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Review Article

Reliable Waste Management and Ecological Consequences of Global Warming - A Review

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ABSTRACT

All human activities including day to day life routines lead to the generation of a variety of waste materials. These wastes have wide ranging compositions such as paper, cloth, residues of fruits, vegetables, organic substances, plastics, metals and host of other unclassifiable products. These wastes are collectively known as the solid wastes. The solid wastes are either biodegradable (degradable by bacteria or other other microorganisms) or non-biodegradable (not degradable by bacteria). In spite of efforts taken for safe disposal of solid wastes, pollution and contamination of the environment results due to the gaps in our approach to effective way for the solid waste handling and management. Human activities such as industrialization, the burning of fossil fuels and deforestation has increased the level of greenhouse gas concentrations in the atmosphere. An inappropriate waste management is a primary driver of climate change, contributing up to 20% of global anthropogenic emissions. Decomposing organic waste in landfills generates methane, a greenhouse gas roughly 28 times more potent than carbon dioxide. Global warming is a gradual increase in the earth's temperature generally due to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants. The chapter highlights the solid waste management and ecological consequences of global warming need for monitoring factors to climate change and developing sustainable strategies to maintain the integrity of ecosystems Climate change is one of the most important global serious environmental issues facing our planet. The way that we manage waste however is the most important factor that affects climate change. .

1. Introduction

Improper waste management is a primary driver of global warming. The anaerobic decomposition of organic waste in landfills emits methane (CH4), a greenhouse gas up to 86 times more potent than (CO2) over a 20-year span. Conversely, sustainable systems like circular economies, recycling, and waste-to-energy reduce emissions and conserve resources.
Global warming and waste management are inextricably linked. An Improper waste disposal particularly biodegradable waste decomposing in landfills generates potent greenhouse gases (GHGs) that accelerate climate change. Conversely, rising global temperatures degrade waste infrastructure, requiring sustainable, circular-economy practices to mitigate catastrophic ecological consequences waste management impacts on climate change. It is estimated that 3.4 percent greenhouse emit from waste sector and contributes to one fifth anthropogenic sources. Compared with other 15 sectors which are listed under Kyoto protocol, controlling, and reducing greenhouse gas emission from waste sector seems to be cost effective through clean development mechanisms. Waste management system is a streamlined process that organizations use to dispose of, reduce, reuse, and prevent waste. Climate change could result in changes temperature, rainfall pattern, wind speed, Storms, and cloud cover.

Sustainable waste management mitigates global warming by preventing methane emissions from decomposing organic waste, decreasing industrial energy consumption through recycling, and generating renewable energy. Conversely, improper disposal exacerbates climate change by polluting ecosystems, contaminating groundwater, and accelerating greenhouse gas releases.

Climate change is primarily driven by human activities and has emerged as a challenging issue of the 21st century. The

impacts of climate change are far beyond rise in temperature, erratic rainfall patterns, floods, and drought, extremely affecting the delicate ecosystem balance across the world. The present is waste and disposal has become a matter of concern owing to the enormous increase in population, the changes in our lifestyles, transport, communication and commercial infrastructures and unrestrained use of modern technology. In fact, waste management has emerged as a serious challenge having major implications not only for human health and social life but also for the environment. It is a global challenge because the earth surface temperature has increased over the last decades.

The major cause of global warming is the greenhouse gases. They include carbon dioxide, methane, nitrous oxides and in some cases chlorine and bromine containing compounds. The build-up of these gases in the atmosphere changes the radiative equilibrium in the atmosphere. Their overall effect is to warm the Earth's surface and the lower atmosphere because greenhouse gases absorb some of the outgoing radiation of Earth and re-radiate it back towards the surface. The objective of this study is to review the role of sustainable waste management in mitigating global warming by examining the environmental and ecological impacts of climate change, greenhouse gas emissions, and their effects on ecosystems and human health.

2. Solid waste

Solid waste refers to discarded materials generated from domestic, commercial, institutional, agricultural, healthcare, and industrial activities. Based on their source and characteristics, solid waste is broadly classified into biomedical waste, municipal solid waste (MSW), industrial waste, and electronic waste (e-waste). Each category requires specialized collection, segregation, transportation, treatment, and disposal methods because of its distinct physical, chemical, and biological characteristics. In India, the management of these waste streams is regulated through separate legislative frameworks, including the Solid Waste Management Rules, 2016, Bio-Medical Waste Management Rules, 2016 (amended), E-Waste (Management) Rules, 2022, and Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016. Effective waste management follows a hierarchy of waste prevention, reduction, reuse, recycling, recovery, and environmentally sound disposal, thereby minimizing environmental pollution and greenhouse gas emissions. The transition from a linear economy to a circular economy has become a key strategy for achieving sustainable waste management and climate resilience (UNEP, 2024; CPCB, 2023).

Municipal Solid Waste (MSW) comprises household refuse, commercial waste, institutional waste, market waste, street sweepings, construction debris, garden waste, food residues, paper, plastics, glass, metals, textiles, and other discarded materials generated in urban areas. In India, Urban Local Bodies (ULBs) and Municipal Corporations are primarily responsible for MSW management through the Public Health and Sanitation Departments under the supervision of the Municipal Commissioner. Their responsibilities include waste collection, segregation at source, transportation, processing, recycling, composting, waste-to-energy initiatives, and scientific landfill management. According to the Central Pollution Control Board (CPCB) Annual Report 2022–2023, India generates approximately 1.7 lakh tonnes of municipal solid waste per day, with collection efficiency exceeding 90% in many urban areas. However, only about 55–60% of the collected waste is scientifically processed, while a substantial proportion continues to be disposed of in open dumpsites and landfills, resulting in methane emissions, groundwater contamination, and public health risks. Rapid urbanization, increasing consumption patterns, inadequate source segregation, and limited recycling infrastructure continue to challenge sustainable MSW management (CPCB, 2023; Ministry of Housing and Urban Affairs, 2023).

Biomedical waste and industrial waste require greater attention because of their hazardous nature and potential impacts on human health and ecosystems. Biomedical waste includes infectious materials, pathological waste, sharps, pharmaceutical waste, and laboratory waste generated from hospitals, clinics, diagnostic laboratories, veterinary institutions, and research facilities. Improper disposal of biomedical waste can facilitate the transmission of infectious diseases, contaminate soil and water resources, and expose waste handlers to serious occupational hazards. Similarly, industrial waste comprises hazardous and non-hazardous residues such as chemical sludge, heavy metals, solvents, contaminated soils, fly ash, pesticides, and manufacturing by-products. Effective industrial waste management involves waste minimization, cleaner production technologies, material recovery, recycling, treatment, secure storage, and safe disposal in accordance with environmental regulations. Adoption of cleaner technologies, resource-efficient production systems, and circular economy principles significantly reduces environmental pollution, greenhouse gas emissions, and ecological degradation while promoting sustainable industrial development (WHO, 2024; UNEP, 2024; CPCB, 2023).

2.1 Incineration

Incineration is a controlled thermal treatment process in which solid waste is combusted at high temperatures in specially designed furnaces equipped with advanced air pollution control systems. Modern waste-to-energy (WtE) facilities significantly reduce the volume of waste requiring landfill disposal (up to 90%) while recovering thermal energy for electricity generation and district heating. Compared with conventional landfill disposal, efficient incineration can reduce methane emissions and decrease dependence on fossil fuels through energy recovery. However, the overall environmental performance depends on the composition of the waste, auxiliary fuel consumption, energy recovery efficiency, and emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter, and trace pollutants. Recovery of metals from bottom ash and the utilization of combustion residues further improve resource efficiency and support circular economy principles. Advanced emission control technologies, including electrostatic precipitators, fabric filters, and flue gas treatment systems, have substantially reduced emissions from modern incineration plants (IPCC, 2023; UNEP, 2024).

2.2 Landfilling

Landfilling remains the most widely practiced method of municipal solid waste disposal worldwide, particularly in developing countries. In sanitary landfills, waste is deposited in engineered cells lined with impermeable barriers and covered periodically to minimize environmental contamination. During anaerobic decomposition, biodegradable waste produces methane (CH_4) and carbon dioxide (CO_2), making landfills one of the largest anthropogenic sources of methane emissions. According to the IPCC (2023), methane has a global warming potential approximately 28 times greater than CO_2 over a 100-

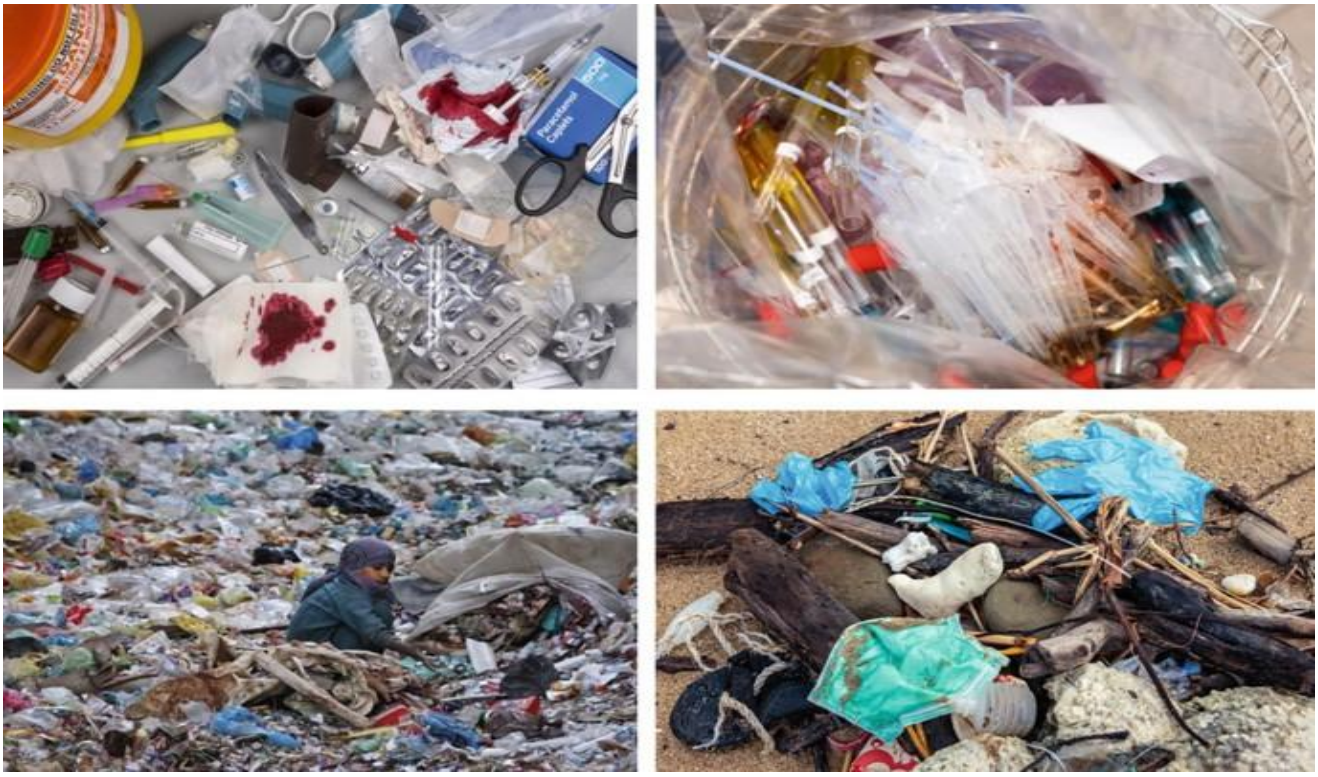

Figure-1. Casually dumped biomedical wastes

year period, making landfill emissions a major contributor to climate change. Modern sanitary landfills incorporate leachate collection systems, landfill gas capture technologies, and biogas utilization for electricity generation or direct thermal applications. Although landfill gas recovery reduces greenhouse gas emissions, energy recovery efficiency remains lower than that achieved through anaerobic digestion or waste-to-energy incineration. Sustainable landfill management therefore emphasizes waste segregation, organic waste diversion, methane capture, and scientific closure of legacy dumpsites to minimize environmental and public health impacts (IPCC, 2023; UNEP, 2024).

2.3 Electronic Waste (E-Waste) Management

Electronic waste (e-waste) comprises discarded electrical and electronic equipment, including computers, mobile phones, televisions, household appliances, batteries, medical devices, and information technology equipment. It is currently the fastest-growing solid waste stream globally due to rapid technological advancements, shorter product life cycles, and increasing consumer demand. According to the Global E-waste Monitor 2024, the world generated approximately 62 million tonnes of e-waste in 2022, of which only 22.3% was formally collected and recycled. E-waste contains valuable materials such as gold, silver, copper, platinum, and rare earth elements, alongside hazardous substances including lead, mercury, cadmium, chromium, and brominated flame retardants. Improper recycling and informal dismantling practices release toxic chemicals into the environment, contaminating soil, water, and air while posing serious neurological, respiratory, developmental, and reproductive health risks. Environmentally sound e-waste management emphasizes extended producer responsibility (EPR), formal recycling systems, resource recovery, environmentally safe disposal, and public awareness to minimize environmental pollution and conserve critical raw materials (UNITAR & ITU, 2024; WHO, 2024).

3. Climate Change and Its Impact on Environment and Human Health

Climate change has emerged as one of the most significant environmental challenges of the twenty-first century, driven primarily by anthropogenic greenhouse gas emissions resulting from fossil fuel combustion, industrialization, deforestation, agriculture, and unsustainable waste management practices. The continuous increase in atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) has intensified the greenhouse effect, leading to rising global temperatures, altered precipitation patterns, melting glaciers, sea-level rise, and increased frequency of extreme weather events. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), global surface temperature has already increased by approximately 1.1°C above pre-industrial levels, with profound consequences for ecosystems, biodiversity, agriculture, water resources, and socioeconomic development.

3.1 Causes of Global Warming

The principal causes of global warming are human-induced activities that increase greenhouse gas concentrations in the atmosphere. Major contributors include the combustion of coal, petroleum, and natural gas for energy production; industrial manufacturing; transportation; deforestation; agricultural practices; and improper management of municipal, industrial, biomedical, and electronic wastes. Landfills release substantial quantities of methane through anaerobic decomposition of organic waste, while industrial processes and energy production contribute significantly to carbon dioxide emissions. Collectively, these activities disrupt Earth's radiative balance, trapping more heat within the atmosphere and accelerating climate change (IPCC, 2023; UNEP, 2024).

3.2 Effects on Climate and Weather Patterns

Global warming has significantly altered Earth's climate system, resulting in more frequent and intense heatwaves, prolonged droughts, severe floods, tropical cyclones, wildfires, and changing rainfall patterns. Rising temperatures have accelerated the melting of glaciers and polar ice sheets, contributing to sea-level rise and increasing the vulnerability of coastal regions and small island nations. Climate variability also affects agricultural productivity, freshwater availability, and food security, posing serious challenges to sustainable development worldwide. These changes are projected to intensify unless greenhouse gas emissions are substantially reduced during the coming decades (IPCC, 2023).

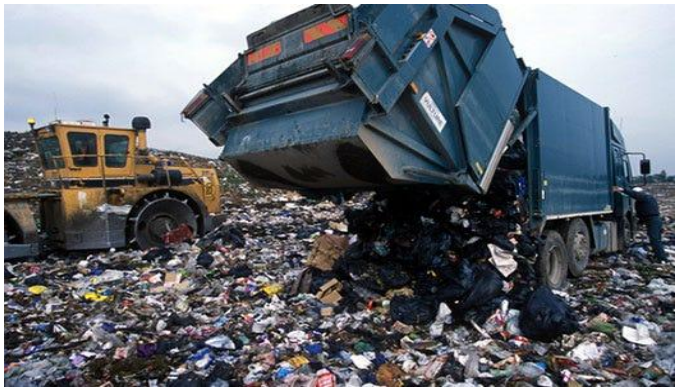

Figure.2.Muncipal waste dumping

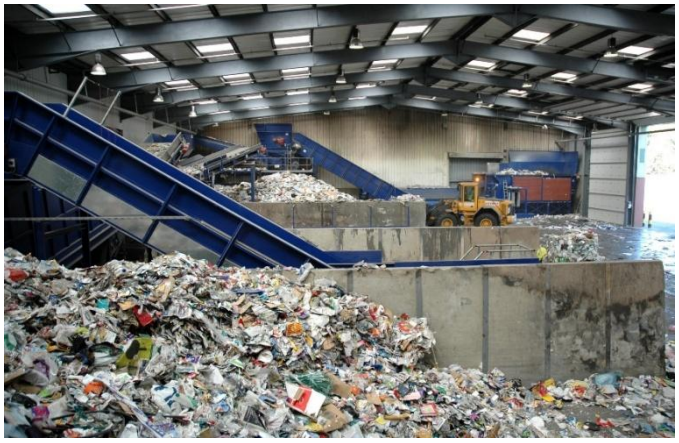

Figure-3. Industrial waste-Reduce, Reuse and Recycle

3.3 Impact on Ecosystems and Biodiversity

Climate change has profound consequences for terrestrial, freshwater, and marine ecosystems. Rising temperatures, habitat degradation, ocean acidification, and altered precipitation patterns have disrupted species distribution, migration, breeding cycles, and ecological interactions. Sensitive ecosystems such as coral reefs, wetlands, alpine habitats, mangrove forests, and tropical rainforests are particularly vulnerable. Biodiversity loss reduces ecosystem resilience, weakens ecosystem services such as pollination and carbon sequestration, and threatens global food security and human well-being. Conserving biodiversity through habitat restoration, ecosystem-based adaptation, and sustainable natural resource management has become an important strategy for climate change mitigation and adaptation (IPBES, 2024; IPCC, 2023).

3.4 Human Health Impacts

Climate change poses substantial direct and indirect risks to human health. Increasing temperatures contribute to heat stress, dehydration, cardiovascular diseases, respiratory disorders, and heat-related mortality. Changes in temperature and precipitation also expand the geographical distribution of disease vectors such as mosquitoes and ticks, increasing the transmission of malaria, dengue, chikungunya, Lyme disease, and other vector-borne illnesses. Air pollution, food insecurity, water scarcity, mental health disorders, and climate-induced displacement further amplify health inequalities, particularly among children, older adults, and vulnerable populations in low- and middle-income countries. The World Health Organization identifies climate change as one of the greatest public health threats of the twenty-first century (WHO, 2024).

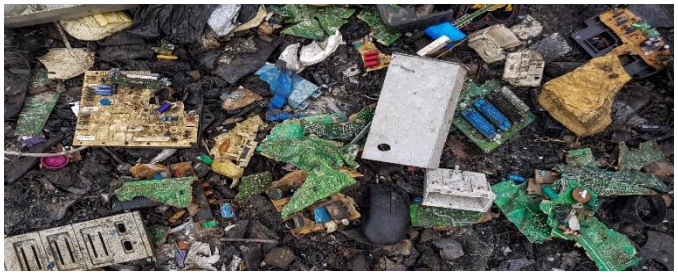

Figure-4. Electronic waste

3.5 Mitigation and Adaptation Strategies

Mitigating global warming requires integrated strategies that reduce greenhouse gas emissions while strengthening climate resilience. Priority measures include transitioning to renewable energy sources, improving energy efficiency, adopting sustainable transportation systems, promoting circular economy practices, enhancing waste segregation and recycling, increasing afforestation and ecosystem restoration, implementing carbon capture technologies, and encouraging sustainable agricultural practices. Effective adaptation strategies involve climate-resilient infrastructure, disaster risk reduction, improved water management, and public health preparedness to reduce the impacts of unavoidable climate change (UNEP, 2024; IPCC, 2023).

3.6 International Cooperation and Individual Responsibility

Addressing climate change requires coordinated international action alongside local and individual initiatives. The Paris Agreement seeks to limit global temperature rise to well below 2°C, while pursuing efforts to restrict warming to 1.5°C above pre-industrial levels. Achieving these goals depends upon strengthened national commitments, technological innovation, financial support, and international collaboration. At the individual level, adopting sustainable lifestyles through energy conservation, waste reduction, recycling, responsible consumption, use of public transportation, and support for renewable energy contributes significantly to global climate mitigation efforts. Collective action by governments, industries, communities, and individuals is essential to achieving sustainable development and safeguarding environmental and human health for future generations.

4. Conclusion

Global warming has emerged as one of the most pressing environmental challenges of the twenty-first century, threatening ecosystems, biodiversity, human health, food security, and sustainable development. Scientific evidence clearly demonstrates that anthropogenic greenhouse gas emissions, including those arising from inefficient solid waste

management, are major drivers of climate change. Sustainable waste management practices such as source segregation, recycling, composting, anaerobic digestion, waste-to-energy technologies, and scientific landfill management can substantially reduce greenhouse gas emissions while conserving natural resources and supporting the transition towards a circular economy. Achieving climate resilience requires coordinated efforts from governments, industries, local authorities, and citizens through effective environmental policies, technological innovations, public awareness, and responsible consumption. A comprehensive and integrated approach to waste management, coupled with the adoption of renewable energy and sustainable development strategies, is essential to mitigating global warming and safeguarding the environment for present and future generations.

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Competing interests:

The authors declare that they have no competing interests

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