks are not spared. Piles of illegally disposed solid waste and various types of scavenging domestic and wild creatures act as nuisance to people (Kharlamova *et al,* 2016; Sinthumule and Mkumbuzi, 2019; Kwenda *et al,* 2022). Therefore, haphazardly disposed institutional solid waste impact psychological health of people near waste sites.

Water contamination

In Zimbabwe, piles of dumped solid waste squeezed and decompose to generate leachates, acids, heavy metals alongside nutrients which reach water sources through runoff and percolation (Mangizvo, 2010; Nhubu and Muzenda, 2019). This means institutional solid waste disposed in non-compacted or lined disposal areas release pollutants which contaminate water. According to Ali *et al.*, (2017) and Vivek *et al.*, (2019) incineration residues like ashes are rich sources of metals like copper, mercury and cadmium which can affect water P.H and electrical conductivity if disposed improperly. Considering this, incinerator residues from hospitals, learning institutions and prisons have ability to deform water quality. Also, continuous accumulation of nutrients in water sources leads to emerging of water hyacinth and death of fish (Vushoma, 2016; Jerie and Mandevere, 2018). This implies that nitrates, sulphates alongside phosphorus from institutional dumpsites results in growth of plants in water sources, therefore increasing chemical oxygen demand. A view upheld by Charis *et al.*, (2019) that increase of biochemical oxygen demand in water sources is attributable to pollutants from solid waste. Existence of solid waste pollutants in water increase suspended solids, temperature and water hardness (Mangore and Taigbenu, 2004; Vushoma, 2016). As a result pollutants from institutional solid waste scarcity of fresh water is accelerating while cost of water treatment is increasing in Zimbabwe. Additionally, Mangizvo (2010) opined that contaminated water impact health of people who reside in the downstream since they utilise water for domestic purposes. Therefore, exposing themselves to gastrointestinal diseases unknowingly.

Air pollution

Incineration and open burning are used in Zimbabwe to dispose solid waste generated at institutions (Mangizvo and Chinamasa, 2008; Chatira-Muchopa and Tarisayi, 2019; Jerie and Musasa, 2022). However, incineration and incomplete combustion are known sources of carbon dioxide, monoxide, nitrous oxide, particulate matter, dioxins and furans into the atmosphere (Taru and Kuvarega, 2005; Makarichi *et al.*, 2018). This reveal that incomplete combustion of institutional solid waste release toxic gases which contaminate the air, resulting in acid rain. Moreover, garbage trucks and compactors produce gases from burning fuel (Nhubu *et al.*, 2019b). Hence, contamination of air is inevitable owing to conveyance of institutional solid waste and compaction processes at dumpsites. Poorly engineered landfills without gas control outlets results in contamination of air by methane and odors (Muchandiona, 2013; Chapungu *et al.,* 2015). However, disposal of institutional solid waste in improperly constructed landfills is order of the era in Zimbabwe, hence air pollution is unavoidable.

Land degradation

Decomposition of solid waste particularly co-disposed waste generate leachates, metals and toxic nutrients and ions which impact soil quality (Mangizvo, 2008; Muchandiona, 2013; Tanyanyiwa, 2015). A view upheld by Mangizvo (2010) that copper, lead and Zinc are highly concentrated in areas located less than 75 meters from landfills or dumpsites. Henceforth, decaying solid waste from colleges, schools, universities release pollutants which affect soil texture, P.H structure as well as microbial activity. Nyatsanza and Kudzai, (2016) and Makarichi *et al.*, (2018) concur that illegally dumped piles of solid waste coupled by littering create land pollution which result into an eyesore environment. Therefore, one can argue that institutional solid waste plays a role in reducing aesthetic value of the land in Zimbabwe. However, Mandevere (2015) and Mandevere and Jerie (2018) coincide that littering of land reduce inflow of tourist since they don't associate with polluted land. Taking note of this, incorrectly discarded institutional solid waste hamper income generation in Zimbabwe, since it affects tourism.

Impacts to flora and fauna

In Zimbabwe dumpsites are utilised as diet sources by scavenging domestic and wild animals (Mangizvo, 2010; Jerie, 2016). Hence, marauding cats, dogs, baboons and birds can consume institutional solid waste, therefore exposing themselves to gastrointestinal diseases and intestinal blocking. Metals and nutrients from decomposed solid waste are absorbed by vegetation through active uptake then stored in leaves, fruits and roots (Radziemska, 2018; Shi and Schulin, 2018; Vaverkova *et al.*, 2019). As a result animals and birds who relied on institutional solid waste landfills' plants encounter various health problems like cardiac failures. Outbreak of fire is a common phenomenon at Zimbabwean dumpsites Chapungu *et al.*, (2015), this is exemplified by the 2013 fire outbreak (Kharlamova *et al.*, 2016). This denotes that institutional solid waste dumpsites are hazardous areas which can generate fire which destroy various vegetation and animal species. Also, Vaverkova *et al.*, (2018; 2019) stated that dumpsites or landfills offer fertile soil which supports growth of invasive species such *Portulaca oleracea, Bromus sterilis, Panicum miliaceum* and *Brassica napus.* This demonstrated that emerging of invasive plant species on institutional solid waste dumpsites can alter the natural vegetation, since native species can be overwhelmed by invasive species. However, besides changing characteristics of natural vegetation, invasive species flowers/pollens increase cropping of human allergies (Greiner *et al.*, 2012; Osborne and Eggen, 2014). Consequently, people in vicinity of areas where solid waste from colleges, polytechnics and prisons is dumped are at risk of allergies, particularly during the flowering season. Therefore, institutional solid waste management methods present to be futile from an environmental health perspective in Zimbabwe. Hence, the country should resort to integrated institutional solid waste management approach.

Potential Benefits of Integrated Institutional Solid Waste Management.

Integrated Solid Waste Management System (ISWMS) may be a panacea to solid waste dilemma in developing nations since it encompass the whole management chain, processes and stakeholders (Marshal and Farahbakhsh, 2013; Asefi *et al.*, 2019). This suggest that pinning of ISWMS to institutional

solid waste management is the route to sustainability in Zimbabwe. According to Mwanza and Phiri (2013), ISWMS upheld utilisation of more powerful approaches on the waste hierarchy namely recycling, reuse and prevention. Consequently, quantity of institutional solid waste deposited in dumpsites will be minimised, hence extending lifespan of landfills and dumpsites. Integration of strategies such as composting enable people to gain fertilizer (Chikobvu and Makarati, 2011). This reveals that besides reducing environmental eyesore ISWMS can increase agricultural production at institutions. In Zimbabwe non-participatory approach fuelled mismanagement of solid waste (Mafume *et al*., 2016; Makarichi et al., 2018; Mandevere and Jerie, 2018). Hence, ISWMS is relevant since it incorporates all stakeholders from various levels, to meet demands of the society.

ISWMS supports incineration of solid waste in incinerators with combustion engines, which divert flue gases into electricity (Mwanza and Phiri, 2013; Nhubu and Muzenda, 2019). This means besides reducing air contamination, ISWMS enable generation of energy, which is scarce in Zimbabwe. A view upheld by Jerie and Jenya (2020) that although waste recovery is at the lower part of the waste hierarchy, it reduces land pollution while increasing energy output. This depicts significance of integrated institutional solid waste management since integration of material recovery boost the country's energy output while minimising littering. According to Muchandiona, (2013) 98% of disposal sites of solid waste in Zimbabwe are not environmentally sound. Henceforth, engineering of sanitary institutional solid waste dumpsites is achievable with ISWMS since it supports incorporation of skilled people and those who provide finance. In the Zimbabwean context, conveyance of leachates from landfills to water treatment plants is still at miniature stage (Nhubu and Muzenda, 2019). However, if there is integration of various approaches leachates from institutional solid waste landfill is processed and treated through nitrification, denitrification, and ultrafiltration to produce consumable water.

Jerie and Tevera (2014) and Mandevere and Jerie (2018) concur that informal sector plays a pivotal role in achieving ecologically sound solid waste management by upholding reuse, recycle strategies as well as recovery and sell. Therefore, in order to recognise informal sector' role in Zimbabwean institutional solid waste management, an integrated strategy is required. In addition, integration of informal sector minimise quantity of waste destined in landfills while people benefit financially through selling waste materials. This congruent with Nemadire *et al*., (2018) that integration of informal sector in solid waste management assist Zimbabwe to reach its visions like environmental protection and poverty alleviation. Moreover, poorly implemented policies and legislation widen the gap to reach sustainability in waste management in Zimbabwe (Jerie, 2013; Kwenda *et al*., 2022). Considering this, jointing of various stakeholders and aspects assist in creating watertight institutional solid waste legal frameworks which support all waste management system elements. ISWMS is regarded as a potential way forward in Zimbabwe since it support strategies which minimise municipal solid waste burden to the environment (Mangizvo, 2010; Mwanza and Phiri, 2013; Nhubu and Muzenda, 2019). As a result, adoption of ISWMS safeguard terrestrial, aquatic ecosystem and humanity from problems that emanate from institutional solid waste. Generally, incorrect management of solid waste in Zimbabwe is attributable to utilisation of inadequate data which force planners to rely on estimations (Nhubu and Muzenda, 2019; Nhubu *et al.,* 2019). This entails that integration of technology like use of weighbridges in recording quantity of solid

waste from institutions is important for easy planning. A view upheld by Jerie (2014) that existence of enough solid waste quantity and composition data is the cornerstone of proper planning. Hence, a comprehensive integrated institutional solid waste management model is crucial since the discussion demonstrate that its strengths outweigh its weaknesses.

Designed Integrated Institutional Solid Waste Management (IISWM) Model In Zimbabwe.

The **IISWM** model supports proper management of institutional solid waste from generation to disposal. It put much emphasis on waste reduction alternatives namely prevention, recycling, reuse and conversion of solid waste into new products, materials and energy. The proffered model also take into account interaction between political, social, economic and biophysical dimensions of human life. The **IISWM** model denotes that achievement of sustainability can be reached through use of current technology, adequately gathered and analysed data coupled by stakeholder participation and training from grassroots level to the apex members. Integration of institutional solid waste management legislations and policies supported by political commitment and enough resources is demonstrated by the model. The model in **Figure 1** shows that besides alleviating environmental health problems **IISWM** model facilitates economic growth and poverty reduction among people.

Conclusion

The verdicts of the review denotes that literature concerning institutional solid waste is receiving little attention. Although, institutions such as universities, colleges, primary and secondary schools, polytechnics, prisons, police stations, prisons, barracks as well as medical facilities are sources of institutional solid waste in Zimbabwe. The study demonstrated that solid waste from medical institutions encompass sharps, pathological, pharmaceutical, cytotoxic, radioactive, chemical, and infectious alongside general waste. However, institutional solid waste also consist of papers, metals, plastics, rubber, glass, wood and food waste from various institutions. Renovation and construction of institutions result in generation of construction and demolition waste namely concrete, dry wall, piles of sand, stones, builder's rubble, broken trusses, glass and metals. Currently, electric and electronic waste notably computers, cell phones and other electrical appliances are generated from institutions, since institutions like learning institutions are driven by availability of technology.

Available literature demonstrated that municipalities are responsible for institutional solid waste management from collection to disposal. Institutional solid waste is collected and disposed in official dumpsites where burning and incineration is also applied to reduce volume of waste. However, owing to collection delays institutions handle the situation of solid by disposing solid waste in open pits, burying, destroying through open combustion and onsite incineration. Existing management approaches present to be ineffectual as shown by inefficiency collection of non-segregated solid waste. Mushrooming of illegal dumpsites along road sides, open spaces and use of poorly constructed and engineered landfills and incinerators is also evidence of insufficient institutional solid waste management.

Review findings indicated that after recognising inefficiency in institutional solid waste management, legal frameworks linked to institutional solid waste were implemented. These include Environmental Management Act, Public Health Act, Water Act, and Urban Council Act among others coupled by Environmental Impact Assessment policy. Nevertheless, despite existence of comprehensive legal framework institutional solid waste management remain problematic in Zimbabwe. This is because legislation and policies fail to support waste reduction alternatives like recycle and reuse coupled by inadequate enforcement. The dilemma of institutional solid waste is worsened by legal framework which disregard integrated institutional solid waste management approach. As a result, published literature demonstrated that institutional solid waste is threatening aquatic and terrestrial ecosystem while humanity is not spared. Improperly managed solid waste from institutions pose water, air and land pollution in Zimbabwe. Also, humans are affected by cholera, typhoid, diarrhoea, genetic mutation and respiratory ailments due to poorly disposed solid waste. Informal and formal solid waste workers who came into contact with institutional solid waste without safety gear are exposed to cuts and injuries. Similarly, reduced land aesthetic value and appearance of various types of scavenging animals at waste sites affect psychological health of people in the vicinity. Institutional solid waste management workers are vulnerable to occupational risks namely back pains, shoulder pain wrist pain and chest pain due to continuous lifting, loading and offloading of waste. Plants that absorb nutrients from contaminated soil are at risk of tissue mutation. Similarly, animals that utilise dumpsites as sources of food and grazing areas are susceptible to cancer, intestine blockage, and diarrhoea or even choked to death since they consume solid waste and green plants with pollutants. Therefore, review results demonstrated that existing institutional solid waste management approach bisect the environment negatively from all angles.

Considering this, integrated institutional solid waste management system is deemed a comprehensive solution. This system enables the country to adopt the most accepted approaches such as recycle, reuse and prevention on the waste management hierarchy. The system reduce quantity of solid destined in poorly engineered dumpsites hence reducing environmental health risks. Integrated management approach create both formal and informal employment through opening up of formal and informal recycling centres. Therefore, people benefited financially from solid waste thus the goal of poverty alleviation can be reached through integrated institutional solid waste management. Also, integration of various stakeholders facilitates sharing of ideas and resources in planning, decision making and construction of disposal and treatment facilities. Through, integrated management approach thorough enforcement of legislation and follow ups is guaranteed. Consequently, information gathered disclose how crucial integrated solid waste management approach is. Hence, the developed integrated institutional solid waste management model in **figure 1** is expected to pave way for sustainability.

Declarations

Authors' contributions

Takunda Shabani (T.S): Preparation and writing of original draft.

Steven Jerie (S.J): Reviewing and formal analysis of the review paper.

Consent to publish

All authors agreed to publish the review

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The authors declare no conflict of interest

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Figures

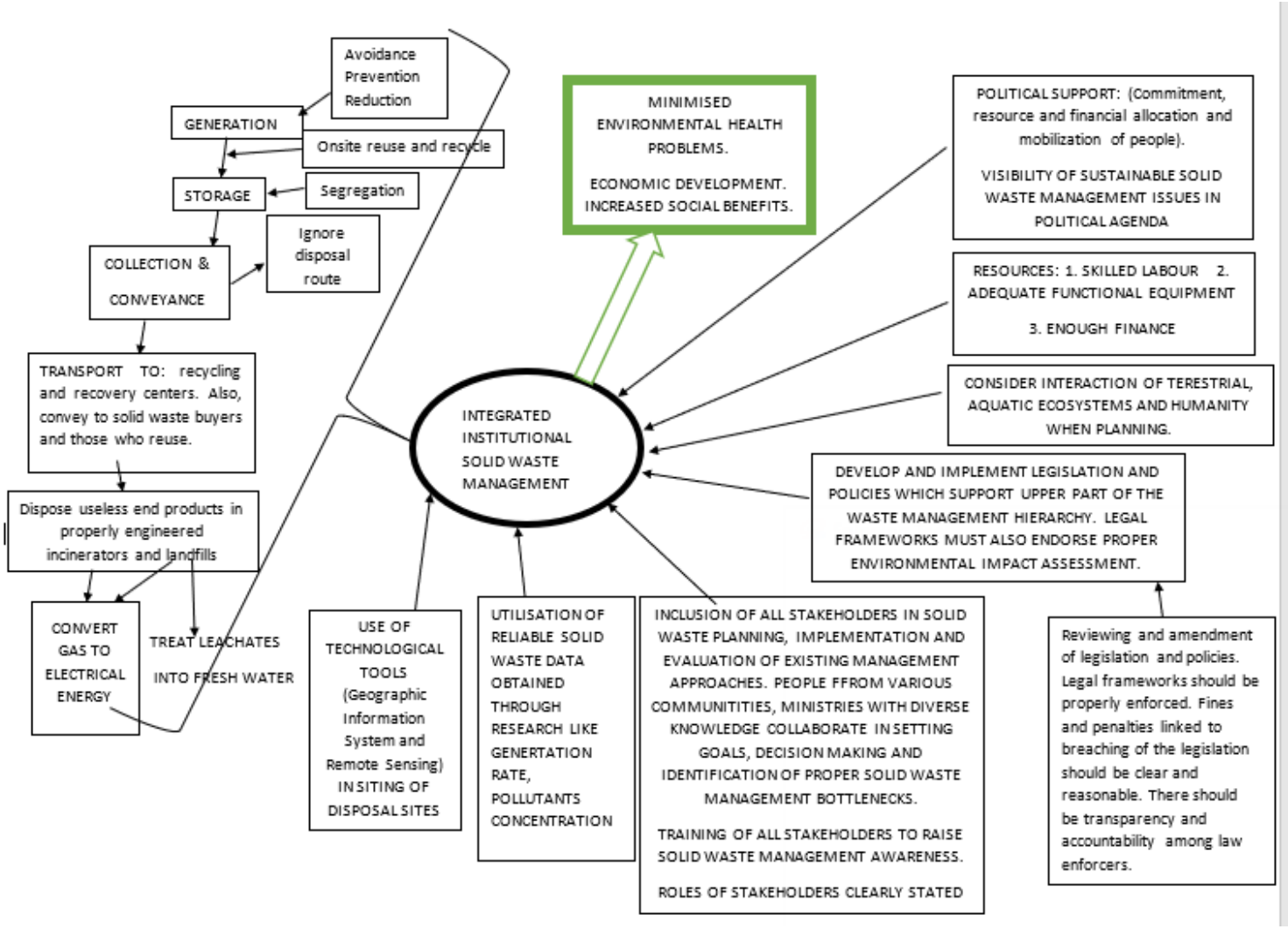

Figure 1

INTEGRATED INSTITUTIONAL SOLID WASTE MANAGEMENT MODEL

SOURCE: AUTHORS