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Interrelation between Climate Change and Solid Waste

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Abstract

Climate change causes an increase in mean temperatures and sea-level, increasing the potential for droughts, flooding, and heat waves. Global solid waste generation rates range from 0.1-0.8t/cap/yr (tons per capita per year) in low-income, 0.2-0.5 t/cap/yr in middle-income and 0.3-0.8 t/cap/yr in high-income countries which is positively correlated with per capita energy consumption, gross domestic product, and private consumption. Solid waste is an important cause of greenhouse gases emissions, providing about 5% of GHGs in the form of carbon dioxide, methane, and Nitrous oxide. This paper is aimed at reviewing the relationship between solid waste and climate change. Flooding creates large quantities of household waste which increases the load on nearby waste sites; heat waves increase odor and dust from sites. Increase in precipitation in winter might increase the risk of flooding affecting facilities, access, and use of mobile waste management plants. Rising sea levels will lead to increased flooding and erosion of coastal dumpsites causing increased pollution of coastal waters. Integrated Solid Waste Management prioritizes waste prevention, reuse, recycling, and energy recovery from waste. To reduce the vulnerability of solid waste management dependency on transport, energy, ICT and water infrastructures, shorter transport distances and more local waste treatment plant, increased water use efficiency, onsite renewable energy generation, and increasing diversity of treatment technologies are suggested.

Keywords: Climate Change; Greenhouse Gases; Solid Waste; Adaptation

Introduction

Earth is under pressure of rapidly changing different extreme weather events such as droughts and flooding. It is universally recognized that the Earth's lower portion and large water bodies are heating progressively because of man-made effects [1].

Many anthropogenic causes to climate change include burning of fossil fuel for energy generation, vehicular propulsion and industrial usage, deforestation, agricultural and waste sector [2]. Increased carbon-based energy and materials consumption in developed countries are among leading causes for the decline of all major life support systems on Earth. Power usage donates straightly to climate change by releasing carbon containing compounds into the atmosphere in surplus of normally available concentrations [3].

A naturally available concentration of greenhouse gases (GHGs) such as: water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), covering 1 - 2% of the Earth's air, which soak-up part of incoming solar radiation that might be emitted back into atmosphere and supports warm the earth to an optimum and comfortable heat level. In the absence of normal "greenhouse effect," the current mean temperature 14 degrees Celsius on Earth could be approximately -19 degrees Celsius [4]. Climate change is an urgent ecological and hydrological worry which disturbs the natural balance of environment, and it became the issue of much research and debate in recent decades. Climate change causes changes in temperatures, cloud cover, rainfall distribution, wind speeds, and storms: those all would disturb upcoming waste management processes [5].

Solid waste is any solid material which is discarded after use by its owner, user, or producer. Solid wastes are left-over arising from human, animal and plant activities that are normally discarded as useless and not having any consumer value to the person abandoning them [6].

Waste generation and waste composition is different in different countries and different regions of the same country, mainly because of variation in population size, urbanization, life standard and wealth. Determinants like climate, level of education, and level of awareness might affect the quantity and quality of waste [7]. World solid waste production quantity varies from 0.1-0.8t/cap/yr (tons per capita per year) in low-income nations, 0.2-0.5 t/cap/yr in middle-income nations and 0.3-0.8 t/cap/yr in high-income nations [8]. Individual's waste produced through sectors diverges from 0.54 kg/cap/day in domestic, 0.018 kg/m^2/day in commercial, 0.015 kg/m^2/day institutional and 0.47 kg/m^2/day in lower and middle level industries [9]. In the world, about 2 billion individuals could not get waste collection facilities, and about 3 billion persons could not get well managed waste disposal services [10]. In small and medium economy countries, the large share of wastes produced is organic wastes, whereas in the high-income countries more homogeneous mixture of wastes is produced but with relatively larger part of plastics and paper [11].

In most parts of the world, population increment, economic growth, and expansion of urbanization, waste collection, recycling, treatment and disposal becomes major temptation to institutions because of rapidly changing climate. Waste generation rate indicates positive agreement with per capita power usage, gross domestic product (GDP) and end user's consumption [12].

The effect of climate change in United Kingdom forecasted to cause increased mean temperatures, outbreak of flood, sea-level rise, high heat waves, and imposes large pressure on water resources. Solid waste management infrastructures and other crucial infrastructures like road are very sensitive and highly exposed to the effects of climate change [13].

Solid waste can play its role in climate change which could release GHGs and climate change can also have its effect on solid waste management. Total greenhouse gas baseline emission from domestic solid waste is estimated as 153.41 ton per day carbon dioxide equivalent, while compostable and recyclable accounted 80.02% and 11.73% respectively [9]. Globally, most municipal solid waste (MSW) is dumped in uncontrolled landfills where landfill gas (LFG) is generated as a by-product. LFG is produced when organic material decomposes anaerobically, consisting of 45% to 60% CH_4, 40% to 60% CO_2, and 2% to 9% other gases which are mostly released to the atmosphere [14]. The decomposition of organic wastes release CO_2 and CH_4 which are main GHGs gas, but inorganic waste does not contribute directly to greenhouse gas emissions unless it is incinerated. CH_4 is created where there is anaerobic reaction while CO_2 is the natural product when an aerobic reaction takes palace [15]. Both CO_2 and CH_4 are greenhouse gases, which contribute to global warming and climate change; however, the relative share of solid waste to climate change is low.

According to Hay JE, Sem G, the contribution of CH_4 emission from landfills and dumps for greenhouse gas is only 1.7% of the total emissions from the Pacific islands region [16]. Climate change has accelerated the need to find a solution to reduce and manage the wastes we are creating. Climate change affects all solid waste management of activities like collection, separation, treatment, transfer, and disposal with varying levels of sophistication [17].

Rising sea levels due to the warming climate will lead to increased flooding and erosion of coastal dumpsites causing increased pollution of coastal waters. Extreme weather events like cyclone, hurricane and strong wind may damage road infrastructures which give rise to disaster on solid waste transportation and processing. Increased numbers of cold days at winter season decrease biological waste treatment (composting and anaerobic digestion). Solid waste deposition area is subjected to the effects of changing weather events. Flood events create large quantities of household waste which increases the load on nearby waste sites; winter storms make accessing sites and transporting waste difficult; heat waves increase odor and dust from sites [13].

Reduction and reuse of waste will help to reduce pressure on the planet's natural resources while potentially reducing emission of greenhouse gases created through mass production and burning of fossil fuels. This review aims to explain the relationship between climate change and solid waste management and to discuss the adaptation measures. It is believed that this manuscript will provide an overview to students, policy makers, or is it to raise awareness among practitioners in the field of relation between climate change and solid waste management.

Effects of Climate Change on Solid Waste Management

Changing Precipitation

Rainfall patterns are changing, and there is an increased probability of extreme weather events such as frequency and duration of drought, cyclones, and hurricanes. Extreme precipitation events would destroy infrastructure and property, which could more complicate the processes of solid waste management. Severe weather events disturbed sunken World War II wrecks, of which there are over 800 in the Pacific, and increased the risk of marine pollution [15].

Increased extreme daily precipitation and higher frequency of extremely wet days might increase the risk of flooding which may affect facilities, access and use of mobile waste storage facilities and increase the risk of flood-related damage to critical infrastructure and suppliers (transport, energy, and ICT) [13]. It also raises the risk of site drainage systems which over flooded during heavy rainfall. During heavy rainfall, open waste storage container will face a danger of waterlogging which affects processing of waste materials. Heavy rainfall increases the risk of erosion and instability of bunds and capping layers of waste management structures. High precipitation can change waste decomposition rate and frequency and increase leachate strength that affects waste damping sites [5].

Changes in seasonal precipitation patterns like wetter winters with less snow and drier summers with a greater likelihood of drought can change the overall hydrology of waste management site. It increases the risk of subsidence in clay substrate areas, with impacts on buildings and facilities and increases the volume of leachate during winter. At drier summer, flow volume might be reduced, but the concentrations of organic waste streams become higher. More frequent low flows in rivers and canals during summer affects riverine and canal waste transportation accesses. Low precipitation reduces water availability for wet processes and site management, particularly during summer. Drought also increases stress on vegetation used in landscaping, screening, and waste management site restoration during summer.

Changing Temperature

Temperature fluctuations by climate change which affects solid waste management increase in average and minimum temperature, increase in daily maximum temperatures and higher frequency of "very hot" days and heat waves in summer. Increased average and minimum temperatures increase rates of waste decomposition and degradation which affect health and safety of workers, quality, and reliability of waste management infrastructure [13].

Extreme temperatures damage and disrupt mechanical parts of machinery used for waste management and increase costs required for maintenance (e.g., to transport). Increase in daily maximum temperatures (and higher frequency of "very hot" days and heat waves in summer): increased health risks to employees from high temperatures and worse air quality [6]. It also increases the need for space cooling in buildings and facilities. High temperature also aggravates cause of fire risk from combustibles waste materials. Fast decomposition of waste causes unpleasant smells on peoples living neighborhood with waste treatment or dumping site.

Sea Level Increase and Wind Storm

Rising sea levels and increase in storm surges increase the risk of flooding/inundation at low-lying coastal waste management sites (Figure 1). Raised water level increases the risk of bund erosion in coastal waste management sites. As sea level increases, the risk of seawater intrusion to coastal landfill is also increased. Areas located at low lands with very small land size and many of the dump-sites located in swampy areas or coastal areas are very vulnerable to sea level rise. Rising sea levels due to the warming climate will lead to increased flooding and erosion of coastal dumpsites causing increased pollution of coastal water resources [5,15].

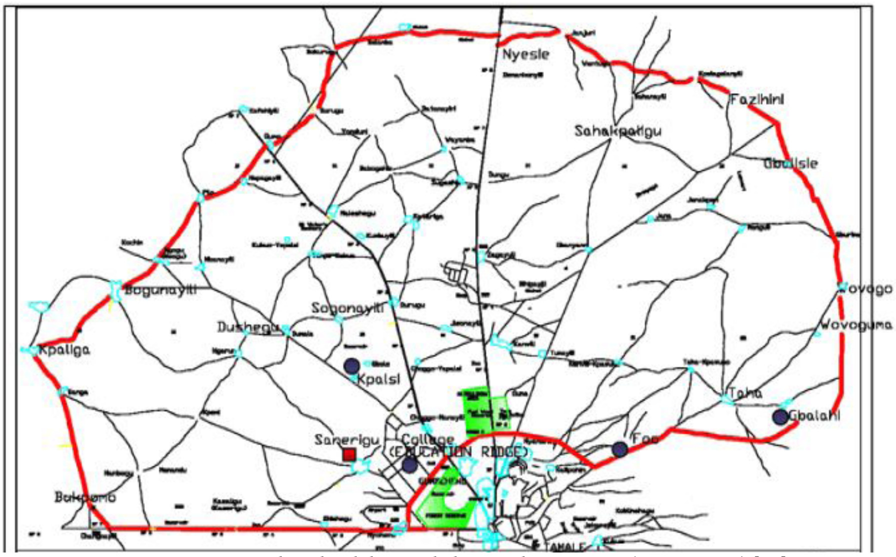

Figure 1: Increased sea level dismantled waste damping site (PYCC, 2009) [15]

Climate variables	Potential climate change	Impacts on Solid waste management
Temperature	Very high temperature	Increase water demand for workers and site operation
	More hot days increases in the dry season	Decline in air quality and following negative impacts of heat on vulnerable groups
	The number of cold days decreases in rainy season	Affects biological processes(composting, anaerobic digestion)
Precipitation	An increase of more water days	Increase risk of flooding
	Precipitation intensity increases	Disruption of infrastructure (rail, road)
		Affect slope stability on waste management site
		Affects biological processes(composting, anaerobic digestion)
Sea level	Increase sea level	Inundation of waste management facilities Increase erosion of coastal areas

Table 1: Summary of Impacts of Climate Change on Solid Waste Management [13,18]

Further, climate change can affect quality and quantity of natural resources and infrastructures which are directly or indirectly related to solid waste management as summarized above (Table 1).

Effects of Solid Waste on Climate Change

The estimated total quantity of MSW generated in the world is 1.7–1.9 billion metric tons [19]. Mainly, municipal wastes are not well collected, processed and disposed of in less developed countries, because cities and municipalities cannot cope with the increased rate of waste generation associated with limited financial capacity. Solid waste collection rates in some low-income countries are lower than 70%. Over 50% of the collected solid waste is sometimes disposed of through open landfilling, and about 15% is processed through risky and poor recycling methods [20]. Almost all MSW management processes produce GHGs during collection, transportation, composting, digestion, incineration, and landfill.

MSW management systems are thus a significant source of GHG emissions, contributing about 5% of global GHG emissions in the form of CO_2, CH_4, and N_2O [21]. GHG generated from MSW management is referred to as direct GHG emission. The most significant of which is CH_4, gas produced in landfill which is mostly released during the break down of organic matter. Collection and transport of waste cause indirect emission GHG due to the use of fuel for vehicle and from the infrastructure. Biological waste treatments include composting; incineration and anaerobic digestion directly release GHG into the atmosphere.

Landfilled organic waste is a major source of CH_4 emissions. These emissions are projected to potentially increase fourfold by 2050 compared to 2010 due to further population growth, increased carbon-based energy demand and economic development in low- and middle-income countries [17].

Greenhouse Gas Emission from Waste Sector

According to the 2006 IPCC guidelines, Solid waste management consists of four sub-categories: solid waste disposal, incineration and open burning, wastewater treatment and biological treatment of solid waste [22]. GHG emissions from solid waste disposal mainly consist of methane generated from anaerobic decomposition of organic material over time in solid waste disposal sites. As such, GHG emissions particularly depend on the quantity of organic matter in the waste.

Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. GWP and lifetime of GHGs vary based on their source released (Table 2).

GHGs and important sources	Reported for	Lifetime (years)	Global warming potential (GWP)	
			20 Years	50 Years
CO_2: Waste incineration (fossil carbon)	Waste sector	Variable and long	1	1
CO_2: Energy consumption during collection, transport, and treatment of waste	Other sectors	Variable and long	1	1
CH_4: Decomposition of organic waste in landfills under anaerobic conditions	Waste sector	12	72	25
N_2O: Composting, biological treatment; Waste incineration	Waste sector	114	289	298
Fluorinated compounds (HFCs, PFCs, SF6): Production, use, and disposal of various products such as electric/ electronic devices (e.g., fridges)	Other sectors	various	various	various
Black carbon (BC): Uncontrolled and open burning of wastes (e.g. "backyard burning") Treatment and transport (fossil fuel combustion)	Not reported	0.028	3200	910

Table 2: GHGs and resulting compounds from solid waste management, source [23,24]
GWP of CH_4 gases released from waste sector seems more dangerous because its lifetime extends up to a decade and its heating effect is relatively high for both 20 years and 50 years analysis.

Adaptation of Climate Change Effects on the Waste Sector

Compared to other sectors, the relevance of sustainable waste management for climate change mitigation might seem relatively easy. However, mitigation activities in the waste sector can have significant impacts on GHG emissions generated and reported in other sectors such as the energy and industry sector. International and national efforts towards climate-friendly waste management should follow the waste management hierarchy. It priorities waste prevention, reuse, recycling (including composting) and energy recovery from waste before landfilling and open dumping or burning [25]. Global Waste Management Outlook estimates that around 10-15% of global GHG emissions could be reduced through improved waste management following a life-cycle assessment approach [10].

Waste Management Hierarchy (R steps)

Conventional waste management concentrates mainly on waste collection, processing (treatment, composting and incineration) and disposal or landfills [26]. A paradigm shift from conventional waste management practices to Integrated Solid Waste Management (ISWM) is crucial for cities development activities and community health through effective waste stream management. ISWM is comprehensive waste prevention, recycling, composting, and disposal program.

Reducing and recycling solid waste can help to curb the emission of greenhouse gases in four important ways [27]. There are R words used which are very important for solid waste management and to reduce the effect of climate change those are mainly concentrated on reducing waste generation [15]. Those R-words are; refuse using what you do not need, reduce what do you need, reuse what you cannot reduce, and recycle what you cannot reuse. Waste management hierarchy is essential to reduce the amount of solid waste generation, transportation demands and costs, and possible release of greenhouse gases.

Landfilling is the simplest and cheapest method for disposing of waste. Despite waste reduction and recycling policies and waste pretreatment programs to lower the proportion of waste going to landfill, landfills will still be required to accommodate residual wastes [28].

Papers that are used for office activities identified as the main source of solid waste [5]. The rise of computer technology for research, communications, and other everyday workplace functions has presented a major opportunity for source reduction in the modern office. Anaerobic digestion of solid waste treatment process releases methane gas which should be used as fuel energy instead of leaving to the atmosphere and increasing GHG. Establishment of a fully sanitary landfill where anaerobic composting and digestion is carried out can reduce up to 60% of the organic waste fraction and reduce the vast amount of GHG [14]. By doing so, we can reduce the impact of climate change on solid waste management, and we can reduce the effect of solid waste on climate change.

Reducing Interdependencies of Waste Infrastructure with other Infrastructure

The Infrastructure interdependencies have been identified in many recent studies [29]. Waste infrastructures are predominantly dependent on transport, energy, ICT and water infrastructures (Figure 2).

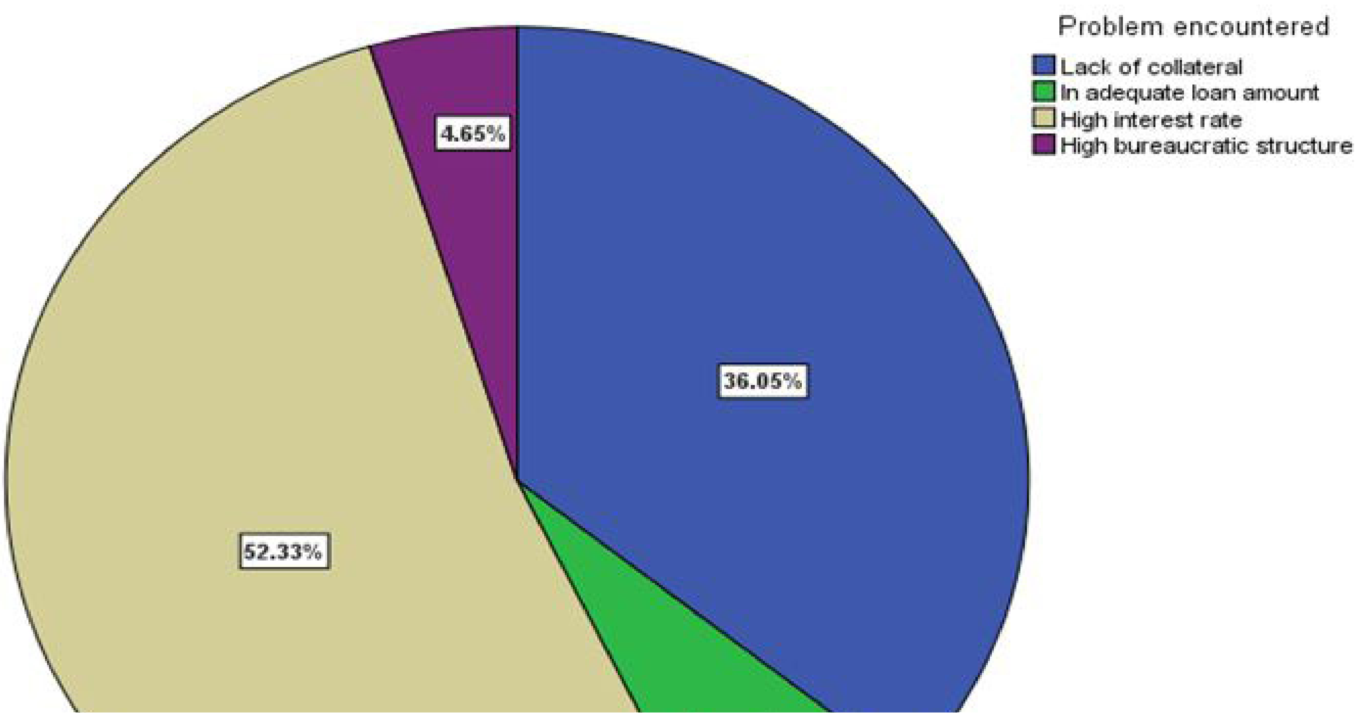

Figure 2: Interdependencies of Waste Infrastructure with Others [13]

To reduce the vulnerability of solid waste management dependency on those infrastructures, there suggested strategies:

- Shorter transport distances and more local waste treatment – may reduce vulnerability to transport disruption.
- Increased water efficiency – may reduce dependence on scarce water supplies

⊳ Onsite renewable energy generation and closed-loop power system – may provide resilience from impacts affecting energy networks.
⊳ Increasing diversity of treatment technologies – may provide greater flexibility if some facilities are temporarily inaccessible.

Conclusion

Anthropogenic activities release GHGs in excess of naturally occurring amounts which becomes the main source of climate change by adding carbon-based molecules to the atmosphere. Climate change is predicted to increases in mean temperatures and sea-level rise, increasing frequency and severity of droughts, flooding, heat waves and greater pressure on water availability.

Solid wastes are waste ruminants left-over after using human, animal or plants that are normally discarded as valueless. Waste generation rates have been positively correlated with per capita energy consumption, GDP, and final private consumption. Global solid waste generation rates range from 0.1-0.8t/cap/yr (tons per capita per year) in low-income countries, 0.2-0.5 t/cap/yr in middle-income countries and 0.3-0.8 t/cap/yr in high-income countries.

Solid waste is identified as the source of GHG emissions, contributing about 5% of global GHG emissions in the form of CO_2, CH_4, and N_2O. The most significant of which is CH_4 gas produced from landfill which is mostly released during the break down of organic matter, but inorganic waste does not contribute directly to greenhouse gas emissions unless it is incinerated.

Sea level rise will lead to increased flooding and erosion of coastal dumpsites causing increased pollution of coastal waters. Flooding increases quantities of domestic waste which increases the load on nearby waste sites and affecting facilities, access and use of mobile waste management plant and increase the risk of flood-related disruption to critical infrastructure and suppliers (transport, energy, and ICT). Winter storms make a difficulty of accessing the sites and transporting of waste and heat waves increase pollution from smell and dust from sites.

Integrated solid waste management priorities waste prevention, reuse, recycling, and energy recovery from waste before landfilling and open dumping or burning.

Waste management infrastructures mainly dependent on transport, energy, ICT and water infrastructures. To reduce the vulnerability of solid waste management dependency on those infrastructures shorter transport distances and more local waste treatment plant, increased water use efficiency, onsite renewable energy generation, and increasing diversity of treatment technologies are suggested.

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