Landfills, Waste and Climate Change

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Landfills have been considered the most convenient approach for dealing with waste from time immemorial, even though some have led to disasters of catastrophic proportions. Moreover, recent findings by the International Panel on Climate Change (IPCC) suggest that the decomposing fraction of landfill waste that generates greenhouse gases (GHGs) may not be adequately accounted for and could become a critical issue in our effort to restrict atmospheric temperature increases to 1.5 °C above pre-industrial levels. (According to the IPCC, the maximum atmospheric temperature rise is a factor of cumulative net CO2 emissions as well as net non-CO2 radiative forcing.

Keywords: wet waste ; landfills ; methane ; waste management ; zero waste ; systemic change

1. Introduction

The growing urban population and the strong correlation between greatly increased per capita wealth since World War II and waste generation have globally produced immense amounts of waste. It was reported that global waste generation is on a trajectory that would surpass a total of 11 million tonnes a day by 2100 [1]. In 1960, Americans produced 1.22 kg/person/day of municipal solid waste (MSW), but by 2015, that had increased to 2.03kg/person/day and with population growth, a total of 238 million tonnes (Mt) of waste annually [1]. Around 90 per cent of this waste could be reused, recycled or composted instead of landfilled or burned, but the United States (US) landfills 52% of the MSW generated, incinerates 13% with energy recovery, recycles 26 per cent and composts 9% [2].

In comparison, during 2016–2017, Australia generated a total of 67 Mt of waste, 57 Mt of which is regarded as core waste [3]. Within the core waste category, 13.8 Mt of MSW, or 20.6% of the total, represents 1.6kg/person/day. Some 40% of the MSW is landfilled, while incineration with energy recovery accounts for 0.03%. Recycling represents 58% of the total MSW in 2014/2015, which remained the same up to 2018. During this period, Australia's adjusted MSW recycling rate was about 45% [3][4].

The most widely used approach for estimating GHG generation from the waste sector is the waste model developed by the IPCC [5]. The methodology used by the IPCC for estimating CH 4 emissions from solid waste is based on 'first order decay' principles. Behind the methodology is the premise that the degradable organic component releases CH 4, CO 2 and N 2O at predictable rates during the decay process, with emissions gradually declining as the carbon decomposes. The model gives methodological guidance to estimate carbon-based gas emissions from landfills as well as biological treatment of solid waste, incineration and open burning of waste and wastewater treatment and discharge [6].

Figure 1 presents the structure and organisation of the paper. The paper briefly introduces landfills as waste management infrastructure as the world sees them today and discusses alternative, though conventional, ways of dealing with waste. The world has already seen the alternatives, and the problem has not been about their capacity for more sustainable waste management methods but the reluctance of responsible authorities to use them to replace existing landfill practices. For example, incineration generally, biomass incineration and mechanical biological treatment, when used within an integrated system of waste management, will offer opportunities to greatly reduce the need for landfills. In the long term, it may be possible to eliminate them, although that will need further creative research to deal with incineration ash and its toxicity [7]. Although most alternatives present their own raft of pollution and logistical problems, the paper argues that in a system of waste management that is entirely localised, that is citizen-based within a government frame of regulations, these obstacles can be overcome. The primary premise of the proposed approach is that waste needs to be dealt with at the source, and the onus for its management is shared between the individual, their immediate community and the local council. Those who create the waste, both residents and businesses, will be expected to deal with it responsibly, including composting, rigorous home-based sorting, an expanded range of recyclables and a strong level of producer responsibility. With attitudinal changes promoted by local government and supported by regulatory measures, it should be possible to reach the long-term goal of zero waste. This is a proposal that will not be implemented quickly but which offers significantly fewer environmental impacts as well as a greater degree of security for the long-term availability of resources.

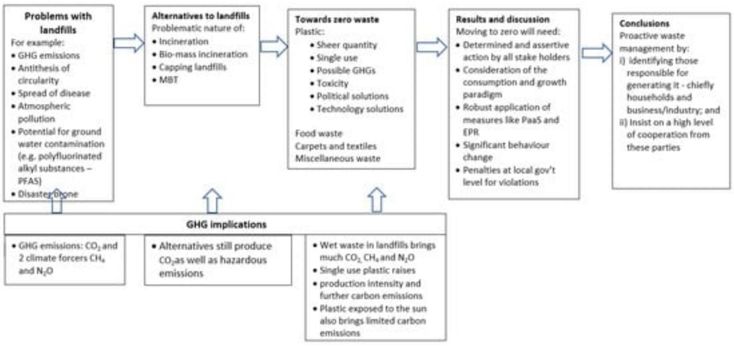

Figure 1. Landfills, GHGs and the focus and structure of the research.

2. Review of Problems Arising from Landfills

Landfills are sites identified for dumping and/or burying waste and are the most common and the oldest organised form of waste disposal in the world. Modern landfills are more sophisticated and designed and operated under strict government regulations. However, such compliance regimes are limited to more developed countries, and in most countries where rapid urban population growth is the norm, landfills have been and are still virtual dumping grounds for waste rather than well-engineered waste disposal sites. Open waste sites with scavenging are regular features of the rapid urbanisation and limited infrastructure services in these countries.

Although quantifying landfill methane emissions is problematic [8], interest in reducing them from landfills has grown, partly a result of the increasing awareness of the overall quantities of emissions, as well the feasibility of reducing them. The Kyoto Protocol may have been instrumental in linking carbon emissions with waste since many of the protocol's mitigation efforts were aimed at trapping methane from landfills. Methane is a key greenhouse gas, second only to CO 2, with a global warming potential recently estimated by the United Nations Framework Convention on Climate Change [9][10] to be 56 times greater over a 20-year time period. Targets for the first commitment period of the Kyoto Protocol covered emissions of the six main greenhouse gases: carbon dioxide (CO 2), methane (CH 4), nitrous oxide (N 2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF 6) [9])

GHG emissions from landfills mainly originate—though not exclusively—due to the degradation of wet waste. Wet waste consists primarily of food and green waste, but other organic materials such as paper and cardboard in the municipal solid waste (MSW) stream may contribute if they are not recycled. As wet waste is covered on the landfill by additional accumulation, methanogens proliferate below the surface in the absence of oxygen and produce CH 4, the potent GHG [11][12]. In the US, for example, 21% of fresh water supplies represent the water used to grow vegetables that are not consumed and which are destined for landfills. It is more than just the food that is wasted but also the resources that went into growing, harvesting and transporting it to market. Then, after dispatching it to landfills, it decomposes with the continuing problem of GHG production in the form of carbon dioxide and methane [13].

As opposed to being landfills, waste is often mounded up into garbage mountains, and without proper care, they can become unstable collapsing garbage mounds which can threaten the lives of people living in close proximity [14][15]. The most recent incident of garbage collapse is in Sri Lanka, where fifteen families in the vicinity of the Karadiyana garbage mountain in Sri Lanka's Western Province had to be evacuated from the collapse danger zone [16]. These families were much luckier than the 17 people who were killed by a lethal avalanche of waste in Mozambique's capital city, the collapse triggered by heavy rains [17].

3. Review of Alternatives to the Landfill Solution

There is little waste incineration in Australia, which has been limited mainly to burning biomass from forestry and agricultural operations. However, research on sugarcane fields in Australia, Brazil and Thailand has shown that biomass residues left on the fields provide ecosystem services such as nutrient recycling, soil biodiversity, water storage, carbon accumulation and a degree of control of soil erosion and weeds [18], so it does seem appropriate to discontinue this form or incineration. Regarding general waste and the sheer quantities in Australian capital cities, recent suggestions that the country may have to resort to incineration have drawn considerable criticism. One of the critics is the industry body, the Waste Management Association of Australia, which suggested that if the technology detracts from a focus on reusing and recycling resources, then it is doing us a disservice and needs to be viewed as one of the lowest options on the hierarchy of waste disposal [19].

Incinerators emit much CO 2, and the mixed waste will (during storing, for example) release small quantities of CH 4 directly to the atmosphere, although any CH 4 remaining would be converted to CO 2 during incineration. However, MSW incinerators emit a wide range of air pollutants, some at a greater rate than fossil fuel power plants, as well as discharging four of the most harmful pollutants to human health: NOx, lead, PM 2.5 and mercury. Despite these apparent social and environmental hazards, roughly half of all municipal waste in Sweden is used to feed sophisticated incineration systems that have been developed to provide electricity and district heating to Swedish households. Certainly, the winter temperatures in these northerly latitudes justify artificial heating, and if waste incineration were abandoned, the energy source would probably be fossil fuels. In any event, the incinerators are strictly monitored to adhere to Sweden's rigid emissions standards. However, the growth in household waste and the rising content of non-biogenic materials directly impacts incinerator emissions with more materials containing toxic chemicals, bringing the potential for more hazardous air pollution [2]. Moreover, relying on incineration to 'solve' a waste problem would do nothing to alleviate countries' consumption of virgin materials. In addition to being the polar opposite of circularity, incineration could create a dependence on garbage as a fuel source and could be a perverse incentive to produce even more waste, although there is no evidence that this has happened in the past [19][20].

Bio-mass incineration is generally criticised as a waste management practice unless burning results in energy generation. Even then, there is a tendency to use waste to energy as a waste management solution [21] rather than a renewable energy source which may be why [22] (p. 2) suggests inefficiency abounds in bio-mass plants in that 'a huge amount of exhaust heat from incineration plants remains unused'. Indeed, in the Australian Capital Territory, any form of thermal treatment of waste such as incineration, gasification and pyrolysis is not allowed [23]. This is far from the case globally with recent research by [24] in Iceland evaluating the global warming, acidification and eutrophication impacts of gasifying organic wastes and the efficiency of producing electricity from the combustion process. The authors compared the results against conventional waste incineration and concluded that producing electricity from waste gasification integrated with combined heat and power was more environmentally friendly than conventional waste incineration in all three impact categories. This is primarily because gasification technology has a lower level of exhaust emissions of significant air pollutants and a higher amount of carbon retained in the ash [24].

A number of local government authorities in Sydney are seeking a long-term, secure and reliable alternative waste technology solution that maximises resource recovery and are sending their waste for processing to an MBT facility in Woodlawn, 250 km south of Sydney. The plant is designed to separate organics from mixed household waste to produce compost which will be used to rehabilitate a former mine site in the area. Stage 1 of the MBT facility can process up to 144,000 tonnes of waste per annum, transported by rail and road from Sydney. Based on waste audit data, approximately 50–60% of the waste received will be diverted from landfills. After the organic material is recovered and converted into compost, the remaining waste is delivered to the bioreactor for further energy recovery [25].

4. Towards Zero Waste and a Circular Economy

Meanwhile, the use of plastic packaging is rising [26][27][28], explained by its value in reducing food waste, population growth and market expansion [29]. Global plastics production reached 380 Mt in 2015, having doubled in 20 years [30]. With increasing plastic production and throw-away cultures comes increased plastic waste, and careless disposal has led to an accumulation of vast quantities of plastic bags, containers and bottles in oceans and on land [31][32]. Much appears in the environment as litter, but substantial quantities are incinerated or deposited in landfills. Even in technically advanced and environmentally conscious Europe, some 50% of plastic waste is still destined for landfill disposal, and more plastic is destined for energy recovery (39.5%) than for recycling (29.7%) [32][33].

There are other encouraging technologies developing as governments struggle with mountains of plastic garbage. Indeed, a shift may be taking place in moving from mechanically recycling plastic to chemical processing. Mechanical recycling is technically down-cycling since it can only take place a finite number of times. On the other hand, breaking the plastic into its original monomers or chemical components, in theory, allows it to be recycled infinitely since it is virtually identical to the original feedstock from oil [34]. If either form of recycling could achieve the scale of glass or metal can recycling, it would represent an enormous advance on current plastic recycling levels. However, there would still be the toxicity issue to deal with in continuing to use plastic intensively, notwithstanding the much-vaunted technology 'improvements' being achieved.

One of the impacts of climate change is likely to revolve around the inextricable relationship between food waste and food security which has received attention from many governments around the world. Landfills have been the most popular destination for food waste, and because they are relatively cheap to use in Australia compared to other parts of the world, it can be difficult to make alternative food waste treatment technologies cost-effective [35]. In Australia, some 3.2 million tonnes of food is sent to landfills each year, enough to fill 5400 Olympic-sized swimming pools, with 75% of the waste originating from our households [36]. It comprises 12.6% of total solid waste going to landfills, and better management of food waste is critical for improving food security [37] (p. 283). Moreover, it has been estimated that food waste costs the Australian economy AUD20 billion each year. However, the Australian Government has worked with state and territory governments to develop a National Food Waste Strategy and introduce levies for disposing of organic waste to landfills. This makes alternative treatment methods such as bio-digestion and composting more cost-effective options for businesses. The strategy was released in 2017 and is aimed at achieving a 50% reduction in food waste by 2030 [38].

Large cities such as New York have the resources to back food waste programs, but despite notable successes, there are barriers. Larger cities usually have many multifamily dwellings where it can be hard to measure success and incentivise participation in food waste programs. Most New York City residents, for example, live in multi-unit buildings, and brown bins and starter kits are automatically delivered to residents of one to nine-unit buildings. Residents in 10-plus unit dwellings must enrol to receive bins, and a challenge has been in recruiting both residents and building staff, with buy-in from building managers and training staff crucial, but the program has evolved greatly from a pilot several years ago [39].

5. Conclusions

Two Canadians, in an effort to live completely waste-free, embarked on a year-long competition to see who could forsake consumerism and produce the least amount of waste. Filmed as the Clean Bin Project, the ethical duel is rather light-hearted, but the background is the bleak problem of the vast amount of waste humankind produces and how the two struggle to find meaning in their infinitesimal influence on the overall problem [40]. However, the pair is to be congratulated for their leadership in encouraging us to think of the unthinkable since what we achieve is little better than tokenism at present. Gaining even a modest degree of circularity with recyclable cans, glass and certain plastic resins and diverting all decomposable waste from food and green clippings from landfills is a long way from realisation at present. Moreover, gaining full waste circularity for some of our difficult materials such as textiles and carpets or mattresses is likely to be even further away so that the solution with such waste is either landfill or incineration which will maintain at least some degree of GHG emissions. However, lessons can be learned from the examples given in this paper, and the potential for them to be mainstreamed cannot be overestimated.

As noted above, waste is an environmental issue, a resource issue and an ethical matter. When Australia approaches 2050 with a population of 40 million, resources will be more valuable than ever. If we persist in having landfills, we could mine them since the immediately recyclable materials such as aluminium and steel cans, glass bottles and various plastics do not decompose, though it would be much better to avoid the journey. Ideally, and perhaps critically necessary given the medium- to long-term non-renewability of many of our resources and the issue of GHGs in landfills, society needs to be moving towards zero-waste. While the ZWIA definition of zero waste is admirable, it should also embrace the chemicals that are used in PFAS. Recently, it has been shown that conventional plastics can produce GHGs, albeit slowly, and perhaps the long-term implications of complex human-made compounds such as PFAS cannot be predicted, so the precautionary principle would be an appropriate addition to ZWIA. However, at this point, society will need to regard it as a long-term goal since it is not likely to be reached until several crucial steps are taken and coordinated. Three strategic ones are, first, to restrain the intensity of consumption; second, to build a degree of consumer waste behaviour change that is genuinely proactive and third, to underpin this with pro-EPR policy and regulation. Additional concrete steps including designing products both for multiple re-uses as well as for disassembly, followed by recycling the component parts. Waste is a ‘low hanging fruit’ compared to most other sources of GHG. While developing an uncompromising system to achieve ‘zero’ waste to remove ‘landfills’ from the equation rests with the state and its regulatory apparatus, incorporating community education, accountability, transparency and participatory governance in that system cannot be underestimated. In the meantime, eliminating contamination, improving recovery rates of materials and prohibiting certain substances such as organic waste from landfills would be useful steps on the journey towards ‘zero’.

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