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Energy Recovery Potential and Environmental Impacts to Energy Recovery Options of Different Waste

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Abstract - This paper presents experimental models that predict the ages of biodegradable and non-biodegradable garbage by factoring in the residents' financial situation. However, while there are a number of models that can predict garbage age rates, none of them can independently predict biodegradable and non-biodegradable trash age rates for any given city using the readily available data related to economic factors. The financial factors utilized for the improvement of models in this study are family size, family pay, training, control of the head of families and fuel utilized in the kitchen. The exactness tests directed on the created biodegradable and non-biodegradable expectation models showed truly apparent outcomes with R 2 upsides of 0.782 and 0.676 separately.

Keywords: Energy recovery potential, Environmental impacts, different waste

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INTRODUCTION

The Earth's resources have been essential for the survival and waste management of both animals and humans since the dawn of civilization. Disposal of human and non-human waste was less of a problem in bygone eras since fewer people meant more space for garbage. There is a current issue in solid waste management due to factors such as a growing human population, an increase in the amount of trash produced, and the prevalence of synthetic, non-biodegradable materials. Among the most critical environmental challenges confronting LDCs is waste management. Since there is no universally accepted system for collecting and sorting waste, processing garbage is a challenging task in most LDCs. Another concern is the proper way to dispose of waste. All of these dangers to people's and the planet's health have devastating effects on the economy. All life on Earth is at jeopardy unless this matter is handled quickly and efficiently.

Solid wastes include any non-biodegradable materials that are created by human and animal activity and are discarded because they are deemed superfluous or undesirable. Both the more uniform accumulations of a particular industrial activity and the more varied bulk of discards from retail and household use are included (Peavy et. al., 2021). The term "municipal solid waste" (MSW) refers to the garbage that is collected and disposed of by local authorities. This garbage comprises items such as non-hazardous trash from businesses, institutions, and markets, as well as yard debris, street sweepings, and debris from markets (Jain, 2007). Rapid growth in urban consumption and production leads to an ever-increasing amount of solid waste. Garbage from all sources, including households, companies, educational institutions, and industrial facilities, increases dramatically as a consequence. Typical urban civilization produces a wide variety of waste products, such as trash, packaging materials, construction and demolition debris, leaf litter, harmful chemicals, and more (Rajput et al., 2009).

Population density, dietary habits, income levels, commercial and industrial activity, local customs and traditions, weather, and many other variables influence the amount and quality of municipal solid waste (MSW) produced in any given area. Waste generation is expected to increase from 2000's 12.7 billion tonnes to 2025's 19 billion tonnes and 2050's 27 billion tonnes (Singh et al., 2008).

METHODOLOGY

Sample collection and composition analysis

The municipal solid waste (MSW) samples will be gathered at a transfer-cum-compactor station in the city of Raipur, India. The current research will use a truckload sampling strategy, in which an entire load of trash will be sampled and analysed for its chemical make-up in accordance with ASTM D 5231-92.

Characterization of municipal solid waste

The gathered samples was first be analysed in the lab to determine their moisture content. Three samples of each component was analysed, and standard procedures will be used for all of them.

Proximate analysis

Proximate analysis of MSW samples was performed using coal and coke testing procedures standardised by the American Society for Testing and Materials (ASTM).

Ultimate analysis

Elements like carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulphur (S) concentration of MSW components will be determined via the final analysis.

Heating value

Using Eq. (1), we shall determine the LHV of MSW's dry weight components individually (1). Eq. (2) will be used to determine MSW's LHV.

$$LHV_i = HHV_i - 9HK$$

$$LHV = \sum_{i=1}^{j} (w_i \times LHV_i)$$

.....Eq. (1) & (2)

Model development

The linear method will use the multiple linear regression (MLR) methodology, while the non-linear method will make use of an artificial neural network (ANN). Waste samples and analyses from each of the year's three primary seasons will be utilised to generate data points for this research. Statistical Package for the Social Sciences (SPSS) 21 will be used to create the models.

Energy recovery potential of municipal solid waste

Using Eq., (3)we calculated the potential for electrical energy recovery from MSW produced in the research region.

$$E = 1.16 \times LHV \times W \times \eta$$ **.....Eq. (3)**

Refuse-derived fuel preparation

The study's goal is to identify a suitable RDF mixture for the mixed MSW stream based on the relative ease of recovering its separate waste components.

Life cycle assessment

The LCA was carried out in four stages, all of which will adhere to ISO 14040/14044 guidelines. Objectives and scope of the study life cycle inventory, evaluation of the effects of the study on the life cycle, and finally, interpretation.

Life cycle inventory for the proposed waste to energy recovery options

Every method used to process municipal solid waste (MSW) results in some amount of air pollution. Direct emissions are those caused by a system in the front, as opposed to indirect emissions, which are caused by a system in the background. The foreground system's emissions are caused by both the input of raw materials and the production of finished goods and pollution. Emissions from the production of fuel and power used in the foreground system, as well as emissions averted from the production of fertilisers and electricity in the foreground system, are examples of indirect emissions from the background system. The majority of the background information used here was generated during the present study, while the rest was culled from existing sources. Emissions from energy, fuel, water, and other raw material usage, as well as savings from emissions during the production of organic fertilisers and power, were collected from the SimaPro database. For this research, we will draw on data from the SimaPro database that has been tailored to the Indian context (for instance, we will use information on power consumption to inform our model of medium-voltage electricity generation in India).

Most methods for converting trash into usable power may be broken down into those that rely on various forms of renewable energy. Anaerobic digestion decomposes waste in the absence of oxygen to generate biogas and landfill gas, whereas incineration burns garbage to generate energy. Biogas and landfill gas may either be burnt directly or refined into a more usable form for purposes like power generating and transportation fuel. In this study, many waste-to-energy recovery methods were considered. These methods included landfill gas to energy, anaerobic digestion, mass incineration, and RDF incineration. Waste composition and suitability to the study site will inform the final decision. The waste generated in the study area will be separated into two categories: combustible and non-combustible.

Scenario development

Five MSWM techniques, including landfilling, landfilling with landfill gas converted to electricity, anaerobic digestion, MSW incineration, and RDF incineration, will be analysed in this study. Energy recovery has considered all five possibilities, with the exception of landfilling.

Life cycle impact assessment

In this research, SimaPro 8.0.5 software and CML-

IA baseline techniques will be used to conduct the life cycle impact assessment. The following five impact categories will be included in this research based on their importance to the environment in general and their relevance to the prior literature:

- Acidification potential
- Eutrophication potential
- Global warming potential
- Human toxicity potential
- Photochemical ozone creation potential

Sensitivity analysis

Due to the fluctuation in the proportion of methane emissions throughout the power conversion operations, scenario 2's sensitivity will be assessed. We will thus analyse how changes in methane emission at 10% and 20% affect the various environmental impact categories.

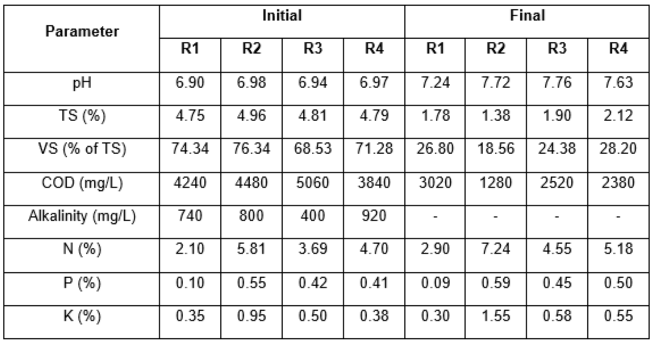
RESULTS AND DISCUSSION

Energy recovery potential of msw using biological conversion techniques

Batch experiments

Four distinct batch reactors, each with a unique mix of primary and co-digestion substrates, were used to begin the experiment. Table 1 provides an overview of the starting and end characteristics of each batch reactor (R1 through R4). The initial TS concentrations in each reactor ranged from 4.75% to 4.96% when they were first started. Better operational stability and process optimization were achieved in this investigation at a lower TS, despite the fact that it was lower than in many other prior studies (Chen et al., 2014). According to El-Mashad and Zhang (2010), the TS used in this investigation was determined to be suitable for the quick initiation of the methanogenesis process and to lessen the inhibitory impact on methane-forming bacteria. In a co-digestion experiment including MSW and sewage sludge at different TS concentrations, Ahmadi-Pirlou et al. (2017) discovered that 5% TS produced the highest methane output.

Table 1: Characteristics of initial and final substrate



Parameter	Initial				Final			
	R1	R2	R3	R4	R1	R2	R3	R4
pH	6.90	6.98	6.94	6.97	7.24	7.72	7.76	7.63
TS (%)	4.75	4.96	4.81	4.79	1.78	1.38	1.90	2.12
VS (% of TS)	74.34	76.34	68.53	71.28	26.80	18.56	24.38	28.20
COD (mg/L)	4240	4480	5060	3840	3020	1280	2520	2380
Alkalinity (mg/L)	740	800	400	920	-	-	-	-
N (%)	2.10	5.81	3.69	4.70	2.90	7.24	4.55	5.18
P (%)	0.10	0.55	0.42	0.41	0.09	0.59	0.45	0.50
K (%)	0.35	0.95	0.50	0.38	0.30	1.55	0.58	0.55

Before beginning the reactor, the initial pH of each reactor was adjusted to be between 6.90 and 6.97, or almost neutral (Raposo et al., 2011). Reactors R1, R2, R3, and R4 had initial COD values of 4240 mg/L, 4480 mg/L, 5060 mg/L, and 3840 mg/L, respectively. Following the substrates' mixing and dilution, the COD in each reactor dropped. R3's maximum alkalinity of 920 mg/L was determined to be caused by the presence of both sludge and cow dung. To comprehend the buffering capability of the reactors, the alkalinity of the original substrate had to be determined in the current investigation. Essential macro- and micronutrients must be present for the anaerobic digestion process to be effective. The starting and end N, P, and K values (in percentages by weight) for the substrates and digestate in each individual reactor are shown in Table 1. The initial high nitrogen level in all of the reactors was caused by the presence of nitrogenous material, namely sludge and cow dung. Every reactor's digestate was a slurry that was centrifuged to produce a thick mass that was then dried. The N, P, and K levels of the dried digestate samples were then measured and compared to the minimum standard values specified by the Fertilizer Control Order, Government of India (FCO) for use as a soil conditioner (Arelli et al., 2018). The digestate of every reactor showed a rise in the N, P, and K levels as a result of the substrate mineralizing during anaerobic digestion. Nevertheless, in this investigation, only the R2 digestate exhibited the minimally necessary N, P, and K values; hence, only the R2 digestate is suitable for use as a soil conditioner. According to Rappolo et al. (2011), trace metals (Cu, Cd, Co, Fe, Zn, Ni, and Mn) are necessary micronutrients for efficient enzymatic reactions and microbial metabolism during the anaerobic digestion process. However, the anaerobic digestion process may sometimes be inhibited by the presence of additional heavy metals such As, Hg, Pb, Cr, and other trace metals at larger concentrations (Jain et al., 2015). Thus, both before to feeding and after the reactors' shutdown, the substrate was examined for the presence of heavy metals. It was discovered that all reactors' digestate samples had heavy metal contents below the uppermost permissible limit for organic fertilizers (NCOF, 2014).

Biogas production

A distinct mixture of co-digestion substrates in varied ratios was used to start the batch reactors. Reactor R2, which produced a maximum of 6025 mL of biogas from a mixture of cow dung, sludge, and food waste, is shown. The generated biogas had an average methane content of 61% and an average carbon dioxide content of around 38%, according to gas chromatograph analysis. The biogas generation was lowest in R4, when sludge and cow manure were fed together. The biogas yield from each reactor was ranked as follows: R2>R1>R3>R4. The reactors' daily and cumulative biogas generation is shown in Figures 1 and 4.2. In all of the reactors, biogas was initially produced quickly. The biogas generation in all the reactors

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was not delayed or lags because soluble organic substance was easily accessible.

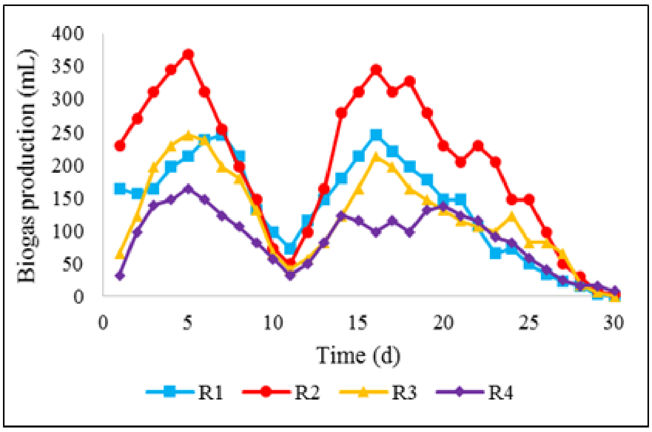

Figure 1: Variation of daily biogas production in different batch reactors

Energy recovery potential of msw using thermal conversion techniques

Physical composition of municipal solid waste

Yard trash, plastic, paper and cardboard, textile and rubber, metal and glass, inert, food scraps, and other were the eight categories into which MSW components were categorized. The MSW components that may be used for energy recovery were divided into combustible and non-combustible categories based on their heating values. There were 72% of flammable fractions and 28% of non-combustible fractions. The typical composition of MSW is shown in Fig. 2. With an average composition of 36%, food waste was the main component. With an average composition of 14%, 11%, and 9%, respectively, plastic, yard trash, and paper & cardboard are the other major contributors to the combustible categories. Used clothing, rags, and rubber made up the least amount of textile and rubber (2%), with an average composition of 21%, inert waste was the highest category under non-combustibles, followed by glass and metals at 3% and miscellaneous materials at 4%. A significant portion of the inert waste from the burning of solid biomass is found in the Indian MSW as dirt, ash, and soil (Kumar and Samadder, 2017b). Table displays the normal range and average composition of several components on a wet weight basis.

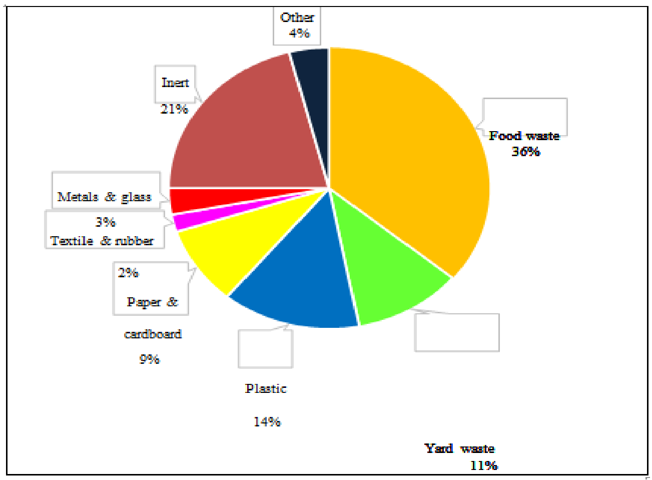

Figure 2: Average physical composition of MSW

Electrical energy recovery potential of different waste to energy recovery options and waste management scenarios

Energy recovery potential of different waste to energy options

Electricity is the primary source of energy production in the tropical nation of India. Table 2 displays the results of this section's analysis of the electricity utilization potential of four waste-to-energy options: RDF incineration, mass incineration, anaerobic digestion, and landfill gas-to-energy. Each option is assessed for its electrical energy recovery potential in kWh/ton of processed trash. It is clear that RDF has the highest burning potential at 1310 kWh/ton, mass incineration is second at 837 kWh/ton, anaerobic digestion is third, and landfill as energy has the lowest electrical recovery potential. Both bulk and rotary kiln incineration have the ability to recover a significant amount of electrical energy since they use dry combustible waste portions. Dried fuel waste fractions release a great deal of energy when burnt due to their high calorific content. For the purpose of making RDF, a high calorific value waste mixture is created by pre-treating (drying, sorting, and crushing) certain fractions of combustible trash, such as plastic, paper and cardboard, textile and rubber, and yard waste. For bulk incineration, it is common practice to dry all combustible debris, including food scraps, in a bunker for a few days before feeding it into the combustion chamber. Since unburned waste fractions do not impact energy generation, mass incineration is solely used to combustible waste fractions (72% of the total garbage) in this study. There are instances where incinerator combustion chambers are damaged by unburned waste fractions. Anaerobic digestion technology's ability to recover electrical energy from food waste was assessed. An efficient biogas basis for energy generation, food waste accounts for 36% of the total waste produced in the research region. There is a 54 kWh/ton of dumped trash electrical potential in the present landfill in the research region. Less landfill gas generation means less electricity recovery possibilities. The limited recovery potential of waste and, by extension, power, may be attributed to two primary factors. To begin, there is currently no bottom liner or landfill cover system in place, and the landfill is shallow and untreated. Secondly, a very high inert content is present when the garbage is transported to the landfill under mixed circumstances. The methane correction factor is much smaller (0.40) in landfills that breakdown topsoil waste aerobically, leading to a decrease in landfill space (IPCC, 2019a).

Table 2: Electrical energy recovery potential of different waste to energy options

Waste to energy options	Electricity potential (kWh/tonneof waste treated)	Energy consumed (kWh/tonneof waste treated)
Mass incineration	837	89.6
RDF incineration	1310	93.074
Anaerobic digestion	404	38.45
Landfill gas toenergy	54	27.8

Comparison of waste management scenarios on the basis of energy recovery potential

The organic components in Indian MSW are quite high. The considerable energy content of the garbage goes wasted because of the high humidity and the fact that it is collected in mixed forms. Anaerobic digestion and landfill gas conversion may make use of the wet organic fractions, while thermal technologies can extract energy from the dry combustion fractions. Anaerobic digestion, landfill energy production, incineration, and any combination of the two are all scenarios that might be considered in this research as potential biological or thermal uses of garbage. The energy potential of six distinct waste management scenarios is examined in this section. These scenarios include several waste-to-energy methods. The investigation's waste management strategy considered every possible outcome. Six distinct waste management systems are shown in Figure 3 to demonstrate their electricity recovery potential. All scenarios save Scenario 1 generated power, with the exception of Scenario 1, which solely included the repository. Because all combustible waste components (72% of total trash) were utilized in mass incineration, scenario 4 had the largest electrical energy recovery potential (602 kWh/ton). Furthermore, dry combustible waste components have shown a great potential for energy recovery by mass incineration. Scenario 5 follows, which demonstrated very high energy usage potential when 36 percent of the total waste of plastic, paper, cardboard, textile, and rubber was used in the manufacture of the rotating drum furnace. Due to the cremation of the generated RDF, the residual trash had to be dumped in a landfill. Anaerobic digestion, mass incineration, and landfill are all part of Scenario 6, which has a 446 kWh/ton electricity recovery potential. Anaerobic digestion takes into account 36% of the wet fraction as food scraps, mass incineration 36% as dry combustibles, and landfill 28% as other materials. Scenario 3 took into account the possibility of anaerobic digestion of both the dry organic portion (food scraps) and the remaining landfill trash. The third scenario shows that the conversion of anaerobic digestion biogas into electricity has a recovery potential of 145 kWh/ton of power. Scenario 2 assumes that all trash is sent to a landfill that has the technology to collect landfill gas and turn it into electricity. This scenario has a potential power recovery of 54 kWh/ton. All of the scenarios relied on landfills as a standard method of disposing of permanent waste and residual solid waste, which were seen as potential energy sources.

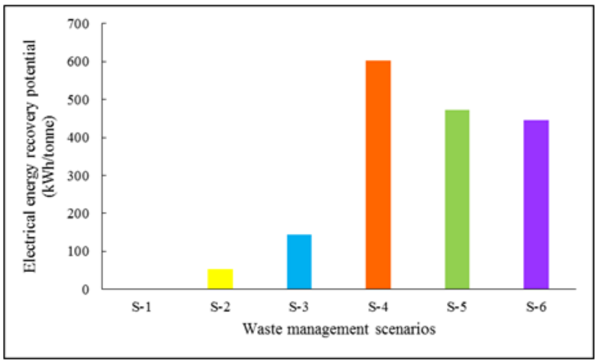

Figure 3: Electrical energy recovery potential of different waste management scenarios

CONCLUSION

Mass incineration and refuse-derived fuel incineration were projected to offer high potential for electrical energy recovery because only combustible waste components were considered in these decisions. In terms of overall waste management, the research indicates that energy recovery from rubbish presents a viable alternative for a city in a developing country. During the landfill gas collecting process, methane emissions from process leaks are one of the main factors influencing the different environmental effect categories.

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