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Design and Experimentation of a Sustainable Solar Organic Waste Convertor (SOWaC)

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Abstract: Municipal Solid waste generation in metropolitan cities is rising daily due to population growth. On average, a family generates about 1.5 kilograms of waste per day, with organic waste accounting for one-third of this amount. If this organic waste is handled at the source, it will ease the load on the current solid waste management systems. Considering this critical problem of organic waste disposal, a pioneering machine was meticulously designed to treat the organic waste at its source. The machine SOWaC (Solar Organic Waste Convertor) is completely automated and converts organic waste into soil additives using bioenzymes. With a primary focus on sustainability, SOWaC is powered by solar energy. This revolutionary machine incorporates an agitator attached to a mixing container, an inlet and outlet, and a temperature sensor among its key components. The capacity of the machine is 20 kilograms. The time required for decomposition is 15-18 days with a volume reduction of 85-90%. The soil additive obtained is dark brown, with a soft, moist consistency and odorless. After processing, the obtained soil additive was analyzed for its physico-chemical parameters. The results obtained demonstrated the effectiveness of this technology in producing valuable organic soil amendments. This machine is suitable for housing societies as well as individual houses.
Keywords: Municipal Solid Waste, Organic Waste, Waste Convertors, Solid Waste Management, Ecofriendly

I. INTRODUCTION

Managing municipal solid waste in metropolitan cities is a complex challenge due to high population and densities and enormous waste generation. Efficient waste management is essential for public health and environmental sustainability[1]. The solid waste management includes segregation, collection, transportation, treatment, and processing. Reducing waste and optimizing resource recovery requires a commitment to sustainability and the circular economy.

An urban family produces a variety of waste daily, it comprises organic waste from the kitchen like food waste, vegetable fruit scraps, flower waste, and yard trimmings; recyclables like paper, cardboard, glass, and plastics; non-recyclables like sanitary products, and some other domestic hazardous wastes[2]. The percentage of organic waste in the solid waste of India typically ranges from 40-60% [2][3]. The problem of this organic waste disposal is complex in metropolitan cities. Lacking infrastructure, limited land, and the risk of methane emissions are key concerns in the management of organic waste. The sheer volume of organic waste in metropolitan areas demands innovative and sustainable solutions to minimalize its environmental footprint.[4]

II. LITERATURE REVIEW

The inclination of converting organic waste into compost is rapidly growing in India. There are numerous technological advancements in the process of decomposition of organic wastes converting it into either compost or a form of energy like biogas.[5] Various approaches for the treatment and disposal of organic waste in urban areas were investigated and are included in the literature below-

1) Composting – Organic materials like leftover food, kitchen scraps, yard waste, and plant residues can be naturally and sustainably degraded to create compost, a nutrient-rich soil conditioner that looks like hummus.[6] This is a widely accepted method that uses a consortium of bacteria to degrade the organic matter. The time required for composting is 45-50 days, depending on the microorganisms. Composting can be performed in both centralized and decentralized methods.[7] Centrally at the urban level windrow composting is adopted while box composting, bin/pot composting, or box composting are the decentralized methods of composting. Challenges from composting arise when the C: N ratio is not balanced properly, and there can be space constraints.[8] The improper segregation of waste and the presence of contaminants in the input materials is also one of the common problems with the method of composting.
2) Vermicomposting – A composting method that uses earthworms to break down organic materials is known as vermicomposting. In this, the earthworms consume and digest the organic waste and convert it into nutrient-rich worm castings which is used to increase the quality of soil and crop.[9] It is a widely used method in agriculture as it provides high-quality, odor-free compost.

Though it is an effective method there are a few limitations. The process is comparatively slow because it takes 60-90 days for decomposition.[10] It is typically used in agriculture fields and organic materials used are restricted. Worms are very sensitive and require proper care hence difficult to maintain. [11]

3) Windrow Composting – This is a large-scale aerobic composting method used for managing organic waste. In this process, the organic materials are formed into long narrow piles called windrows.[12] This process releases heat hence regular aeration is required. Aeration also encourages the activity of beneficial microorganisms that break down the organic matter. This method is adopted for handling substantial volumes of organic waste in a controlled and efficient manner.[13]
4) Bokashi Composting – Bokashi composting is a method of organic waste treatment that can help reduce food waste and contribute to environmental sustainability[14], [15]. It involves fermentation of organic waste such as kitchen scraps or banana peels, using a mixture called bokashi bran, which contains effective microorganisms[15]. Bokashi composting can be included in household waste management and agricultural practices. The bokashi compost produced can be used as a good quality soil amendment, with optimal ratios of C: N.[16] Its effectiveness in improving soil fertility and crop reforestation varies depending on agricultural area and soil conditions.[17]
5) Anaerobic Digestion – It is a biological process in which organic matter is broken down by microorganisms in the absence of oxygen. This process produces biogas which is a mixture of methane and carbon dioxide and nutrient-rich slurry.[18] It's an eco-friendly method that not only generates renewable energy but also provides a valuable soil conditioner.[19] It is widely used in waste management and renewable energy production.
6) Waste to Energy **–** The organic waste is decomposed, releasing energy in the form of biogas or heat, which can be harnessed for power generation. This approach not only reduces the volume of waste in landfills but also produces renewable energy, contributing to sustainable waste management goals.[20], [21]

A research gap in several technologies in the aforementioned literature was analysed, and it was learned that the processes and technologies mentioned above were shadowed by several difficulties. Initial infrastructure and operating expenses, site availability, regulatory compliance, odor management, leachate management, and aesthetic problems are a few frequent gaps. In contrast to a centralized organic waste management plant, decentralized or at-source treatment of organic waste is a better option because it offers substantial advantages and helps create a cleaner, more sustainable environment in India's fast-urbanizing regions.

III. CENTRAL AIM

The core purpose was to develop an innovative and environmentally responsible at-source processing system for organic household waste that reduces the burden on landfills, minimizes greenhouse gas emissions, and promotes resource recovery, contributing to a more sustainable urban environment.

IV. SOLAR ORGANIC WASTE CONVERTOR (SOWAC): THE CONCEPT

In response to the pressing issue of organic waste disposal, a novel machine was fabricated to address the problem at its source. This machine named the "Solar Organic Waste Convertor" or SOWaC, distinguishes itself as a sustainable and fully automatic running on solar energy. It is a compact organic waste convertor and harnesses the power of bio-enzymes to effectuate the decomposition of a broad spectrum of organic waste materials into a valuable soil additive. This machine can process up to 20 kilograms of organic waste with 85-90% of volume reduction in a relatively short span of 15-18 days.

V. DESIGN AND PRINCIPLE

Solar Organic Waste Convertor (SOWaC) is a prototype fabricated having inside height of 33.5 inches and diameter of 22.5 inches. The capacity of SOWaC is 20 kilograms and the components are – Raw material inlet, Processing container, outlet, Solar panel (10-12 watt), agitator installed in the container for aeration and movement of waste material, gear motor (DC) 10 rpm, temperature sensor and display, a battery, geotextile membrane to maintain the moisture content, heat insulation, a mesh to sieve the processed container and a collection container to collect the soil additive. The diagrammatic representation of Solar Organic Waste Convertor (SOWaC) is given in the Figure 1 below-

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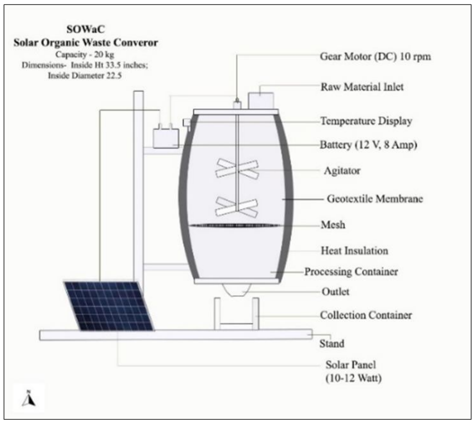

Figure 1: Diagrammatic representation of Solar Organic Waste Convertor (SOWaC)

Image 1: Photo of Solar Organic Waste Convertor (SOWaC)

VI. EXPERIMENTATION

A series of three experiments was conducted to analyse the efficiency of SOWaC. The details of experiment involving different combinations of organic waste materials, culture or inoculants used, experimentation date and degradation times are presented in the

Table 1 below-

Sr. No.	Experiment Number	Components	Culture used	Date of Experimentation	Time required for degradation
1	A	Dried Leaves	Buttermilk + Sugarcane juice	15-05-2022	Around 90 Days
2	B	Household Organic Waste, Flower waste, Dried Leaves	Panchgavya	21-10-2022	Around 30 Days
3	C	Household Organic Waste, Flower waste, Dried Leaves	Bio-enzyme obtained from citrus peels	10-12-2022	Around 18 Days

Table 1: Combination of Experiments conducted on Solar Organic Waste Convertor (SOWaC)

Note: In the above table, EA = Experiment A, EB = Experiment B, EC = Experiment C

The above experiments demonstrate the effectiveness of different culture or inoculum which influences the degradation times and the quality of soil additive. These experiments showcase the sustainable methods for converting the organic waste into valuable resources.

VII. RESULTS AND DISCUSSION

The provided Table 2 below shows the results of all three soil additive samples obtained from SOWaC. The physico-chemical analysis provides valuable insights into the quality and suitability of the soil additives.

1) Colour and Odour – All three samples have a dark brown to black colour and exhibits an earthy smell which is a characteristic of organic rich materials. This depicts the organic waste was well decomposed.
2) pH at 25^0C – The pH values of all samples are slightly alkaline with Sample A at 7.6, Sample B at 7.34 and Sample C at 7.59.
3) Electrical Conductivity (EC) - Sample A has the highest EC at 15.2 ms/cm indicating a higher salt content. Sample B and Sample C have lower EC values, which are preferable as higher EC levels can be detrimental to plants.

4) Moisture Content – Sample B has the highest moisture content at 18%, while sample C has the lowest at 13%. Moisture content can affect the water holding capacity of soil.
5) Organic Carbon – Sample C stands out with highest organic carbon content at 36.2%, making it rich in organic matter, which is essential for soil fertility.
6) Available Nutrients (N, P, K and other nutrients) – As compared to other samples, Sample C has higher nutrient levels making it promising soil additive for enhancing soil fertility.
7) C/N Ratio – All three soil additive samples exhibit C:N ratios within range suitable for soil enhancement (30:1 to 32:1), signifying a balanced decomposition of organic matter and their potential to improve soil fertility and support plant growth.

Results of Physico-Chemical analysis Soil Additive Sample Obtained from SOWaC					
Sr.No.	Parameters	Units	Results		
			Sample A	Sample B	Sample C
1	Colour	NA	Dark brown	Dark brown to Black	Dark brown to Black
2	Odour	NA	Earthy smell	Earthy smell	Earthy smell
3	pH at 25^0C	NA	7.6	7.34	7.59
4	Electrical Conductivity	ms/cm	15.2	13.2	10.1
5	Moisture Content	%	15	18	13
6	Organic Carbon	%	22	17	36.2
7	Available Nitrogen as N	mg/kg	6541	5272	11300
8	Available Phosphorous as P	mg/kg	880	625	1431
9	Available Potassium as K	mg/kg	15691	14020	15383
10	Copper as Cu	mg/kg	0.31	0.456	0.104
11	Iron as Fe	mg/kg	16.55	6.55	29.7
12	Manganese as Mn	mg/kg	8.83	7.83	5.78
13	Zinc as Zn	mg/kg	3.8	23.8	4.42
14	Calcium as Ca	mg/kg	760	880	600
15	Magnesium as Mg	mg/kg	423	499	474
16	C/N Ratio	NA	30.1	32:01:00	32.1

Table 2: Results of Physico-Chemical analysis Soil Additive Sample Obtained from Solar Organic Waste Convertor (SOWaC)

Note: In the above table, Sample A, B and C are the soil additive samples obtained from Experiments A, B and C (EA, EB, EC) respectively.

To summarize, the physico-chemical analysis of soil additive samples obtained from SOWaC reveals distinct differences among three samples. Sample C stands out as the most promising option due to its high organic carbon content, excellent availability of essential nutrients (N,P,K) and favourable C/N ratio. Its high level of organic matter indicates that it has potential to greatly increase the soil fertility and plant enhancement. Its nutrient rich composition makes it a potential asset for agricultural or horticultural purposes. But it is important to consider the particular requirement of the target plants whether the slightly higher pH and lower moisture content of the sample meets the respective demand.

On the other hand, sample A and sample B exhibits slightly lower carbon content and nutrient levels with sample A having highest electrical conductivity. While these samples may still offer benefits as soil additives but they may require adjustments to meet specific needs of the planting.

VIII. CONCLUSION

The results of the Physico-chemical analysis of the soil additive samples obtained from the Solar Organic Waste Converter (SOWaC) demonstrate the effectiveness of this technology in producing valuable organic soil amendments. The data highlights the ability of the convertor to transform the organic waste into nutrient rich dark brown to black soil additives with favourable pH levels, high organic carbon content, and abundant available nutrients. This highlights the potential of Solar Organic Waste Convertors as sustainable and environmentally friendly solutions for converting organic waste into valuable resources for landscaping, agriculture and horticulture in urban areas. The issue of land requirement is also solved as the machine is compact and is solar powered. SOWaC is suitable for at-source treatment of Organic Waste hence, it can be implemented in housing societies and residential communities.

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