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Comparing Greenhouse Gases from Composting and Landfilling

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Abstract

Landfills are the most significant anthropogenic source of methane released into the atmosphere in the United States. Methane and other greenhouse gases, like carbon dioxide and nitrous oxide, contribute to global climate change. Methane is the largest contributor to global climate change because it absorbs infrared radiation twenty-five times more than carbon dioxide. In 2012, the EPA estimated that 38-52% of what was landfilled could have been composted. Composting organic waste versus landfilling saves land, does not produce groundwater pollution, and provides citizens the opportunity to create a more sustainable waste management system as compost recycles organic waste into garden soil rich in nutrition. However, composting is the aerobic breakdown of organic material and also releases carbon dioxide, and can sometimes release other greenhouse gases such as methane and nitrous oxide. This paper compares the greenhouse gases produced by landfills and composting in CO2 equivalents. It validates that although composting does release some methane and nitrous oxide into the atmosphere, it is still far less of an impact on the environment overall than landfilling organic material, and releases less than 10% of the greenhouse gases produced by landfilling for every ton of waste.

Keywords: greenhouse gases, composting pollution, landfill pollution

1. Introduction

Municipal landfills are the most significant anthropogenic source of methane released into the atmosphere in the United States[1]. Methane and other greenhouse gases, like carbon dioxide, trap heat in the atmosphere and contribute to global climate change, which affects weather patterns, glacier melting and sea level rise, and the health of ecosystems, humans, and wildlife[4]. The EPA reports that methane is currently captured at almost three-fourths of the 3,581 operational landfill establishments and burned as an alternative energy source[5]. This only accounts for a small percentage of the total methane that is produced at active and inactive landfills collectively over time, as it is a relatively new technology that has just recently taken hold in the industry. The small amount of methane captured and used to generate energy is of concern when processed using certain methods such as flaring and energy recovery, which do not use the latest technology that filters other gases out so that they are not released when the landfill gas is burned, causing even more air pollution than before it was captured[6]. Methane is between 40-60% of landfill gas captured, while the remainder is carbon dioxide and other non-methane organic compounds (NMOCs), halogenated compounds, and non-halogenated toxic chemicals[7]. When halogenated chemicals such as chlorine or bromine are combusted in congruence with hydrocarbons, they can formulate highly toxic compounds such as furans and dioxins that are released with the waste heat during methane flaming, causing depletion of the ozone layer[7].

Landfills are also responsible for water and soil contamination from hazardous landfill leachate. Leachate is a toxic combination of household chemicals and chemical reactions from the breakdown of organic waste, leaking into underground aquifers, due to imperfect leachate collection and lining systems in active landfills, and is especially true in older inactive landfills. Although there have been improvements in leachate collection and landfill lining

technologies over past decades, they are not perfect. More than 10,000 inactive landfills still exist in the United States, and have had little to no installation of quality leachate collection systems or lining procedures[8]. The amount of land that is used for active landfills is estimated by NASA to be about 600 acres on average, with some going as deep as 600 feet into the ground[9]. Not only is this a large amount of land being used for storage of unnecessary waste in the United States, but this land use also contributes to habitat loss, economic loss, and large amounts of land that could be polluted and potentially hazardous. Many human health issues have been associated with landfills, and there have been many studies that suggest on-site landfill employees get sick more often than off-site employees, and have dermatologic, neurologic, hearing, and respiratory issues[10]. Many studies also show that residents living close to landfills have demonstrated higher rates of depression, respiratory problems, low birth weights, birth defects, and certain types of cancer[11]. Aside from health issues, landfills also create problems for neighbors from their foul odor, attraction of pests, and decreased property values. Landfills have a bad reputation for being a nuisance and are known contributors to global climate change due to the large amounts of methane released during its processes.

In 2012, the EPA estimated that 38-52% of what was landfilled was organic material and could have been composted[3]. The reputation of composting is known as green, safe, and a more sustainable way of managing waste by recycling organics into nutrient-rich soil. Although it may appear to be a superior alternative than landfilling waste, little research has been conducted on the effects of the amounts of greenhouse gases generated by composting processes. Composting is known to produce more carbon dioxide than methane, and few people know that it produces other greenhouse gases like nitrous oxide. This research explores whether composting is more or less beneficial to the environment compared to landfilling with emphasis on greenhouse gas production.

2. Methodology

This research was completed by comparing the published literature on pollution and greenhouse gas emissions for both landfills and composting. Most literature found on air pollution from composting was research on non-residential composting projects. It is important to note that most literature found on composting air pollution results from studies done on agricultural composting, mainly consisting of animal manure. These compost piles contain significantly more nitrogen than food waste piles, leading to more nitrous oxide production. It was difficult to find literature on municipal composting air pollution figures, which was the main original focus of this research. There is very little research found currently on how much methane or carbon dioxide is produced by a small residential compost pile or even municipal composting. Exact measurements are hard to determine because they vary and it is expensive to measure. Most of this research was conducted by concluding from the given literature and the United States Environmental Protection Agency's Inventory on U.S. Greenhouse Gas Emissions and Sinks of 2014.

In 2009, The United States Environmental Protection Agency mandated that major contributors of greenhouse gas emissions with more than 25,000 metric tons of CO_2 equivalent a year report their annual emissions[12]. To compare these emissions' statistics easily, the main greenhouse gases are converted to a unit of CO_2 equivalents in million metric tons (MMT CO_2 Eq.) using a formula based on their 100-year Global Warming Potential (GWP) in comparison to carbon dioxide. Their GWP value is based on how efficiently a compound, or greenhouse gas, traps heat on the Earth's surface over a given period of time[13]. The GWPs for the three greenhouse gases that this study reviews (carbon dioxide, methane, and nitrous oxide) are presented in Table 1 below. This table displays the 100-year GWPs researched, calculated, and published by the International Panel on Climate Change (IPCC) in 1995, 2007, and 2014[14]. GWP figures have varied over time, which is important to note because the statistics for the greenhouse gas emissions rely on the most recently published GWP figures to calculate an accurate CO_2 equivalent for that greenhouse gas for that given year[15]. The GWP figures published in the IPCC Fourth Assessment Report of 2007 are what the EPA used when calculating the most recent greenhouse gas emissions statistics reported in 2014 figures[15]. These are the statistics used for this research.

Table 1. Global warming potentials (GWP) for 100-year time horizon, equivalent to MMT of CO_2

Industrial designation or common name	Chemical Formula	GWP in IPCC's Second Assessment Report (SAR) 1995	GWP in IPCC's Fourth Assessment Report (AR4) 2007	GWP in IPCC's Fifth Assessment Report (AR5) 2014
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265

Carbon dioxide consists of 81% of the total amount of all greenhouse gases in the United States in 2014[15]. Although the least potent of Global Warming Potential (GWP), carbon is considered by the EPA to be the most abundant and the most important of the greenhouse gases (with all GHG gases compared to it in units of MMT CO_2 equivalent)[15]. The data used to compare landfill and compost greenhouse gases will all be considered in units of CO_2 equivalents.

3. Data

The aerobic and anaerobic breakdown of organic waste in both landfills and compost piles produces carbon dioxide and methane. According to the EPA's Inventory of US Greenhouse Gas Emissions and Sinks 1990-2014, methane in landfills added up to 181.8 MMT CO_2 eq., versus composting only producing 2.1 MMT CO_2 eq. in 2014, even though composting increased in activity over the last decade[12]. The calculation provided for the net methane reported was not the total amount of methane generated, but the remainder of total methane emissions following the subtraction of methane burned for energy at landfills[12].

The EPA, as well as the IPCC, do not consider composting nor landfill procedures to be a major contributor to the United States' carbon dioxide emissions since fossil fuel combustion is the cause of 93.6% of total carbon dioxide emissions in the United States[15]. Landfill carbon dioxide production was estimated outside of the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks *Waste* chapter of the report and recorded in the *Land-use* chapter as 11.6 MMT CO_2 eq. for 2014 [16]. This was a calculation based on net CO_2 flux, which subtracts the carbon dioxide that was sequestered from forests from the total emissions estimated from landfilling[16]. Composting CO_2 emissions were not even calculated in the EPA's Inventory of US Greenhouse Gas Emissions report at all. Since there was not a valid or precise statistic for United States carbon dioxide emissions produced by composting activities, for the sake of this paper, carbon dioxide was estimated by dividing the given landfilling statistic for carbon dioxide by three (an overestimate) since the average carbon dioxide emissions are measured to be less than a third of landfilling emissions per dry kg of MSW according to several studies[17-19].

The EPA seems to be concerned with the amounts of nitrous oxide that composting produces however, which mainly occurs during agricultural management practices when animal manure rich in nitrogen is being composted, or under certain circumstances when the carbon sources are used up in the composting process due to poor carbon**:** nitrogen ratios[20]. According to the EPA, composting produced 1.8 MMT CO_2 eq. of nitrous oxide in 2014[15]. Landfill nitrous oxide generation has not been reported by the EPA since the IPCC determined the emissions were too miniature or "not sufficient enough"[12]. Landfills do produce nitrous oxide though, which some studies have suggested around 3% of their total GHG emissions are nitrous oxide[21]. Landfill nitrous oxide emissions is omitted from this analysis.

A portion of the *Waste* section in the EPA's Inventory of US GHG Emissions is presented in Table 2 below. This gives some insight on the comparison between landfilling and composting and how the data has not varied much within the past decade, or in 4-5 year time spans. With the statistics available through the IPCC and EPA, a compilation and summary of the total emissions from the three most concerning greenhouse gases produced by landfilling and composting organic material in the United States (in 2014 using IPCC's 2007 GWP calculations for CO_2 equivalents) are presented in Table 3.

Table 2. Composting vs. Landfills. GHG Emissions from Waste (MMT CO_2 Eq.) From EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014 – Chapter 7: Waste (Figure 7-1)[12]

GAS / SOURCE	YEAR 2005	YEAR 2010	YEAR 2014
Methane	(MMT CO_2 Eq.)	(MMT CO_2 Eq.)	(MMT CO_2 Eq.)
Landfills	187.3	176.3	181.8
Wastewater Treatment	15.9	15.5	15.0
Composting	1.9	1.8	2.1
Nitrous Oxide			
Wastewater Treatment	4.3	4.7	4.9
Composting	1.7	1.6	1.8

Table 3. Total Emissions from the three concerning GHG produced by landfilling and composting organic material in the United States in 2014.

GHG CHEMICAL NAME AND FORMULA	LANDFILLS (MMT CO_2 eq.)	COMPOSTING (MMT CO_2 eq.)
Carbon dioxide, CO_2	11.6	3.9
Methane, CH_4	181.8	2.1
Nitrous oxide, N_2O	N/A	1.8
TOTALS	193.4	7.8

4. Discussion

The data indicates that landfills produce more of the top three concerning greenhouse gases (193.4 MMT CO_2 eq.) than composting does (7.8 MMT CO_2 eq.). To put the unit of MMT into perspective, avoiding just one MMT of CO_2 equivalent is estimated to be similar to taking 216,000 passenger cars off the road for one year, or saving 2.3 million barrels of oil[22]. It is also considered equal to the same volume of air as what would be in 200,000 hot air balloons, or sequestering as much CO_2 as 833,000 acres of pine forests would in one year[22]. Landfilled waste in the United States was calculated to be 185.6 MMT CO_2 equivalents higher than composting in 2014. This amount of difference in pollution is assessed to be similar to burning almost 200 billion pounds of coal or the electricity use of almost 17 million homes for one year, which would power more homes than there are people in Los Angeles, California[23]. Some may say that landfilling produced more greenhouse gases than composting because more was landfilled than composted in weight, so it was calculated how much CO_2 equivalent per ton of waste for both landfilling and composting in the United States. The EPA reported that citizens generated 254 million tons of trash in 2013, and recycled and composted (these figures cannot be separated) about 87 million tons of material[3]. Using these figures it was estimated that landfills produce 0.76 metric tons of CO_2 equivalent per ton of waste landfilled, and composting creates 0.09 metric tons of CO_2 equivalent per ton of waste composted (although this is an overestimation since

recycling statistics are also included). This suggests composting creates less than 10% of the main greenhouse gases that landfilling contributes to the atmosphere for every ton of waste. Composting emissions are not only less of a contribution to global climate change and air pollution, but it also has many benefits in its recycled end product. Several studies suggest agricultural advantages to using composted humus such that it improves soil health by supplying significant organic matter and microorganisms to the soil, improves water holding capacity, reduces erosion and water runoff, and improves cation exchange capacity[24]. Some studies have shown an increase in plant biomass when compost is applied to the soil, which contributes to further carbon sequestration up to 183 kg of CO_2 per ton of wet compost[18]. Another study demonstrated less cadmium hyperaccumulation within farm plants with the addition of compost humus, meaning the farm fresh produce had significantly lower levels of cadmium than before composted humus was added to the soil[25]. This paper confirms that composting is not just a greenwashed fad, but significantly reduces potent greenhouse gases that contribute to global climate change, while providing beneficial uses of its product that landfills cannot.

5. Future Research

If time and finances were permitted, I would have been thrilled to measure the local municipal composting facilities' methane, carbon dioxide, and nitrous oxide outputs myself to get a more definite measurement of municipal composting greenhouse gas emissions. I hope to continue this research by doing so in the future in order to expand the capacity of the scientific knowledge on this subject further than comparing literature statistics.

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