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A study on carbon dioxide & ammonia evolved during composting of solid agricultural waste

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ABSTRACT

In the modern era of industrialization, the solid waste such as agricultural waste, municipal solid waste, food waste, papers waste etc. are increasing at an alarming rate. The annual production of these wastes in India is around one million tons and with only a few modern landfills available, the majority of waste are still disposed of in dumps which give rise to other environmental problems such as emission of harmful gases like carbon dioxide, ammonia etc. which affects the environment badly. Therefore the best solution of solid waste management is composting. In the present work the composting of solid agro waste & food waste incubated with municipal waste was studied. The carbon dioxide & ammonia evolved were measured at a regular interval so as to determine the effect of microbial degradation. It was observed that higher CO_2 production rates appear due to presence of more readily decomposable substrate (agro waste) and of a higher microbial population concentration present due to seeding with Municipal Solid Waste. Similarly the ammonia production rate initially increases due to the presence of higher N_2 content and then decreases due to its consumption by microorganism for their survival & growth.

INTRODUCTION

At present the solid waste management is becoming a global problem in developing countries. Solid wastes such as food and yard waste, agricultural waste and waste paper are clogging landfills. This leads to problems in finding new replacement sites. The annual production of these wastes in India is around one million tons and with only a few modern landfills available, the majority of waste are still disposed of in dumps. Accurate information about the quantity of industrial and hazardous wastes is lacking. Now a day's industrial solid waste, with a TOC content above 200 mg/l in the aqueous fraction, can no longer be disposed of in the sanitary landfill. The increase in the production of wastes in a society can be diminished or even ceased to be a problem if an added value was attributed to them. Accordingly, such types of solid wastes have to be either incinerated or transformed into a humus-like product by composting.

Composting is one of the natural bioprocess and environmentally friendly technology capable of treating organic wastes through the microbial activity, to treat and recycle organic wastes. Composting can destroy pathogens; converts nitrogen from unstable ammonia to stable inorganic form, reduce the volume of wastes and satisfies the needs of fertilizer for agriculture use seasonally.

The Composting is an aerobic process in which oxygen is used as the terminal electron acceptor. Heterotrophic Bactria and fungi oxidize the biodegradable carbon fraction of each substrate to obtain energy for metabolic activities and to build new biomass. Nutrients and oxygen concentrations, substrate moisture content, the presence of seed and temperature levels play critical roles in determining the composting rate.

The composting process was carried out on the basis of following findings and guidelines:-

1. Moisture content was maintained from 52% to 60% (wet basis) do not limit composting of most organic substance[3].
2. A minimum of 15% (by weight) of oxygen present inside the composter has been found to not limit the composting process[5].
3. A C/N ratio of 25 to 30 has been suggested for optimum composting[4].
4. Researchers stated that the thermophilic temperature ranges (50 – 70 Deg. Cent.) occur frequently in active composted substrate. Schulez[2] showed that at high compost temperature higher oxygen uptake rates are observed. At temperature more than 70 Deg. Cent. Decomposition rates decreased significantly. As per Arrhenius law the biological reaction rate increases with the increase in temperature up to a maximum level. And thermophilic temperatures are expected to result in higher composting rates than mesophilic temperature.
5. Seeding of substrates with microorganism derived from active MSW & supported by food waste accelerate the initial rate of decomposition & sustainability of the composting process.

The method developed here was designed to degrade the solid waste aerobically. A closed batch system was used with defined input material to collect & measure all gaseous emission per unit of substrate. Water seed & nutrients are added to the batch at the beginning of the process based on the above guidelines obtained from the researchers and excess air was supplied continuously throughout the process.

The total initial & final CO_2 (C) and total initial & final Carbon was measured until full decomposition was reached as was indicated by termination of measurable carbon dioxide flow rates.

The materials used in the present investigation constitute the chief substrate selected for undertaking the composting experiments are the Food waste & agrowaste. All of them are collated form IPS Academy campus located in Indore. They are the two major waste of IPS Academy campus.

MATERIALS & METHOD

Approximately 10% of each of the individual substrate used was sampled and subjected to moisture content and volatile solids content analyses prior to each experiment. Periodically samples were also analyzed for carbon & nitrogen content. All substrate were weighed to an accuracy of +/- 2.5 g. The composter is filled 50% of Food Waste & 50% of Agrowaste crushed in a size 5 mm to 10 mm by weight. The overall initial moisture content was maintained up to 55% to 60% by wet weight. If found less, water was added by spray bottle to reach the moisture content of approximately 60% and the material was mixed.

Nitrogen was added to for which the initial average C/N ratio was higher than 30. Nitrogen was added in the form of NH_4NO_3 salt that was dissolved in the water used to raise the moisture content. The Nitrogen forms present in the NH_4NO_3 salt were assumed to be available to micro-organisms. A distinct ammonia odor was felt during spraying of water with the nutrient salts on the substrate while the digester was open. No phosphorus or other trace elements were added to the substrate to simulate the conditions. Overall dry weight of the combined materials used in all runs ranged from 130 – 1100 gm. Overall wet weight after addition of moisture ranged from 1.5 Kg to 2.5 Kg.

SUBSTRATE SEEDING

Seeding was considered necessary to start the decomposition process and supply an active microbial population suitable for composting in a reproducible manner. All the substrate in all digester was seeded with partially composted MSW collected from nearby area in order to enhance the degradation rate of agro waste. Approximately 5 Kg of MSW was collected and it is kept in drum digester for 5 days without any preprocessing. After 5 days retention time the MSW was sieved & passed through the 12.7 mm screen to remove larger pieces of glass, plastic etc. It was then stored at 4 °C for its continuous runs. It is used in small quantity in the ratio of 1:10 as seeding agent. The Food Waste along with the seeds already present in the mixture of agro waste enhances the decomposition of organic matter content.

The microorganism i.e. fungi & bacteria present in the seeding agents secrete cellulase enzyme which readily digests cellulose and degrade the same quicker. This helps in the present experimentation to reduce, the bio-degradation time and enhances the kinetic reaction rate.

To determine the contribution of seed decomposition to total gaseous emission of a seeded MSW mixture, seed was composted separately. The average volatile solids content of seed measured immediately after collection (i.e. raw) from the facility was 94% (approx.) +/- 0.19% (dry weight basis). A decrease of the volatile solids content of the seed was found when the samples are burnt at 550°C for 1 hour in and the oven. The volatile solids, representing the organic matter, were steadily decomposed throughout the experimental period. The maximum decrease in the Volatile solids was achieved during the second week and third week of the composting period. This decrease in the volatile solid and subsequent increase in the ash content of the sample indicates that the biological constituents in the MSW were reduced during the composting.

EXPERIMENTAL WORK

For experimentation experimental set up is prepared which consist of a composter or digester. The composter is made up air tight stainless steel container of 25 liters capacity having water jacket outside the steel container to circulate the hot water to maintain the inside temperature of the composter. It contains the removable lid with one input & output port. Inside the digester a perforated plate of stainless steel is provided to place the substrate at the height of 4.5 cm above the bottom of the container. This arrangement is done to provide the uniform distribution of the air throughout the substrate mixture inside the digester.

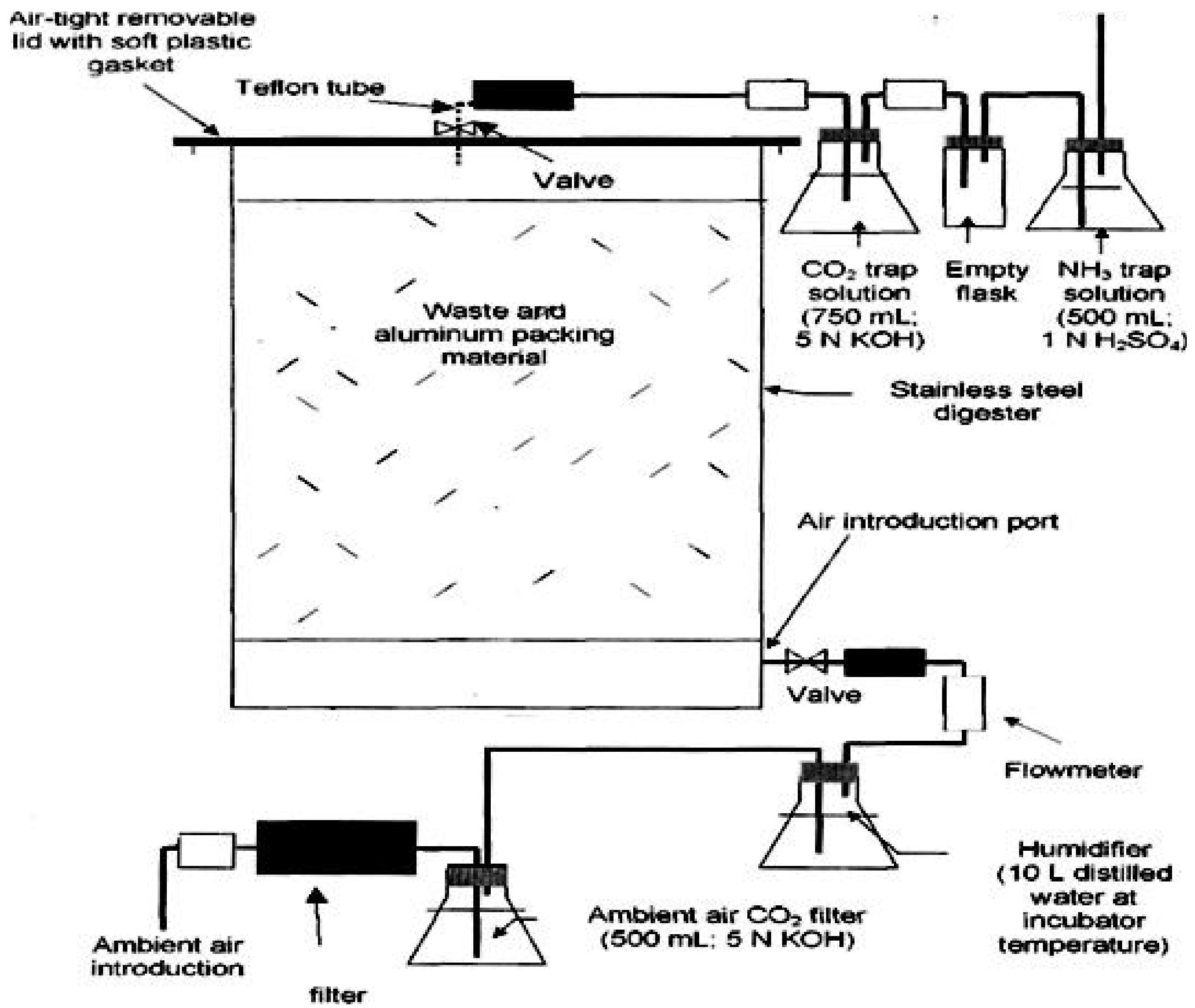
All the substrate is placed in the digester with the aluminum packing material. The packing material was uniformly mixed with the substrate to approximately 10% – 15% of the volume occupied by the substrate. The packing material was introduced to facilitate the air flow, preventing the excessive channeling of air at the sides of digester and to ensure the aerobic conditions were maintained within the substrate. This experimental setup was for as to carrying the operation batch wise.

The ambient air was allowed to enter in the digester through a compressor operating at positive pressure. A 200 gm activated carbon filter to retain the Volatile organic carbon (VOC) of the ambient air was connected. Then VOC free air passed through 500 ml 5 N KOH solutions to capture ambient carbon dioxide. It is then passes through 10 L of distilled water, kept at incubator temperature, to humidify the substrate and to reduce the excessive drying. A valve and a flow meter were connected at the inlet of each digester.

The VOC trap was placed immediately at the exit of the digester. The VOC trap was is filled with an activated coconut charcoal to trap or to remove VOCs for quantification and to partially remove organic compounds of acidic nature e.g. acetic acid etc. that could interfere with the CO_2 quantification to follow. The coconut charcoal trap consists of a 400 mg activated coconut charcoal (20 mesh to 40 mesh). This trap is connected with a bubbler having 750 ml 5 N KOH solution to retain & absorb carbon dioxide which was followed by a 500 ml 1 N H_2SO_4 solution trap to capture ammonia.

The concentration of the O_2, CO_2, CH_4, H_2 and N_2 content of the exit gas stream were measured occasionally in the exit gas stream, before and after the CO_2 trap. These measurements were done to adjust the air flow rate according to the 15% O_2 content minimum level and were especially important during first 15 days after initiation of a run, as this was period of highest O_2 consumption. These measurements also help us in determining the saturation of CO_2 trap if the CO_2 was detected in the gas stream after the alkaline trap.

When CO_2 production rate decreased and stabilized at essentially zero, the digester was opened to check whether this rate reduction was due to moisture limitation. If excessive drying had occurred, moisture was uniformly added to achieve moisture level of at least 50% wet weight and the digester operation was continued. The reason of excessive drying of the substrate may be the less production of water due to low biologi-



Digester setup

cal activity and the excessive amounts of air supplied for this activity. The total period of composting was about 30 days. The experiment was terminated when carbon dioxide production rates dropped below approximately 0.5 g CO_2 (as C) dry Kg/day and after ensuring that this was not due to a moisture limitation.

Carbon dioxide measurements

The cumulative mass of captured carbon dioxide (expressed as total carbon) was measured periodically by removing 3 ml of the alkaline trap solution diluting it with 30 ml of deionized water and performing titrations.

Ammonia measurements

The mass of ammonia captured in 1N H_2SO_4 solution is determined by titrating with 0.02N NaOH.

pH measurement

The leachate collected as a result of degradation is collected every day and its pH is measured using pH Meter so as to determine the extent of composting. The amount of material left in the composter mainly depends on the extent of composting.

RESULT & CONCLUSION

Carbon dioxide production rate interactions

Mixtures of components appear to affect the CO_2 production rates. Initially higher production rate of car-

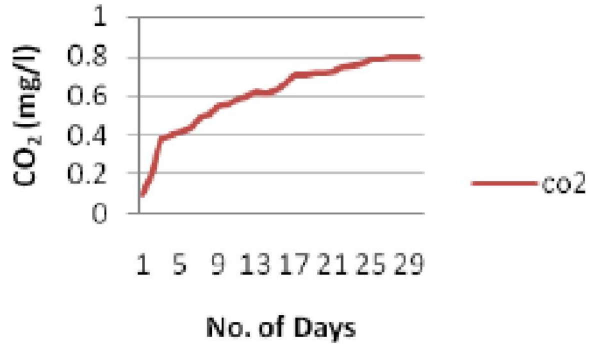


Figure 1 : CO_2 production rate

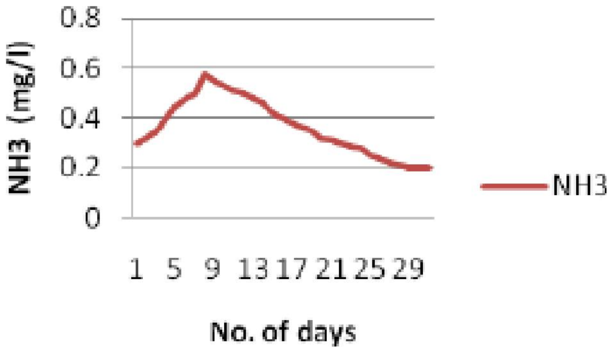


Figure 2 : Ammonia production rate

bon dioxide was observed due first 15 days of the experiment as shown by the steeper CO_2 curve slope of the first 15 days of the experiment (Figure 1). Because substrate utilization rates are usually a function of the substrate and biomass concentrations, the higher CO_2 production rates appear to be a result of the presence of a more readily decomposable substrate (agro waste) and of a higher microbial population concentration present due to seeding with Municipal Solid Waste.

Ammonia production

The high ammonia yields predicted for food wastes are a result of their high initial N content. The addition of agro waste in a mixture reduces ammonia yields due to the relatively low initial N content of agrowaste despite the addition of nutrients. This addition of nutrients resulted similar to the initial N contents of agro wastes. It can also be explained by the fact that some of the externally added nitrogen (probably nitrates) might have become only partially available to the existing microbial population and therefore did not enter the N cycle. Leaching of the ammonium nitrate salt to the bottom of the digester is also suspected and could contribute to a probable low initial N content. Nitrogen losses could also have occurred during the addition of NH_4NO_3 to the substrate, prior to the initiation of a run.

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