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Production of biofertilizer by aerobic digestion of domestic waste

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Abstract

The aim of this paper is to determine the difference in quality of the digested residue after the process of aerobic digestion by using different input raw materials. The raw material used for biofertilizers production was municipal waste. The investigation included chemical analysis and bacteriological tests of the samples taken. It was found that the physicochemical analysis show that all parameters reached relatively stable levels reflecting the stability and maturity of the final product, and revealed the biodegradation of components that can be easily assimilated by microorganism. This biocompost tested to the effect of plant growth promotion on Chicory and onion crops. The growth parameters: height of plant, number of branches, and number of leaves, root length, fresh weight and dry weight were found to be improved in the plants, which were given the application of biocompost as a biofertilizer. Hence, this analysis leads to the conclusion that the digested residues of all input materials can be used in agricultural production.

Keywords: *aerobic digestion, biocompost, physicochemical parameters, chicory plant*

1. Introduction

Sewage sludge consists of by-products of wastewater treatment. It is a mixture of water, inorganic and organic materials removed from wastewater coming from various sources (domestic sewage, industries), storm water run- off from roads and other paved area, through physical, biological, and/or chemical treatments. Sewage sludge is also referred to as biosolids. Various agencies have put forth different definitions of Biosolids. Biosolids are nutrients rich organic materials resulting from the treatment of domestic sewage in a treatment facility (US-EPA, 1993).

Some regards biosolids as stabilized organic solids derived from biological wastewater treatment process, which can be managed safely to utilize their nutrients on sustainable basis, and used for soil conditioning, energy, or other value (VEPA, 2000). The utilization of biosolids/sewage sludge in agriculture is gaining popularity as a source of waste disposal. Biosolids/sewage sludge generally contain useful compounds of potential environmental value. They also contain useful concentration of organic matter, nitrogen, phosphorus and potassium and to lesser extent, calcium, sulphur and magnesium. The availability of phosphorus content in the year of application to agricultural lands is above 50% and is independent of prior sludge treatment. Nitrogen availability is more dependent on sludge treatment. Untreated liquid sludge and dewatered treated sludge release nitrogen slowly with benefits to crop being realized over a relatively long period.

There are two basic modes of operation in the effluent treatment processes, namely aerobic and anaerobic. From the view points of efficiency, economics, energy and engineering, anaerobic treatment over run the advantages of aerobic treatment. The process limitations and higher energy requirements of aerobic treatment systems make the anaerobic treatment a viable and feasible option for treating almost all biodegradable industrial effluent streams. Though the capital cost of an anaerobic wastewater treatment process is generally higher than that of an aerobic one, it operates at a lower operation cost, offers a benefit for biogas production and yields lesser amount of excess sludge.

In an aerobic sludge digestion, the microorganisms access free, gaseous oxygen directly from the surrounding atmosphere. If the biodegradable starting material contains nitrogen, phosphorus and sulfur, then the

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end products may also include their oxidised forms- nitrate, phosphate and sulfate (Aerobic and anaerobic respiration, 2007.). The organic matter content in sludge can improve soil physical, chemical, and biological properties with ensuring better cultivation and aquiferous capacity of soil (Csattho, 1994), especially when applied in the form of dewatered sludge cake (FAO, 1992). Biosolids reduce runoff and increase surface retention of rain water (Joshua *et al*., 1998). Organic nitrogen in sludge is much less likely to cause ground water pollution than chemical nitrogen fertilizer (Long, 2001). The application of sewage sludge to agricultural land is the best way of recycling the nutrients present in it. Therefore, sewage sludge may be considered an important biological resource for sustainable agriculture. It produces favorable plant yield responses, when used as an organic fertilizer (Tsadilas *et al*., 1995 and Tester, 1990).

Biofertilizers has become a hope for most countries as far as economical and environmental viewpoints concerned. Especially in developing countries like India it can solve the problem of high cost of chemical fertilizers and help in saving the economy of the country (Al Masri, 2001: Masse, *et al*., 2004). The disposal of biodigested slurry after biogas production is a major concern for the environment (Algawadi and Gaur, 1988; Gaur, 1990; Gaind and Gaur, 1991; Hedge *et al*., 1994; Rupela *et al*., 2004; Dinesh kumar *et al*., 2008). It contains considerable amount of plant nutrients and helps to improve crop production, also preventing adverse environmental impacts of waste disposal (Singal *et al*., 1991; Vander zee *et al*., 2006). Having the above research background in mind the present work was carried out the digestion experiments were performed under aerophilic conditions and the produced digestate was subjected to several analyses to determine its fertilizer quality.

2. Materials and Methods

The research was conducted on municipal solid waste, Chennai, Tamil Nadu. The plant uses organic household waste stored in plastic containers. All the facilities included in the research used the technology of aerobic digestion – the mesophilic process. Sludge digestion will be processed in the bioreactor, which helps to digest the sludge and reduce the concentration of the sludge. Concentrated sludge will be separated through the gravity separation process. Supernatant effluent will be removed through the motorized valves and concentrated sludge will be transferred to the packed drying bed. The concentrated sludge will be scooped manually and transferred to the composting pit; separated effluent will be transferred to the equalization tanks. The samples for analysis were taken immediately after the process of aerobic digestion.

The physicochemical analysis of the aerobically digested residue was carried out by the following chemical procedures. The measurement of pH was taken directly in the sample by means of pH-meter with the combined electrode and the by the device of conductometer MA5964 was used for Electrical conductivity (EC) measurement. Total nitrogen was calculated according to Kjeldahl (Kjeltec system); ammonia nitrogen (NH3-N) was counted by means of Nesler reagent method according to Jackson (1958) spectrophotometrically at the wavelength of 436 mm. For Phosphorus analysis, the molybdate-blue method on a UV/VIS spectrophotometer PU 8600 was used, potassium and sodium were analyzed by flame-photometrically, and all the other elements (Ca, Mg, Mn, Zn, Cu, Fe, Pb, Cd) were analyzed by the atomic absorber spectrometrically (Jackson 1958).

At the same time, the following bacteriological tests were conducted: general test, pathogen bacteria test for *Bacillus* spp and *Salmonella* spp., the number of bacteria in the samples was recorded as well – Colony Forming Units (CFU).

The incubation of the digested material was done at the temperatures of 4°C, 30°C and 50°C on culture media (PEMBA and XLD). At the temperatures of 4°C and 50°C, the incubation lasted for 3 days, and at the temperature of 30°C, the CFU was made (the number of increased colonies in a 1 ml sample) due to the increase of various bacterial colonies. Isolating the pathogenic bacteria was accomplished by the selective broth culture method. Because the digested residue was intented to be applied in the agriculture, it was sterilized in the autoclaves for a period of 15 min at 121°C; after that, the samples were subjected to a repeated series of bacteriological tests.

2.1 Preparation of Compost Cake

The compost was air dried, powdered in a mortar with pestle and sieved through different screen size (ISS 2mm, 1mm, 250mm and 53 microns). The compost powder was then stored in an air tight bag which was placed in shade. 150 g of diatomaceous earth was added in 350ml distilled water and boiled until it completely dissolved in water. The compost powder was added to this at a temperature of 40 ^{0}C until it became a semisolid paste. The aliquot was air dried in shade which resulted in the formation of compost cake. The cakes were cut, packed in air tight bags and stored in shade.

The plants; *Hibiscus cannabinus* (Chicory) and *Allium cepa* (onion) were cultivated at the garden for studying the effects of compost on the yield of a number of crops. We set up plots of 60 X

60 cm, each of the two crops and cultivated each of them on soil without any fertilizer, on soil fertilized with compost (digested) for two month for Chicory and one month for Onion. Morphological and physiological changes in the plants continuously observed and recorded. Surface areas of the leaves were measured and results recorded.

3. Results and discussion

The result of physicochemical properties of the aerobically digested residue samples is presented in Table 1. The pH value (7.9) was within the optimal range for the development of bacteria 6–7.5 and fungi 5.5–8.0 (Zorpas *et al*., 2003). The residue showed that it was low in C/N ratio (14.7) and the phosphorus content of the sludge was 1.18%, while the potassium content was 2.1%. Some reported results proved that the potassium level in residue is usually low and can range from 0.02 to 2.645%, but is enough for plant uptake and is still sufficient for crop requirement (Sommers, 2000).

Apart from the plant nutrient the analysis of the residue showed that it contained permissible limit of trace elements especially calcium, magnesium, manganesh, zinc, copper, ferrous, lead and cadmium, which all have a positive impact on plant growth and these trace elements i.e., P, Ca, K, Mg, and Na as well Fe and Mn were more important to use this material as mineral fertilizers (Soumare *et al*., 2003; Hsu and Lo, 1999; Ouatmane *et al*., 2000). Therefore, application of material will increase the stable organic N and humic carbon and improve mineral elements necessary for plant growth.

Table 1:The physicochemical analyses of the digested residue of municipal waste

No.	Physico chemical analysis	Household waste
1.	pH	7.9 ± 0.43
2.	E.C. mS/cm	44.3 ± 0.89
3.	TOC	64.6 ± 0.72
4.	C/N organic	14.7 ± 0.33
5.	Ash	36.2 ± 0.24
6.	C	39.8± 0.27
7.	N	6.5± 0.06
8.	P_2O_5	1.8± 0.03
9.	K_2O	2.1± 0.01
10.	% Ca	2.9 ± 0.07
11.	% Mg	1.2 ± 0.05
12.	% Na	0.8 ± 0.03
13.	mg/kg Mn	265.8 ± 5.1
14.	mg/kg Zn	47.5 ±3.61
15.	mg/kg Cu	33.5 ± 1.69
16.	mg/kg Fe	429.6 ± 25.36
17.	mg/kg Pb	1.9 ± 0.11
18.	mg/kg Cd	0.4 ± 0.01

The tests performed on the digested residue where the input raw material was municipal waste indicated that in the period of 72 hours there was no increase in the bacterial colonies in the culture media at 4°C. A small number of bacteria from genera *Bacillus* and *Salmonella* grew in the culture media in the period of incubation at 35°C. The number of bacteria approximated 20 × 10^4 (CFU). During the incubation period, some thirty colonies of *Bacillus* genus members grew at the temperature of 55°C. The methods of enriching and oversaturation in the selective broth culture media did not prove the presence of the bacteria from the genera *Bacillus* and *Salmonella*.

However, the optimal pH for the development of pathogenic bacteria *Salmonella* spp. is 6.2–7.2 (Fields 1979). Therefore, in order to prevent the development of pathogenic bacteria and the recontamination, the digested material should be sterilized (Sahlström 2003). The digested residue samples of the effluent were sterilized in the auto-clave after the tests were conducted. A repeated bacteriological test of all samples was performed afterwards. The culture media did not show any bacterial growth; i.e. the samples of the effluent manure were sterile. A procedure of this kind (sterilization) should be obligatory when utilizing the effluent manure in order to prevent possible infections of people and animals.

The effect of biocompost treatments on chicory plant height was shown in Table 2. Biocompost treated plants has the highest (134 cm) plant height while without fertilizer treated plant had the least plant height (69 cm) at 2th month compared to control plant. Other parameters like stem length, branches development, leaves, root and flowers formations also was observed the maximum compared to control.

Table 2: Plant Growth Parameters - Chicory leaves

S.NO	PARAMETER	CONTROL RANGE	COMPOST RANGE
1	Total plant length (cm)	40 - 69	59-134
2	Stem length(cm)	30.5 - 59.5	47-109
3	Stem diameter(cm)	0.3 - 0.4	0.4-1.0
4	Total number of branches	19-Nov	13-25
4	Total number of leaves	14-43	17-42
6	Total number of roots	27-Sep	25-39
7	Root length(cm)	8.5-9.5	25-Dec
8	Total number of the flowers	-	0-2

Plant growth parameters of Onion

The effect of biocompost treatments on Onion plant height was shown in Table 3. Biocompost treated plants has the highest (7.8 cm) plant height while without fertilizer treated plant had the least plant height (5.5 cm) at a month compared to control plant. Other parameters like shoot and root length formations also was observed the maximum compared to control. According to the present analysis, biocompost increased plant growth parameters by enhancing the nitrogen content. Results are confirmed by the work carried out on *Corriandrum sativum* (Akhani *et al*., 2012).

Table 3: Plant growth parameters of Onion

S,NO	PARAMETER	CONTROL (RANGE)	COMPOST (RANGE)
1	NUMBER OF PLANTS GERMINATED	14	17
2	TOTAL PLANT LENGTH (cm)	0 – 5.5	1.5 –7 8
3	SHOOT LENGTH (cm)	0 – 3	1.5 – 4.8
4	ROOT LENGTH(cm)	0 – 2.5	0.5-3

The study concludes that the municipal waste sludge composting, physicochemical analysis show that all parameters reached relatively stable levels reflecting the stability and maturity of the final product, and revealed the biodegradation of components that can be easily assimilated by microorganism. The C/N ratio reaches the optimal range of stable compost; inorganic nitrogen is transformed into stable organic forms. The compost can supply all micro and macronutrients necessary for plant growth. The total concentration of Cr, Zn, Cu, Pb and Cd is very low rendering final compost acceptable for agricultural use. The growth parameters: height of plant, number of branches, and number of leaves, root length, fresh weight and dry weight were found to be improved in the plants, which were given the application of biocompost as a biofertilizer. Hence, this study suggested that using aerobically digested biocompost have resulted in the greatest plant yield. In general, it can be concluded that use of this compost as a biomanure and biofertilizer considerably improved yield and yield component of medicinal plant.

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