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SHORT COMMUNICATION

Biodegradable solid waste management by microorganism: Challenge and potential for composting

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Abstract

Purpose Composting is known since long for reducing the use of synthetic chemical fertilizers. These fertilizers are applied to the crops for the supply of required macro/micronutrients. The present study describes how to decompose biodegradable solid wastes quickly into compost without harming the environment.

Method The microbial inoculums were developed from cow dung concentrate. The cow dung concentrate was mixed with water. The cow dung concentrates, and water mixture was then mixed with another water solution containing Jiggery. After a week, a creamy layer was observed to have formed. This confirms the development of microbial inoculum.

Results After 2-3 days, temperature started to increase slowly. On the 15th day, temperature of the compost pile was 40 °C. At this temperature, the waste changed its colour and showed rapid decomposition. On the 25th day, temperature was noted to be around 60 °C. This showed the completion of the process. After 30 days, the compost was ready and showed signs of the process of maturation. Decrease in temperature confirmed completion of maturation process and complete conversion into compost.

Conclusion The cow dung microbial inoculum consists of decomposing bacteria, protozoa and fungi which are effective to convert biodegradable waste into bio-fertilizer. The regular application of synthetic fertilizers causes adverse effect on greenhouse, environmental pollution, killing of earthworms and other beneficial micro-organisms of the soil, marine inhabitants, depletion of ozone layer, increase of toxicity among human beings due to excessive heavy metals, spoilage of soil fertility, and change in the soil pH.

Keywords Compost, Biodegradable, Waste-management, Cow-dung, Microbial inoculum, Synthetic fertilizer

Introduction

The biodegradation of organic waste is a beneficial process and supplies balanced nutrients to the plants/crops. This process of converting organic waste into compost is known as composting. Composting is known since long for providing strength to soil for reducing impacts of synthetic chemical fertilizers. The biodegradation of solid waste is a common phenomenon. The scientists/farmers have been using anaerobic method of composting since long which is dangerous for both environment and human life. In the present studies, aerobic microbial inoculums have been developed from cow dung concentrate (method of development is given material method section). These microorganisms start biodegradation in the presence of oxygen without producing any kind of obnoxious gases.

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The biodegradation become very fast when these microbial inoculums fed on carbon present in the biodegradable waste. It takes less time to develop and is prepared in a safe manner without disturbing the environment. Hence, the aerobic microbial inoculum developed from cow dung concentrate can help to bring healthy practices and attract the farmers towards organic farming. The decaying of biodegradable waste is harmful for human health both in the society and in the surroundings. It causes air pollution, affects water resource, causes depletion of ozone layer, global warming due to emission of methane and carbon dioxide in the environment. The imperfect waste management by conventional methods (Alam and Ahmade 2013; Clay et al. 2018; Aruna et al. 2018) is not effective to reduce the waste and sometime waste are burnt, thrown in the ocean, dumped in the water bodies accumulated on the roadside, are the common practices (Ogwueleka 2009). Ultimately, all these practices release offensive odour due to anaerobic decay of the biodegradable waste. But in aerobic conditions, a good quality compost is produced without harming the environment (Lasaridi et al. 2018; Wang et al. 2018). The biodegradation of waste by microorganisms is a safe and effective method and produces compost as well as inorganic by-products (Khan et al. 2018). The final product of decomposition contains humus-type substances that are different from the natural soil. The bio fertilizers are active and beneficial to change soil composition and to attain the healthy soil conditions (Cai et al. 2007; Toledo et al. 2018). The composting enables to shield the underground water from pollutants as compared to the dumping of waste in the water bodies. Due to less chemical pollutants and toxic substances during composting, underground water retains its purity for human beings and animals. The microorganisms also absorb toxic substances during decomposition (Bai et al. 2010). The microbial inoculum increases decomposition and produces rich compost, totally free from toxic substances or at the max, may only have negligible quantity of various toxic metals. It also increases the fertility of the land (Yu et al. 2019). It provides the supply of nutrients for promoting the growth of organisms which leads to healthy growth of the crop. This imparts good food quality to a greater extent. The application of compost is also helpful in bioremediation (Pane et al. 2014; Luo et al. 2017) and to controls plant diseases (Ventorino et al. 2019; Pane et al. 2019). It also gives positive impact for controlling the pollution, stopping erosion, and restoring of wetlands (Coelho et al. 2019; Uyizeye et al. 2019). The composting is a safer process and protects the environment more as compared to the uncontrolled anaerobic decaying and impacting of human beings and animals (Caceres et al. 2018; Aziable and Koledzi 2018; Hashim et al. 2022). Looking into the organic farming and composting, its application is safer in comparison of synthetic fertilizers. The microbial inoculums produced from cow dung extract can withstand high temperature and enhance nutrient value (Rajan et al. 2019; Holanda and Johnson 2020). The compost prepared is treated with anti-germicide to get nontoxic compost. The decomposition of waste done by micro-organisms has a lot of benefit in enhancing biodegradation of the scattered waste on the roadsides, water bodies and unwanted areas. This process has less adverse effect on the environment and is safer for next generation to maintain good health and safe lifestyle. The developed microorganisms need oxygen for the decomposition of waste which enhances biological activity and consumes less time for complete stable decomposition of the waste. In the cities and societies, wastes are the unwanted solids, liquids, or gaseous substances (Ali et al. 2019; Langdon et al. 2019; Awasthi et al. 2020). Mismanagement of the waste causes adverse effect on the livings (Wang et al. 2017). Approximately 50% of the generated waste is found to be rich in carbon, nitrogen, phosphorus, and potassium (SI 2016; Ayilara et al. 2020; Pande and Hedaoo 2021). The biodegradable waste is decomposed into stable compost in different ways (Iqbal et al. 2010; Baduru and Sai 2015). In

windrow composting, the thermophilic homogenized waste of 1m^f volume was heaped into conical piles in about 1 m^2 area after being wetted with water to 50-60% (Maso and Blasi 2008). In pit composting, any kind of biodegradable waste is kept in the pits and covered with soil. In windrow composting, waste is kept in pipelines and are mixed time to time and turned regularly. It takes long time to complete decomposition and maturation of compost. It requires more time as well as hardship. Vessel composting biodegradation is carried out in closed vessel or container or building. In this method, mechanical turning is required for proper aeration for biodegradation (Padmavathiamma et al. 2008). This is also an expensive and time-consuming method. In windrow composting, wastes are kept in pipelines and are mixed time to time and are turned regularly. The waste is mixed to supply aeration in the setup. This is also costly, but it is rapid and retains heat. In vermin composting, the cow dung and biodegradable waste is fed by earthworms in the bed of waste (Mupondi et al. 2010). The excreta of the worms are rich in nitrate, phosphorus, calcium, magnesium and improve soil fertility (Baduru and Sai 2015). In static composting, perforated poles are applied for aeration. This method is time consuming although it a simple method of composting and decomposition take slowly. In sheet composting, thin layers of biodegradable waste are spread simply into the soil. The multiple layers are made and left for decomposition. This method is cheap and straightforward. It takes more time as proper aeration does not take place. In India Indore, composting all the biodegradable wastes are made in layers about 15 cm thick and height approximately one meter. The heap is cut into vertical slices, moisturizing is done after 15 days and then after one month. These procedures are time consuming and require more workers, and there may be insects and wind may cause loss of nutrients (Baduru and Sai 2015). In Berkley, rapid composting material size is made 0.5-1.5 inches in size. Once a pile is made, then nothing can be added otherwise it will take longer time for decomposition of the waste. (Bohacz 2019).This is clear from various methods of composting that they are time consuming and need more attention to convert biodegradable waste into perfect mature compost. The present microbial innoculum method is eco-friendly and less attention is required to convert biodegradable waste to mature compost. The effective and fast-growing microbial inoculums are developed from cow dung concentrate. The solid wastes collected from kitchen, roadsides, agro- wastes are crushed and kept in auriferous container in different layers. The microbial inoculums are aerobic and fed on the biodegradable waste. The various types of biodegradable waste have also been segregated and classified as highly decomposable waste (kitchen waste), slowly biodegradable (paper, cardboard, wood) and non-biodegradable waste (thermocol, plastics etc.). The microbial inoculums developed from Cow dung showed rapid action in the conversion without harming the environment. This is a quick and safe method for solid waste management and will bring revolution in organic farming. The overloaded biodegradable waste will also be utilized and will bring green revolution and this method will protect from any harmful impact on health as well. The objectives of the study are to utilize the biodegradable waste by microbial inoculum in aerobic conditions rather than the decomposition of waste in the environment by anaerobic micro-organisms and causing environmental pollution. The biodegradation of waste by microbial inoculums developed from cow dung has been found to be an effective and fast method to produce compost. This way accumulation of waste could be minimized. This way the biodegradable waste obtained from kitchen, green leaves, paper, and cardboard will be minimized to greater extent (Mansi et al. 2020). The approach which was taken in the present study is novel for composting. The aerobic inoculums have been developed from cow dung concentrate which was rich in aerobic microorganisms. These microorganisms feed over carbon as a source of energy, require the introduction

of oxygen to compost piles to allow aerobic inoculums to thrive. Therefore, accelerating the treatment of degradable organic substances to achieve rapid stabilization, eco-friendly and reduce economic cost. Hence in the present method aerobic composting takes place in presence of oxygen. The aerobic micro-organisms break down organic matter and produce small amount of carbon dioxide, ammonia, water, heat to kill the *E. coli* and humus, the relatively stable organic, end-product in safe and short span of time. But in anaerobic composting intermediate compounds including methane (causing global warming), organic acids (causing acidity of soil), hydrogen sulphide (causing bad and obnoxious gases) and other substances accumulate and are not metabolized further in aerobic environment.

Materials and methods

The aerobic microbial innoculum has been prepared in the laboratory. All the chemicals and reagents were purchased from Merck India. For the preparation of this microbial innoculum, 30 gm of cow dung concentrate has the potential to develop 200 litres of culture of micro-organisms (These 200 litres of microbial culture have the potential to decompose one ton of biodegradable waste or agricultural waste). For this, 2 kg of jiggery is added in 200 litre of water as source of carbon for the development of micro-organisms. For the experimental purpose, 20 litres of microbial culture have been made in the laboratory.

1- In plastic bucket 20 litre of water was poured and 200 gm of Jiggery and 3 gm of cow dung concentrate obtained from National Centre for Organic and Natural Farming, Ghaziabad, India was added.
2- The mixture was agitated well and coved with a cardboard.
3- The mixture was agitated every day twice or thrice for proper development of micro-organisms.
4- After the 7th day and 8th day, a creamy layer was developed as culture of perfect micro-organisms.
5- The micro-organisms and other organisms have been confirmed by microbiology laboratory, Teerthanker Mahaveer University, Moradabad.

Method of composting by cow dung microorganisms

This is fast and quick method for composting biodegradable waste. In this method, approximately 10 kg Kitchen waste, green leaves, and dry leaves and cardboard have been used.

The whole collected wastes were chopped into fine particles. Two part of green crushed material was mixed with one part of brown crushed material and left for two hours. The whole mixture was kept properly in a perforated plastic tray. A thick layer of crushed waste was filled nicely in the tray. Now the microbial culture developed from cow dung was sprayed on the crushed biodegradable waste and layers were then added to layers and covered with plastic sheet. The increase in temperature was also recorded from time to time.

The microbial inoculum was sprayed, and the process repeated after 3days, and moisture content was maintained 60-70%. The decomposition started after 5 days, and brown liquid started on the bottom of the perforated plastic tray.

The decomposition of biodegradable material was watched along with moisture control and temperature. After 10days, it turned brown and rapidly changed into stable compost in 30-40 days. The experimental part helped to understand the mechanism of decomposition and to observe various stages in short span of time. These studies proved that the aerobic microbial decomposition is faster and rapid decomposition takes place by using cow dung microbial flora as mentioned and as shown (Fig.1).

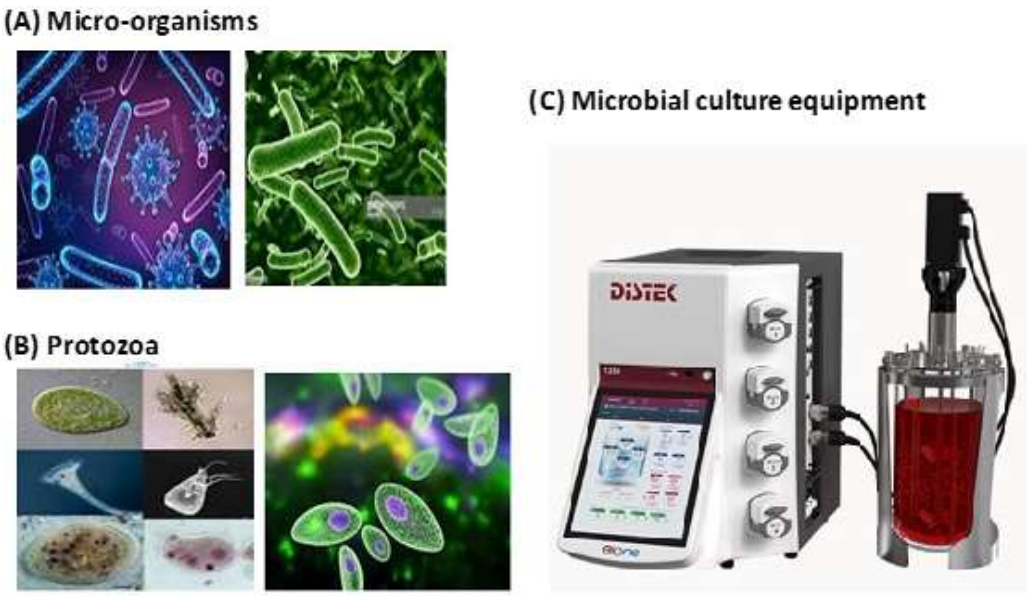

Fig. 1 Picture of microbial inoculum has been shown only to understand types of micro-organisms (A) Micro-organisms, (B) Protozoa and (C) Microbial culture equipment

Slides obtained from Transchem AGRITECH Pvt. Ltd, India (Compost testing Kit), Vadodara-390010 and Orlab Instruments Pvt. Ltd. (Digital soil meter, STFR), Hyderabad, India. The aerobic micro-organisms have been developed in the laboratory at NTP. The seeds of micro-organisms were taken from National Centre of organic farming, Ghaziabad. The cow dung concentrate has been used to develop a culture of aerobic micro-organisms for decomposing the biodegradable waste. The prepared compost has also been studied for various important parameters to justify the quality and elemental verification of the compost. Various analyte e.g., pH, soluble salts, solids, moisture, organic matter, total nitrogen(N), organic nitrogen, Ammonium N (NH_4-N), Carbon (C), C:N ratio, Phosphorus as (P_2O_5), Potassium as K_2O, Calcium (Ca), Magnesium (Mg), Particle size, *E. coli*, Rate of respiration, Rate of CO_2 evolution. and conversion rate of CO_2 to carbon and organic carbon were analysed.

Test method for determining *E. coli* in compost

2 ml of m-coli blue 24 Broth liquid media Ampoules (Cat. No. M00PMCB24) have been applied for the determination of Escherichia coli (*E. coli*) in compost. This medium has been recommended for simultaneous detection of total coliform bacteria and *E. coli* within 24 hours in water samples/compost samples. This is an enzymatic indicator in the medium causes non-faecal, total coli form colonies grow on the medium to be red, while the *E. coli* colonies are blue. The selectivity of the enzymatic indicator eliminates the need for confirmation. The low false positive rates allow for the detection of 95% of all *E. coli*. The medium enhances the growth rate of coliform bacteria. Special inhibitors efficiency minimizes the growth of non-coliform bacteria but do not inhibit the growth of stressed organisms. 100 gm of the prepared compost was taken in a sterile container and 200 ml distilled water was mixed with the compost. The compost was agitated with water in presence of sodium thiosulfate which act as disinfectant. The agitated mixture of compost and water was filtered to get 100 ml of sample. m-coli Blue Broth ampoule was inverted 2 to 3 times. The contents of the ampoule were carefully poured onto the absorbent pad in the petri dish. The membrane filtration apparatus was made ready and membrane filter was kept in assembly with the help of sterile forceps. The water sample as prepared was inverted for approximately 30 seconds to thoroughly

mix the sample. Now the 20 ml of sample was poured into the funnel and vacuum was applied until the funnel was empty. Then the vacuum was stopped. The funnel was rinsed with 20 ml of sterile buffered dilution water. The funnel was rinsed two or more times. The membrane filter was placed on the absorbent pad in the petri dish. The membrane was allowed to bend to remove the air bubbles below the filter. The petri dish was kept for incubation at 35±0.5 ºC for 24±2 hours. After the allowed time, petri dish was removed from the incubator. The microscope was used to count the number of bacteria colonies on the membrane filter. The colony density was taken as the number of colonies in 100 ml of sample.

The colonies in 100 ml = Colonies counted per ml of sample x 100.

This is a quantitative method, and 20% to 30% characteristic colonies were identified. The test method for determining *E. coli* was repeated in triplicate and standard deviation obtained was found to be ±2-3%.

Result and discussions

The composting by microbial innoculum developed from cow dung concentrate showed very interesting and safe way to convert biodegradable waste without posing injurious impact on the surroundings. The micro-organisms developed from cow dung concentrate were kept in a bucket with continuous aeration. These micro-organisms were sprayed every after two days and simultaneously 60-70% moisture was maintained for fast composting. In the microbial activity, microbial population decomposes waste substance and releases CO_2, H_2O. It impacts on the rise of temperature and maturation of compost; the concentration of *E. coli* was 20% to 30%. This confirms that most of the bacterial strains (*E. coli)* were destroyed at composting temperature that ranges from 40 ºC to 60 °C and did not support for the survival of *E. coli*. The carbon matter ultimately changed to stable organic end-product and took 30-40 days for complete transformation of biodegradable waste into stable enriched compost. As per optimization, the decomposition follows three phases. First phase shows moderate temperature, and this is known as mesophilic or moderate temperature phase. In second phase, temperature increases and is known as thermophilic or high temperature phase, which last from few days to several days, but during these studies the micro-organisms enhance the biological activity to change waste into compost. Third phase is cooling and maturation phase which takes long time without micro-organisms, but in the presence of cow dung micro-organisms cooling and maturation time has been reduced to 30-40 days. Various microorganisms in the cow dung predominate the composting phases. The decomposing initiation is done by mesophilic micro-organisms which fed on degradable substances and produce temperature to rise rapidly. As the temperature increases up to 40 °C, the mesophilic microorganisms become less competitive and are replaced by thermophilic (heat loving) micro-organisms. At the temperature of 55 °C micro-organisms slow down the decomposition and at 65 °C, most of the micro-organisms control the rate of decomposition. During the process, aeration was maintained to control the temperature below 65 °C. At this temperature, complex molecules are decomposed and simultaneously, high temperature enhanced the decomposition of complex molecules like protein, cellulose, and carbohydrates (Fig. 2). As soon as the bigger molecules are broken the temperature start decreasing, and mesophilic micro-organisms once again promote decomposition and take over the final stage of maturation of the compost. In the present study, composting has been observed within 40 days. The biodegradable waste changes to stable compost rich in various organic nutrients beneficial for plants and crop. The organic compost so obtained after 35 days was kept and stored in the bucket. The pile of this compost was made by spreading onto the rubber sheet.

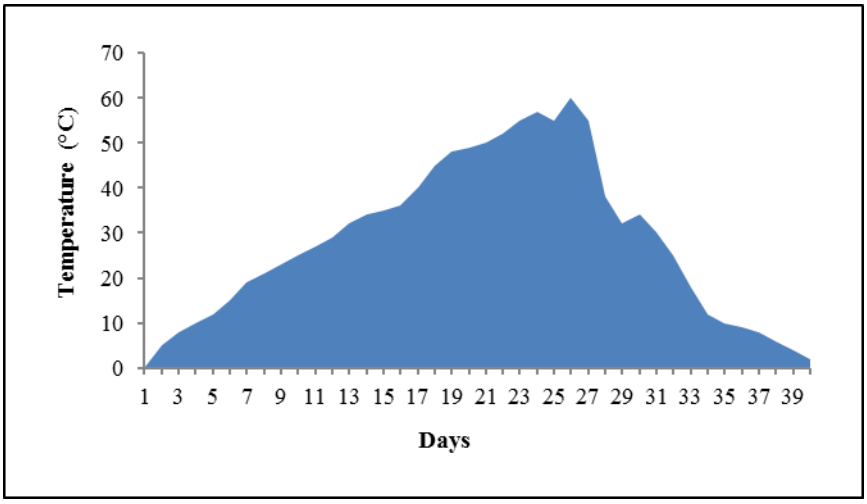

Fig. 2 Decomposition of solid waste by microorganisms

Now it was made homogeneous, and a sample of 500 g was prepared by taking compost from different points of the pile from the base, from the top, and from different depth for physico-chemical analysis and all the experiments were done in triplicate.

Report of compost prepared by microbial inoculum

The measured pH of the compost was found to be 7.6±1.5. Most of the finished compost is found to have pH value in the range of 5.0(acid) to 8.5(basic). Ideal pH value depends on the application of the compost. A lower pH is preferred for certain ornamental plants while a neutral pH is helpful for other applications. pH is not a measure of total acidity or alkalinity and cannot be used to predict the effect of compost on soil pH. The available soluble salts (1.65 mmhos/cm) are determined by measuring electrical conductivity (EC) in a 1:5 (compost: water, weight ratio) slurry. Compost soluble salt level typically range from 1 to 10 mmhos/cm. High salinity may be harmful to plants and may cause toxic effects. The salt level depends on the use of the compost. Finally, compost is blended with soil and tested for soluble salts level. The moisture content of the compost depends on the water holding capacity of the biodegradable materials being composted. In general, high organic matter materials have a higher water holding capacity and higher level of moisture. In the present compost, solid contents are 33.4% with a moisture content of 69.8%. These values are very close to the standard solid content of 35-55%. Similarly, 69.8% moisture in the compost is very close to the 50-60% moisture (Table 1).

There is no ideal organic matter level for finished compost. Generally, organic matter content decreases during composting. The presence of 22% organic matter confirms the perfect decomposition. The required organic matter content of the finished compost ranges from 30-70% on dry weight basis. The desirable organic content must be 50-60% on dry weight basis. The total Nitrogen includes all form of nitrogen, Organic-N, ammonium-N (NH_4-N), nitrate-N (NO_3-N). The finished compost consists of 0.7% of nitrogen. This value is very close to the standard value of 0.5-2.5% on dry weight basis. The organic nitrogen is found to be 0.65% and ammonium nitrate as 2.5 mg/kg. The ammonium-N and NO_3-N are quickly available to the plant. In stable finished compost, N-should be in organic form. The breakdown of organic nitrogen into inorganic form depends on the C:N ratio as well as on the percentage of moisture and temperature. C:N ratio is an indicator for compost stability and N-availability. The C:N ratio of the prepared compost is around 22.50. The C:N ratio normally decreases during composting. If ratio is greater than 25, then it may increase the ratio and ultimately organic nitrogen breaks down into inorganic easily for the plant. The

phosphorus and potassium are macronutrients and very important for healthy growth.

The finished compost consists of 0.16% P and 0.26% Potassium. These are important for the healthy roots and more flowering during blooming season. N:P:K are the major elements for healthy crops. The ratio of these elements is balanced by adding required fertilizers. But it is found that the compost prepared by micro-organisms have good quantity of nutrients and have enough macronutrients for healthy crops.

Table 1 Physico-Chemical characteristics of compost

Analyte	Result (As is basis)	Result (Dry Basis)
pH	7.6 ±0.32	
soluble salts (mmhos/cm)	1.65±0.16	
Solids	69.8±0.15%	
Moisture	22±0.25%	65.3±0.62%
Organic matter	0.7±0.02%	1.85±0.001%
Total nitrogen	0.65±0.01%	1.79±0.002%
Organic nitrogen	2.5 mg/kg or 0.00025%	6.7mg/kg or 0.00065%
Ammonium N (NH_4-N)	14.5±0.17%	40±0.61%
Carbon	22.50±0.002%	22.3±0.001%
Carbon Nitrogen ratio (C:N)	0.16±0.001%	0.48±0.03%
Phosphorus	0.26±0.002%	0.76±0.01%
Potassium	0.75±0.032%	2.43±0.001%
Calcium	0.18±0.001%	0.47±0.003%
Magnesium	91.46±0.12%	Same
CO_2-C/g solid/day	1.0±0.01	----
CO_2-C/g organic matter/day	1.5±0.012	--
Particle size (<9.4 mm) (MPN g^{-1})	3400	9565

[a]Standard deviation occurred from 1.00% to 1.50% for analyte is shown in the Table-1

Compost analysis report for pollutants

The prepared compost was also analysed for the possible pollutants, mainly toxic metals which were present in the biodegradable waste. The studies have been done to justify the presence of toxic metals in the soil and these impurities gradually move to the vegetables and plants. The present studies prove that even biodegradable waste consists of toxic metals (Table 2). The presence of metallic pollutants shows that the kitchen waste, green leaves, and even dry leaves and cardboard consists of metallic pollutants like Arsenic, Cadmium, Copper, Lead, Mercury, molybdenum, Nickel, Selenium and Zinc and are obtained from synthetic fertilizers, water, and soil. The study is very useful as it indicates that the environment is contaminated and produces contaminated vegetables. Although the result shows poor percentage, but their presence is injurious for human beings and animals.

Conclusion

The biodegradation process of organic waste is markedly influenced by the method of composting employed. The microbial inoculums developed from cow dung played a vital role to decompose the crushed

solid-waste in a short span of time (30-40 days) without any obnoxious gases, bad-odour, and limited emission of by-products. The present work focuses on the feasibility to control biodegradation of bio-degradable waste safely in short span of time (30-40 days) by aerobic microbial inoculums instead of decaying waste by anaerobic micro-organisms and producing bad odour.

Table 2 Showing analysis of compost for toxic metals according to the standard procedure*

Analyte	Results (as is basis) in mg/kg	Results (dry basis) in mg/kg
Arsenic	2.8 ±0.12	7.0 ±0.12
Cadmium	>0.18 ±0.001	> 0.47 ±0.002
Copper	13.4 ±0.27	40.0 ±0.61
Lead	6.7 ±0.09	20.1 ±0.52
Mercury	0.019 ±0.001	0.05 ±0.001
Molybdenum	> 0.4 ±0.002	1.3 ±0.012
Nickel	2.9 ±0.04	7.9 ±0.32
Selenium	> 0.8 ±0.001	> 1.9 ±0.02
Zinc	32.5 ±0.25	99.6 ±0.32

*Methodological procedure: Sch-IV, Part D-10-12, The FCO, 1985, Ed. 21st

The emission of more carbon dioxide and methane is minimized which directly affects the greenhouse effect. Normally, biodegradation of solid waste takes place in six months to one year causing huge damage of the environment and producing obnoxious gases. In this method, larger quantity of waste can be converted into mature compost by applying the spray of micro-organisms developed from cow dung concentrate. If the compost produced by this method is used in agriculture, persisting soil pollution will be eradicated and a time will come when pure organic vegetables and fruits will be available for healthy lifestyle. This method can be applied in the society where large volume of the kitchen waste, papers, plants leaves, cardboard can be collected free of charge. This needs to be managed properly for threshing the waste into small pieces and composting for earning good amount per month. To minimize the toxic effects of synthetic fertilizers, application of compost is needed to enhance toxic-free crops/fruits etc. In anaerobic composting much less heat is generated which is not enough to kill the pathogens, parasites and *E. coli*. Hence the present study is beneficial and rapid for biodegradable solid waste management.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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