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Climate Change Mitigation and Adaptation through Anaerobic Digestion of Urban Waste in Malawi: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author HBNC wrote the fast draft and authors RGM and EOA contributed to the subsequent drafts and performed further editing of the study. All authors read and approved the final manuscript.

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ABSTRACT

Improper waste management and disposal in major cities of Malawi transpires to be one of the major environmental setbacks as waste remains uncollected and usually disposed in open dump sites. Such waste emits greenhouse gases (GHGs) into the atmosphere that contribute to global warming and climate change in addition to pollution of water sources. The effects of climate change to Malawi have been far reaching to the extent of experiencing floods and droughts. This in retrospect has also had lasting impacts on Shire River where more than 95% of the country's electricity is generated. Consequently, the rate of power generation is greatly hindered which has thus left only 11% of the population with access to electricity partly due to droughts. This paper therefore focusses on the capturing of methane from municipal solid waste as a solution to climate change and energy challenges through the utilization of methane, a combustible gas which is beneficial in regard to cooking, heating and electricity generation. This is amplified with particular review of the challenges, opportunities, policy framework in place and the pertinent role of anaerobic digestion as the game changer in climate change mitigation and adaptation in Malawi.

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1. INTRODUCTION

Malawi, a country located in the South-Eastern Africa is one the poorest in the world, ranking 171 out of 188 countries in the 2018 Human Development Index [1]. By 2018, the country had a population of 17.5 million people where the majority lived in rural areas [2]. Poverty levels are very high especially in the rural areas of the country where people do not have access to basic services such as water, sanitation and electricity among others. Currently, there is high rate of urbanisation as more people move to the urban areas in search for better livelihoods [3].

It is anticipated that the country's urban population will reach a third of the total population by 2050 [4]. One of the major challenges that are being experienced due to urbanisation is the provision of essential services such as waste collection, clean water and housing [3]. Waste management in urban Malawi will continue to be a challenge [5], as waste generation rates keep on rising partly due to changes in lifestyle, consumption patterns and extended use of disposable materials [6].

In Malawi, most cities lack sufficient resources to properly manage waste [7] which consequently contributes to low waste collection rates [8]. Collected waste is dumped in the city's open dump sites where uncontrollable burning and biodegradation takes place while waste that is not collected ends up being dumped in public places and water bodies [9], which eventually makes it dense and difficult to combust [10]. Substantially, all these waste disposal methods in current practice contribute to Greenhouse Gases (GHGs) emission which leads to adverse weather implications [11].

Reducing GHGs emission is in the interest of Malawi considering that the country is greatly affected by climate change [12]. The country experiences droughts and floods frequently which among others affect power generation [13,14]. Therefore, the country needs to join the global fight on climate change by contributing to GHGs emission reduction.

Municipal Solid Waste (MSW) management decisions can impact on the release of GHG emissions that contribute to climate change and global warming [15]. MSW during its biodegradation emits methane into the atmosphere, a gas which is 25 times more potent GHG than carbon dioxide (CO_2) [16,17]. However, most developing countries like Malawi have limited financial resources for waste management therefore the country needs to adopt cost-effective measures for managing MSW [18]. Controlled biodegradation of MSW through anaerobic digestion (AD) treatment can play an important role in cutting emissions from MSW which serves as one of a kind under the Clean Development Mechanisms (CDM) through the Kyoto Protocol scope of projects in developing countries that could enhance waste handling and reduction of emissions though methane capture [10]. Control and reduction of GHG emissions from the waste sector is regarded as cost-effective when compared to other sectors of the Kyoto Protocol [19], as such waste related projects can easily be implemented by Malawi with the few resources available. In addition, methane gas being combustible, it can be used as an alternative source of energy for cooking, heating and electricity generation thereby helping to reduce overdependence on fossil fuels [20], which is in view of the country's vision 2020 [21].

2. AN OVERVIEW OF MUNICIPAL SOLID WASTE GLOBALLY

Waste management is regarded as a basic human right [22]. As such, one of global goals on waste management within the Post-2015 Global Agenda is to ensure access for all to adequate, safe and affordable solid waste collection services by 2020 [11]. The waste challenge is regarded as a global rather than a local environmental issue due to its contribution to GHG emission and climate change [23], [24]. Globally, cities generate 1.3 billion tonnes of waste every year and it is anticipated that by 2025 waste generation will grow to 2.2 billion tones [25].

Most developing countries like Malawi are struggling to manage their urban waste mainly because waste management is expensive. Currently, the cost of waste management globally is at $205.4 billion. However, this amount will increase to about $375.5 billion by 2025 [25]. The most opportune are the developed countries where MSW management has improved as energy efficient and environmental friendly technologies are being employed [15,24]. Conversely, in developing countries both collection coverage and controlled disposal rates are still very low [26,27] regardless of waste management constituting the bulk of a municipality's budget whose cost increment severity is anticipated to proliferate.

Habitually, inefficient waste management practices such as open dumping and burning of waste to reduce waste volumes are still prevalent in the management of MSW in low income countries [28]. The outcome of such practices leads to emission of GHGs that contribute to climate change and global warming [29]. On global scale Malawi's contribution to GHG emission is very low; however the impacts of climate change have serious implications on the country [30].

3. COUNTRY POLICY AND REGULATORY FRAMEWORKS

Malawi is a party to a number of international treaties and instruments on climate change which among others are the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, as well as the Paris Agreement [31]. In harmony with these treaties, the country developed its National Climate Change Management Policy (NCCMP) that guides the implementation of relevant provisions enshrined in those international treaties and legislations [12,30]. The policy also affirms the government commitment to addressing climate change issues in Malawi through adaptation and mitigation, capacity building and technological transfer. The 2004 National Environment Policy (NEP) is well supported by the 1996 Environment Management Act. NEP also resonates with the NCCMP as it deals with issues such as reduction of air pollution and GHGs emission [12,23].

Local councils have a great role to play in climate change mitigation and adaptation [32] as they are responsible for local development activities which catalyse and sustain behavioural change at a local level [33]. The 1998 Local Government Act mandates city councils to promote infrastructural development [34,35] including development of proper waste management infrastructure in the cities [9].

4. URBANISATION AND WASTE MANAGEMENT IN MALAWI

4.1 Urbanisation

Urbanisation is characterised by drastic increase in population possessing vast cultures, economic activity and land use [2,35]. The urban population in Malawi increased from 850,000 in 1987 to 2.8 million in 2018 which is as of this publication representative of 16 percent of the total population [2]. In developing countries, rural to urban migration is regarded as a contributing factor to shortages in provision of basic services [35]. And usually, the rate of infrastructural development in urban areas does not match with the growing urban population which eventually poses challenges to provision of basic services such as waste management [6,36,37]. City councils are struggling to manage waste properly in cities of Malawi [38] as evidenced by low waste collection rates in the cities, partly due to lack of the required resources for waste management [39].

The oversight role of waste collection in district and city councils is under the auspices of the Ministry of Local Government and Rural Development (MoLGRD) but the country lacks a waste management law [9]. This has far reaching consequences on the regulatory authorities in drawing a line between their jurisdictions hence limiting proper law enforcement. The unwillingness of the government to support start up waste management initiatives exacerbates the problem further [8].

4.2 MSW Generation

Developing countries usually generate significantly less waste as compared to developed countries due to a difference in industrialisation levels, however developing countries are faced with more waste management challenges than developed countries [28]. In the case of Malawi, there has been a sharp increase in waste generation in recent years due to the significant population and economic growth [9,40]. According to [41] the overall waste generation for the four major cities of Malawi which are Lilongwe, Blantyre, Mzuzu and Zomba in 2014 were as indicated in the Table 1.

The characteristic percentage of organic matter in MSW for most low income countries ranges from 40-85% [25] which was evidenced by the

NCST study performed in the four major cities of Malawi where more than 68% of the waste generated in 2014 was organic. The sum of generated waste in Tab.1 stems to an organic content of 709 tonnes from which a theoretical biogas potential of 32,174 m^3/day can be realized. It is anticipated that waste generation for cities of Blantyre, Lilongwe, Mzuzu and Zomba by the year 2025 will increase to 610, 862, 193 and 103 tonnes/ day respectively [41]. These projections further widen the opportunity for more gas generation due to a 70% increment (493.24 tonnes) in organic matter for these cities with respect to the base year. The promise of AD development can be hinged to target areas including boarding schools, prisons, markets, health institutions, commercial premises (hotels and lodges) and in households.

4.3 MSW Collection

In developing countries the waste collection and disposal activities consume 80-90 percent of municipal solid waste management budget, yet less than 50% of the population is served [42]. The waste collection is greatly affected due to inadequate resources by city assemblies and consequently low waste collection (Fig. 1) rates have been recorded in all four major cities of Malawi. Waste collection in the country is done by private operators, contractors, own collection as well as city councils. The two former waste collection service providers collect customers' waste at a fee while the latter two are free.

NCST [41] reported that waste collection rates for the cities of Blantyre, Lilongwe, Mzuzu and Zomba in 2014 were between 14.0% and 18.6%. Regular waste collection usually is limited to commercial, industrial, high and middle-income areas in urban Malawi [35,43]. This eventually leaves the low-income areas throughout the country underserved if not unattended to [8].

A recent study by [43] on 1256 residents in Blantyre, the second largest city in the country revealed that the willingness to pay (WTP) is still a critical issue to be addressed which is overly dependent on the age, gender and level of satisfaction. This therefore reduces private sector's involvement in waste collection and disposal. Waste collection efforts are further hampered by lack of access roads in informal settlements [39], yet infrastructure development was one of the key aspirations of the country's Vision 2020 that requires prompt attention in fast tracking environmental sustainability through provision of social services that provide a platform for the country to attain middle income status [21].

Table 1. Waste generation in four major cities of Malawi

City	Population	Waste Generation (Tonnes/Day)	Generation rates (Kg/ day /employee)
Blantyre	849,741	403.32	0.475
Lilongwe	978,780	482.35	0.493
Mzuzu	209,094	100.17	0.479
Zomba	130,377	56.49	0.433
Total	2,167,992	1,042.33	1.88

Source: [41]

Fig. 1. Uncollected waste at a hospital
Source:[41]

4.4 MSW Disposal

Municipal solid waste disposal is a major challenge especially in developing countries [26], [44], mainly due to the burden posed on the municipal budget [45]. As a result, open uncontrolled dumping still is the method of MSW disposal that is normally used. Poor waste disposal methods have led to serious environmental pollution and ecological deterioration in developing countries [40,46]. This thus leaves the country at a very critical stage necessitating implementations with regards to appropriate waste disposal techniques.

In order to address the challenges associated with waste disposal, there is a need to employ appropriate technologies and efficient facilities that can help to protect the environment [9,36]. However, low income countries have trailed the uptake of advanced technologies for waste disposal due to funding constraints and lack of expertise and technological awareness [6,44]. Conversely, the adoption of these technologies shall provide jobs, improve health standards and in the long term conserve the environment.

There are a number of common methods of waste disposal employed globally of which controlled and uncontrolled burning are amongst those that are widely used. Burning of waste can be categorized into residential open burning which is done in order to get rid of uncollected waste; deliberate open burning in landfills and open dump sites which usually is done in order to reduce waste volumes; spontaneous burning in landfills and open dumpsites which happens due to unintentional fires; and incineration which is an acceptable technique for waste management [18,28]. However, in Malawi just like in many other developing countries incineration technology which is a controlled form of waste burning is not yet employed.

In Malawi, open dumping is commonly practiced by residents (Fig. 2) in areas that are not properly connected to the waste collection network [9,36]. Meanwhile, the uncollected waste remains dumped in public places and streams presenting health and environmental risks to the public [5]. In order to reduce waste volumes due to lack of collection residents usually burn waste in uncontrollable way. Currently, open dump sites are approaching saturation [35], therefore it becomes habitual to simply dispose waste negligently.

4.5 GHG Emissions from MSW

In Malawi it is estimated that in 2015 the country had an annual GHG generation level of 29,000 Gg CO_2 of equivalents which is anticipated to rise to 42,000 Gg CO_2 of equivalents in the year 2040, an increment of 38%. The major sectors contributing to GHGs (Fig. 3) emissions are agriculture, energy, forests and waste [47].

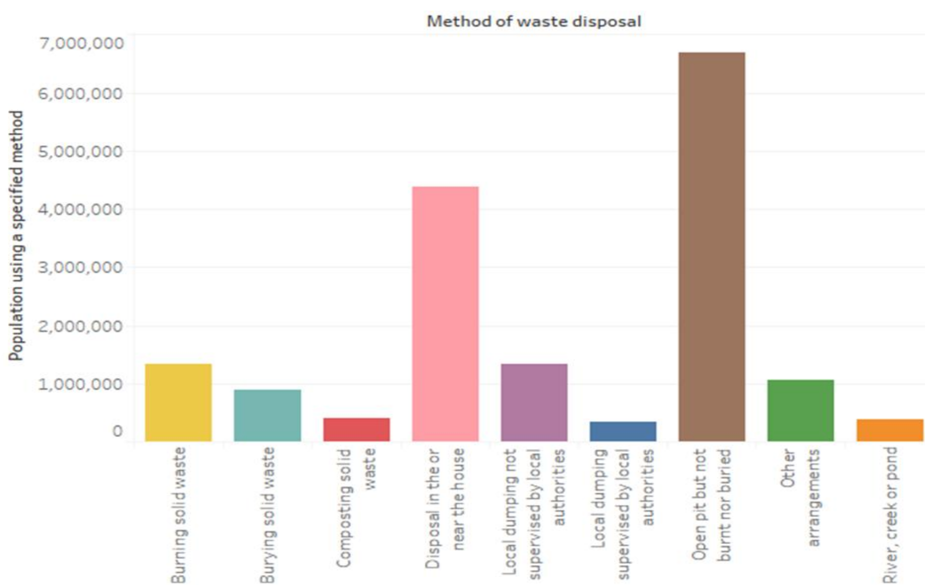

Fig. 2. Common waste disposal methods used in Malawi
Source: [41]

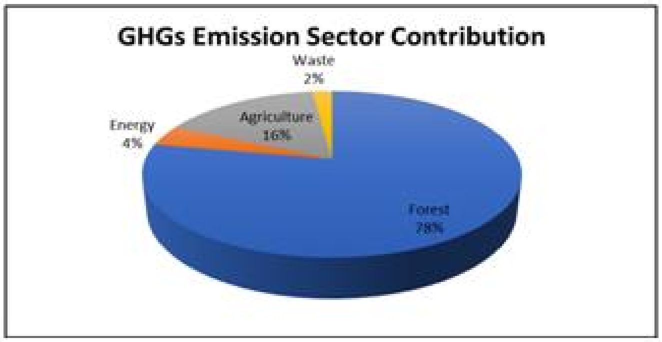

Fig. 3. GHG emission by sector in Malawi
Source: [47]

There is a strong correlation between poor waste management and environmental issues such as pollution and GHGs emission [18]. For a while now, there has been a great concern about GHGs emission from MSW [47] as they contribute to climate change and global warming. Organic wastes in landfills or dumps undergo anaerobic degradation releasing methane, a gas whose effect on climate change and global warming is 25 times that of carbon dioxide. Globally, waste disposal is associated with about 20-40 million tonnes of methane, accounting for 5-20 global anthropogenic methane [25].

The country has had its share of environmental concerns to contend with mainly due to the rapid population increase which has permitted a knock-on effect on environmental sustainability stemming from MSW. Furthermore, the use of inappropriate waste disposal technologies [46] escalates these concerns by imparting negative pressures leading to staggering site disposal capacities which is not only alarming but also underpinning the fact that conventional methods are still here for some time [2]. Ultimately, the environmental impact of such improper methods of waste disposal on large scale can be severe [11] considering the fact that open burning, that is widely practised is the major source of GHGs and toxic gases such as dioxins and furans [40]. It is satisfactory to note however, that the consolidation of the mitigation action plans in Malawi could save the environment from GHGs emanating from the waste sector a tune of 2,793 Gg CO2 equivalent between 2015 and 2030 [19].

5. CLIMATE CHANGE IN MALAWI

5.1 Status of Climate Change in Malawi

In present times the world is grappling with climate change challenges as the environmental changes are disrupting earth's life-supporting mechanisms in different parts of the world [19], with Sub-Saharan Africa being the most vulnerable to climate change [48]. The impacts of climate change in Malawi cannot be underestimated as the country has been experiencing droughts, erratic rainfall, floods (Fig. 4), strong winds and heatwaves [4,49], which influence energy access, water and food security [50,51]. It is estimated that currently more than 84 percent of Malawians who depend on natural resources based livelihoods and rain-fed agriculture are affected [52]. Increased vulnerability to the impacts of climate change have also hampered socio-economic development and this therefore led to the drafting of the NCCMP to demonstrate the government's commitment to climate change mitigation and adaptation [12].

Fig. 4. Flooding in Nsanje District of Malawi
Source: [53]

Fig. 5. The infestation of aquatic weeds on Shire River which affects power generation
Source: [57]

5.2 The Impact of Climate Change on Access to Electricity in Malawi

The electricity generation is almost wholly obtained from hydro [54] and as a result, there are high risks of energy insecurity in a climate change prone country like Malawi. Currently, over 96% of the electricity generated in the country is sourced from hydro schemes on a single river, Shire [14,49]. However, Shire River has been experiencing low water levels due to such droughts [53] which have contributed to a reduction in power generation [55]. According to ESCOM, in 2015 there was a power generation capacity reduction by 67% that was attributed to dropping water levels in Shire River. Furthermore, in instances of much rains, floods carry eroded soils full of nutrients into the river causing multiplication of aquatic weeds hence eutrophication [56]. Flooding further results into damage of infrastructure which could take time to reconstruct and consequently leading to power outages [54].

5.3 Waste-to-Energy (WTE)

Energy is regarded as the life-blood of any growing economy; therefore renewable energy will play an important role in achieving socio-economic development and environmental sustainability [58]. With the increasing demand for sustainable energy in many countries, WtE technologies are promising to provide reliable heat, electricity and transportation fuels [59]. The WtE market in 2015 was valued at about US$25 billion and it is anticipated that in 2020, it will reach US$36 billion [60], which is evident enough that the role of WtE in meeting energy demand is on the increase. Correspondingly, there underlies a great potential for reduction of waste disposal problems through embracing material energy recovery options. These WtE technologies are being driven by their role in meeting renewable energy and GHG emission reduction goals [61]. Examples of waste to energy technologies that are in use around the world are sanitary landfills, composting, AD, incineration and pyrolysis [61], [62]. The ultimate importance of WtE in energy generation, environmental conservation, material recovery and reduced dependence on fossil fuels therefore stands as an opportunity not to be missed in the country.

5.4 Organic Waste Potential in Urban Malawi

Decision makers especially local authorities are challenged with the problem of identifying the most economic, environmentally, socially, legally acceptable and technically feasible techniques for waste handling [7]. Understanding the waste quantities and their composition is very crucial when determining the most appropriate technique for handling of waste especially for WtE application [45]. In urban Malawi, a major fraction of MSW generated is organic [8,41]. In addition, most of it undergoes uncontrolled biodegradation in open dump sites in the cities. However, the use of AD in the treatment of MSW shall be significant provided waste segregation is carried out prior to the treatment as it is rarely practised [8]. With reference to the organic waste of 709 tonnes that was present in 2014 anticipated to be augmented to 1202 tonnes by 2025 [41], a good opportunity not to be neglected is thus presented. This organic waste resource base shall inevitably keep growing due to the increasing urbanisation rates [3].

5.5 Anaerobic Digestion (AD) of MSW and Its Role in Climate Change Mitigation and Adaptation in Malawi

AD is a microbiological process in which organic matter decomposes in the absence of oxygen, a process that takes place in an airproof reactor usually called a digester [27,59]. AD is one of the promising technologies for recovering energy from the Organic Fraction Municipal Solid Waste (OFMSW) [47]. During this AD process, biogas is generated which typically is made up of 60% methane (CH_4), 40% carbon dioxide (CO_2), water vapour and trace amounts of hydrogen sulfide [45,62]. Methane is a highly combustible gas that can be used as an alternative source of energy for heating, electricity generation and transport fuel [27]. Fig. 6, shows the methane generation from OFMSW and its uses.

Climate benefits of methane generation and usage are highly dependent on the feedstock, where organic waste as feedstock offers the best climate outcomes as compared to other materials [63]. In cities of Malawi the largest proportion of waste is organic, accounting for more than 68% [41], which can be used to generate more methane in an energy starved country [64].

5.6 Climate Change Mitigation

5.6.1 Decarbonisation of transport sector

The transport sector is the largest consumer of oil and its related products in the country [65], and therefore responsible for GHGs [66], inclusive of carbon dioxide and methane [67]. Globally, the transportation sector is responsible for about 17% GHG emissions which necessitates the drastic cutting of GHG emissions, among others by shifting to low carbon fuels [68]. Under this vein, liquefied methane is often seen as a decarbonization solution for the transport sector [69] which can substantially cut GHGs emission by 60-80% compared to gasoline [70].

The utilisation of bio-methane as a liquefied or compressed gas as well as the bio-syngas which forms the basis for producing fuels such as dimethyl ether, methanol, liquid hydrocarbons and hydrogen, shall enhance fossil fuel substitution with upgraded biomethane for the decarbonisation of the sector [66,71]. A car running on gasoline can easily be converted by adding a second storage cylinder and fuel supply system for bio-methane so that it operates on either of the fuels [70].

The National Environmental Policy of Malawi emphasizes on addressing climate change by reducing GHG emissions from the transport sector [72], which among others can be achieved through the use of cleaner sources of energy. The use of biofuels in form of ethanol is not novel in Malawi as the practise of blending of petrol with ethanol was approved by Malawi Energy Regulatory Authority (MERA) [73]. Therefore, a combination of biofuels like methane, ethanol and biodiesel can play a crucial role in decarbonizing the transport sector in the country[63,68].

5.6.2 Reducing carbon-footprint of Electricity Supply Industry (ESI)

Over the years there has been an increase in demanded for oil in the ESI as diesel generators have been employed by Malawi Electricity Supply Commission (ESCOM) and Energy

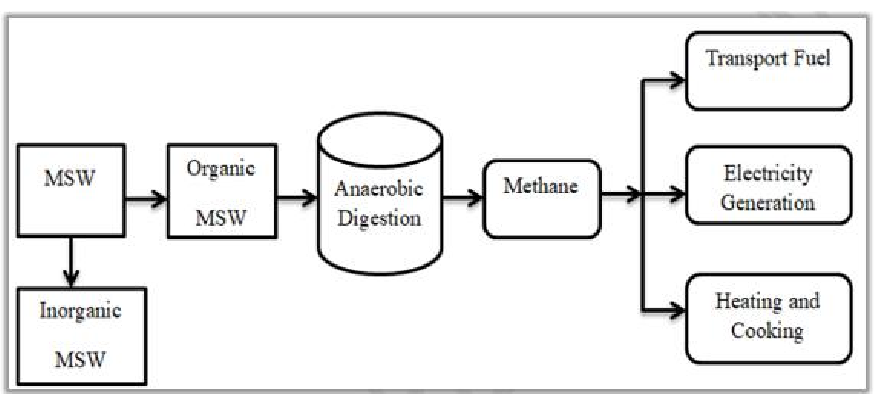

Fig. 6. Methane generation and its potential use

Fig. 7. Diesel generators in operation in Malawi
Source: [77]

Generation Company (GENCO) to provide 130 MW of peak capacity [74,75]. Methane (biogas) can be used to generate electricity through the use of micro turbines, fuel cells and hydrogen production [76]. And as a measure as well as strategy for meeting the close to doubling electricity demand, methane generation from renewable biomass can replace the use of fossil fuels and reduce GHG emission from the ESI [45]. Fig. 7 shows diesel generators employed in Malawi as the country experiences power generation challenges.

5.6.3 GHGs emission reduction from uncontrollable biodegradation and burning

Controlled biodegradation of MSW through use of AD technology helps to reduce the emission of GHGs in the atmosphere especially for methane which is more dangerous than carbon dioxide [78]. On average AD provides the least GHGs reduction per metric ton as compared to other waste treatment methods such as land filling with gas extraction and incineration [45]. However, landfilling with gas extraction technology is far from being adopted in Malawi unlike biogas technology which is being used in many parts of the country though on small scale especially by farmers [79].

5.6.4 Reduced deforestation

It is estimated that 97% of Malawians rely on fuelwood for cooking and heating related activities. This has endangered the downstream ecosystem and favoured climate change. This is mainly because forests are natural carbon sinks and as such play an important role in climate stabilization [80]. However, the efficient use of methane generated from MSW as an alternative source of energy as opposed to charcoal and fuelwood can also help to reduce deforestation (estimated to be at 2.8 percent per annum) as well as promote environmental conservation in Malawi [79]. Corrective actions call for the diversification in the use of available energy sources of which MSW forms part to suitably cut down on deforestation because forests shall still need to be part of the future energy mix.

5.7 Climate Change Adaptation

5.7.1 Methane as an alternative source of energy to unreliable hydropower

The adoption of methane capture from MSW at decentralised areas, shall aid in provision of energy for localised productive uses unlike the dependence on the centralised grid that is both unreliable and also costly due to the need to transfer power lines to remote locations [58]. Therefore, the use of methane as an alternative to unreliable hydropower can help the country adapt to the impacts of climate change on energy access as well as supply power to the growing demand [49].

5.7.2 Methane generation providing alternative livelihoods through employment creation

Poor people around the globe are more dependent on ecosystem services and products; therefore vulnerability of the natural systems has great implications on their livelihoods [81].

Climate change interacts with various aspects of people's livelihoods [82], including land, energy, water and agriculture. The impact of climate change on agriculture is a concern globally [83], especially for agro-based economies like Malawi where farming is the source of livelihood to the better percentage of the population [39]. A successful adaptation to climate variability demands diversification of livelihoods [83], which among others involves employment creation. The methane (biogas) industry may provide employment to a number of people in activities such as feedstock supply, methane generation, transportation and marketing, thereby providing an alternative source of income for improved livelihoods.

6. CONCLUSION

The urban population in Malawi is growing and thereby contributing to high waste generation rates. Meanwhile, local authorities are struggling to manage such waste whose magnitudes are simply proliferating and as a result, such waste is becoming a source of GHG emissions due to uncontrollable burning and biodegradation. AD of organic MSW can play an important role in reducing GHG emissions from MSW thereby helping in climate change mitigation. On the other hand, methane produced from carbon neutral biomass apart from reducing deforestation can also help to reduce the consumption of fossil fuels which are a major source of GHGs in the energy sector. Hydropower being the main source of electricity is greatly affected by climate change due to droughts for which diversification into use of other energy sources shall be pertinent to solve the recurrent issue of power cuts.

Therefore, reinvigorating methane from MSW as an alternative source of energy for heating, cooking and electricity generation can play an important role in helping the nation adapt to the impacts of climate change on energy access. However, in order to maximise the environmental and socioeconomic benefits of AD of OFMSW, there is a need for government to come up with proper policies that override the prevalent inter policy overlap so as to help guide the biofuels industry in Malawi.

7. RECOMMENDATIONS

- Government of Malawi (GoM) is making efforts to reduce GHGs emissions from different sectors of economy. However, little is being done to address emissions from MSW. Therefore, energy recovery from OFMSW through AD among others should form part of an integrated waste management in the cities.
- In order to take advantage of large quantities of organic waste generated in the cities for AD there is a need to promote source separation of waste as AD is very sensitive to impurities which affect the operation of digesters.
- Currently, AD is used on small scale especially by farmers, prisons, health and education institutions as such its impact on climate change mitigation and adaptation is limited. Therefore, in order to increase the benefits of AD of OFMSW, the country needs to move towards commercialisation of methane generation, which may also provide alternative livelihoods through employment and business creation.
- GoM introduced carbon tax on old vehicles in 2019 in order to decarbonise the transport sector. However, revenue from the carbon tax among others should be used to develop the biofuels industry, an important sector not to be left behind in the attainment of the country's vision.
- GoM should phase out subsidies on petroleum in order to make biofuels more competitive in view of alignment of the country policies to global environmental goals.
- Effects of unreliable hydropower caused by climate change on national economy can be minimised through diversification of sources of electricity. This among others can be achieved through electricity generation using methane.
- In addition, considering the fact those solutions best suited for proper MSW management need to both be cost effective and socially acceptable, the increased adoption of AD shall be able to provide slurry which shall boost agriculture while encouraging sustainability.
- Since waste management incorporates a multi – tier governance system, proper co-ordination of the central agencies which are mandated to formulate the strategies and policies together with the local authorities that perform the implementation shall prove very necessary moving forward.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declare no competing interest exists.

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