Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
e-ISSN: 2395-3454
Vol. 18 No. 1 pp. 231-236 2019
Original Research Paper Open Access

Biodegradation of Sludge Produced from Common Effluent Treatment Plant (CETP) Using Drum Composting Technique

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 30-05-2018
Accepted: 02-08-2018

Key Words:
Biodegradation
Common effluent treatment plant
Rotary drum composting
Sludge
Volatile solids

ABSTRACT

Composting of sludge is suitable waste management option as it maintains all essential physico-chemical parameters, stability parameters and maturity parameters as per standard norms. The present study was carried out to investigate the applicability of the rotary drum composting technique for the stabilization of sludge from a Common Effluent Treatment Plant (CETP). Rotary drum composting was performed in two runs i.e., winter run and summer run. During the whole composting period in the two runs, the continuous monitoring of the physico-chemical parameters like temperature, pH, electrical conductivity, volatile solids, total organic carbon, ash content, NH_4^+-N, NO_3^- -N and phosphorus was made. All these parameters are in the agreement with recommended standards of the mature compost. It can be concluded that rotary drum composting could produce acceptable quality of compost which can be used further as fertilizer or soil amendment.

INTRODUCTION

Disposal of industrial sludge is becoming a great challenge to industries due to high cost of sludge stabilization reactors, dehydration systems and transportation of sludge to disposal site. There is no use of hazardous sludge produced in common effluent treatment plants due to presence of heavy metals, high COD and BOD, low pH, high TDS and TSS. It can only be disposed off in landfills which creates many problems in nearby soil by destroying soil fertility and changing in soil chemistry, land degradation, contaminate surface and ground water and also affect public health. During the recent years, the methodology of sludge management shifted from conventional methods such as incineration and landfill to the conversion of sludge into nutrient rich products. Composting technology seems to be a reliable alternative method for managing Industrial waste and for production of stabilized organic matter (Hajia et al. 2012). The understanding of organic matter transformation throughout the composting process and proper evaluation of the quality of compost from maturity and stability viewpoint are essential for successive utilization of compost. Mokhtari explained the method to evaluate the stability indices in municipal solid waste composting for selecting the best index in quality monitoring of the wastes (Mokhtari et al. 2011). In addition to this, physico-chemical and biological characteristics of municipal solid waste at different stages were informed by Shymala and group (Shymala et al. 2012). Dhal et al. (2012) reported composting of water hyacinth using saw dust/rice straw as a bulking agent (Dhal et al. 2012). Composting of tannery wastes in an ecofriendly method, focused mainly on the heavy metal characterization, was explained by Ahmed et al. (2007). Ashbolt et al. (1982) conducted bench scale system studies for composting of organic waste. Kalamdhad et al. (2012) studied organic matter transformation during pilot scale rotary drum composting for different C/N ratios for the mixture of grass cutting mix vegetables waste, cattle manures and saw dust. Characterization of the sludge generated from paper, sugar and agro oil industries to assess its agro potential to consider as fertilizer substitute was established by Machiraju et al. (2011). Maturity and stability parameters of compost prepared with a wide range of organic waste were explained by Bernal et al. (1997).

Due to industrialization lots of waste is produced, posing a problem for their disposal. So the purpose of the present work is the production of stabilized, matured compost by rotary drum composting technology using sludge of Common Effluent Treatment Plant (CETP) and to evaluate physico-chemical and stability parameters of industrial solid waste.

MATERIALS AND METHODS

The chemicals, used during the course of present work were purchased from E. Merck. The reactor was placed inside old

Hydraulics Lab and analysis was carried out at Environmental Engineering Lab, MNIT Jaipur and Agricultural Research Lab, Durgapura, Jaipur during winter and summer season (January to April). The main material used in the study included a rotary drum composter, CETP sludge, cowdung and sawdust. Sludge was collected from hazardous waste storage site at common effluent treatment plant, Bhiwadi, District Alwar, Rajasthan, where effluents come from various industries such as aluminium, lead, battery, carbon black, steel bars, chemicals, sun glass, edible oils, wire and cable industries, etc. The bulking agent saw dust was collected from a wood shop and cow dung from the H-Quarters at MNIT Jaipur. The biological and physico-chemical analysis of the compost samples collected from the drum composter were carried out in PHE laboratory, Civil Engineering Department MNIT and Agricultural Research Laboratory, Durgapura. The physico-chemical and biological parameters were analysed, by the methods described in APHA, AWWA, WEF (1995). The initial parameters of different ingredients for composting of sludge with saw dust and cow dung with different combinations according to C/N ratios are given in Table 1.

The sludge, cow-dung and sawdust were mixed into the drum by means of a metal container and it can be filled up to 50 % of the total volume, but capacity of filling volume could be further increased up to 70%. Aerobic conditions were maintained by opening up both half side doors of the drum after a certain period of rotation which ensures proper mixing and aeration. Different combinations of ingredients were calculated by online calculator in Cornell University website. The study was conducted in two runs: Run 1: C/N ratio 25.1037 (in winter season) Run 2: C/N ratio 30.1 (in summer season). A good composting process requires that the temperature, oxygen and moisture levels be maintained uniform throughout the compost matrix. Therefore, the side doors of the drum were kept closed, two rotations were provided manually on a daily basis, whereas the doors were kept open for the rest of the time for aeration.

RESULTS AND DISCUSSION

Stabilized, matured compost by rotary drum composting technology was produced from sludge of a Common Effluent Treatment Plant (CETP) followed by physico-chemical analysis of various parameters. There are two distinct phases in the composting system: the active stabilisation phase and the maturation period. In this study both the phases were undertaken in the rotary drum by adjusting aeration by means of the rotation process. In context to the composting process, the key function of the rotation was to expose the composting material to air, provide oxygen and release the heat and gaseous products of decomposition.

Table 1: Initial parameters of different ingredients for composting process.

Parameter	Sludge	Cow dung	Saw dust
pH	8.44	8.3	6.95
E.C. (mS/cm)	2.73	1.01	0.83
M.C. (%)	73.25	55.75	16.75
V.S. (%)	44.47	78.23	84.1
Ash Content (%)	55.53	21.77	15.9
TOC (%)	24.9	43.8	47.09
TKN (%)	1.22	1.56	0.89
NH_4^+-N (g/kg)	0.092	0.158	0.041
NO_3^--N (g/kg)	0.877	0.332	0.121
P (g/kg)	5.61	4.76	8.26

The moisture adjusted composting material was supplied to the rotating drum for fermentation. Inside the drum, the tumbling action mixed and agitated the material. The physico-chemical parameters at different stages during composting are presented in Table 2.

PHYSICO-CHEMICAL PARAMETERS DURING COMPOSTING

Temperature: The temperature observations ware made at three different locations in the composter, i.e. at its centre and at two ends. Variation of temperature of the composting material with time is illustrated in Fig. 1. Actually, two runs were performed in different seasons, i.e. Run 1 in winter and Run 2 in summer, so initially temperature was 15.1°C and 22.3°C in Run 1 and Run 2 respectively.

The gradual increment in temperature showed the increase in microbial activity. The final temperature increased up to 30.1°C in Run 1 and 38.9°C in Run 2. Here, there is sharp increase in temperature in Run 2 from 15 to 27 days than Run 1. This could be because of the seasonal variation but study shows that the rate of decomposition was higher in Run 2 than Run 1.

pH: pH is a measure of acidic or alkaline nature of compost with the progress of composting. pH values varied from 6.98 to 8.39 in Run 1, and 7.76 to 8.32 in Run 2 in the first week of the experiment. At the end of the composting period, final pH values were measured as 7.03 and 7.06 in Run 1 and Run 2, respectively. The optimum pH values are 6 to 7.5 for bacterial development, while fungi prefer an environment in the range of 5.5 to 8.0 (Kapetanios et al. 1993). The pH was initially low due to the acid formation, then it increased and at the latter stage became constant. Slight increase in pH level during the composting process could be due to release of ammonia from protein degradation (Liao et al. 1996).

Electrical conductivity: Electrical conductivity value reflects the degree of salinity during the composting and in-

Table 2: Comparative study of physico-chemical parameters in Run 1 and Run 2 during composting.

Days	6 Days		12 Days		18 Days		24 Days		30 Days	
Parameters	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
Temperature (°C)	20.2	26.1	24.4	27.4	26.9	29.6	28.1	34.9	29.5	37.9
pH	8.39	8.41	7.94	8.51	8.3	8.34	7.13	7.42	7.03	7.06
EC (mS/cm)	1.8	2.47	2.27	2.5	2.08	2.28	2.36	2.04	2.46	2.98
Ash content (%)	62.24	51.99	62.46	54.55	64.99	54.78	67.81	54.56	69.96	55.02
Volatile solids (%)	37.76	48.01	37.54	45.45	35.01	45.22	32.19	45.44	30.04	44.98
Ammonia-N (g/kg)	0.056	0.123	0.055	0.071	0.044	0.063	0.038	0.059	0.018	0.048
Nitrate-N (g/kg)	0.066	0.118	0.093	0.165	0.117	0.188	0.136	0.256	0.178	0.308
TOC (%)	21.145	26.885	21.022	25.452	19.605	25.323	18.026	25.446	16.822	25.189
Phosphorus (%)	2.835	3.897	6.935	3.595	8.52	5.15	7.595	8.035	8.63	12.02

dicates its possible phytotoxicity effect on growth of plants if applied to the soil. Electrical conductivity is the measure of a solution's ability to carry electrical charge, i.e. a measure of the soluble salt content of compost. The salt content of compost is due to the presence of sodium, chloride, potassium, nitrate, sulphate and ammonium salts (Brinton 2003). During the study, electrical conductivity values varied between 1.79 mS/cm and 2.46 mS/cm in Run 1 and 1.82 to 2.98 mS/cm in Run 2. As suggested by Campell, the increase in the electrical conductivity during the process of composting could be due to the effect of the concentration of salts as a consequence of degradation of organic matter (Campell et al. 1997). It was found that the increased electrical conductivity shows the availability of macronutrients and major cations in compost, which was higher in run 2 than Run 1 as shown in Fig. 2.

Total organic carbon: During the composting process organic matter is decomposed and transformed to stable humic substances (Prasad et al. 2013). The Fig. 3 shows the trend of organic matter degradation during 30 day composting process in two different runs. The content of organic matter was decreased as the decomposition progressed as from 21.36 % to 16.82 % in Run 1 and 27.87 % to 25.19 % in Run 2. So in Run 1 there was greater reduction in TOC and hence greater decomposition can be predicted. As per TOC data, observed rate of decomposition, and hence, rate of the volatilization is greater in Run 1 than in Run 2 as shown in Fig. 3.

Ammonia nitrogen: Ammonia concentration is an important indicator of compost stability and maturity. Mostly ammonia nitrogen present during aerobic composting is derived from rapidly decomposing waste. When ammonia concentration decreases and nitrate appears in composting material, it is considered ready to be used as compost. It has been noted that the absence or decrease in NH_4^+-N is an indicator of a high-quality composting process (Hirai et al. 1983). Initially in Run 1, ammonia nitrogen concentration was 0.085 g/kg and finally reached up to 0.018 g/kg. On the other side, ammonia nitrogen concentration was decreased from 0.134 to 0.048 in Run 2 showing the maximum limit suggested by Zucconi (Zucconi et al. 1987) for a mature compost (Fig. 4).

Nitrate-nitrogen: Nitrate-N concentration rises gradually during composting and is a limited factor in assessing compost maturity. Morisaki et al. (1989) also reported that the major decrease of ammonia nitrogen occurred after thermophilic stage leading to an increase of nitrate concentration through nitrification. In aerobic composting process, the percentage conversion of ammonia to nitrate was higher than others due to continuous aeration of compost. Haug (1993) stated that during the composting process, the appearance of appreciable quantities of nitrate could indicate the acceptable maturity of compost. Initially, nitrate concentration was 0.0325 g/kg in Run 1 and 0.1012 g/kg in Run 2. Slight variations were observed in the values of nitrate nitrogen during the study period. After 30 days, the final nitrate nitrogen was found to be 0.178 g/kg in Run 1 and 0.308 g/kg in Run 2. Net increase in nitrate concentration was observed to be 0.146 g/kg and 0.207 g/kg in Run 2. So it can be predicted that Run 2 has better quality compost with the higher nitrate-N content (Fig. 4).

Volatile solids: The content of organic matter was decreased as the decomposition progressed. The Fig. 5 shows the trend of volatilization during 30-day composting process in two different runs. The final VS were observed to be 30.04 % in Run 1 and 44.98 % in Run 2. So, there was net reduction of 7.74 % of VS in Run 1, and 4.78 % in Run 2. So, in Run 1 there was greater reduction in VS, and hence, greater decomposition or volatilization can be predicted. As per VS data, observed rate of decomposition, and hence, rate of the volatilization is greater in Run 1 than in Run 2.

Ash content: The ash content is an important indicative parameter for decomposition and mineralization of the substrate. Ash content was observed to be increasing with

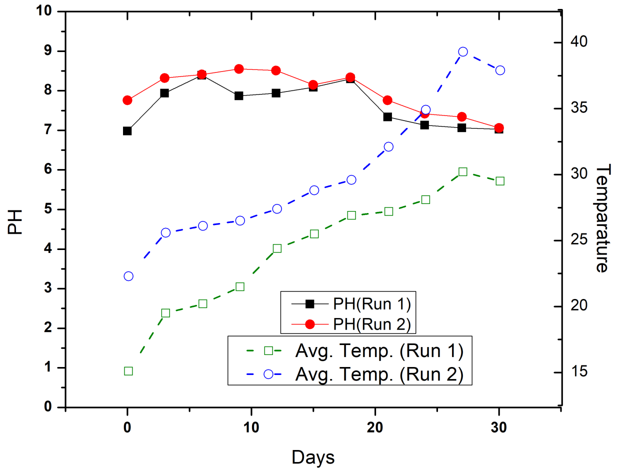

Fig. 1: Variation in pH and temperature in Run 1 and Run 2 during composting.

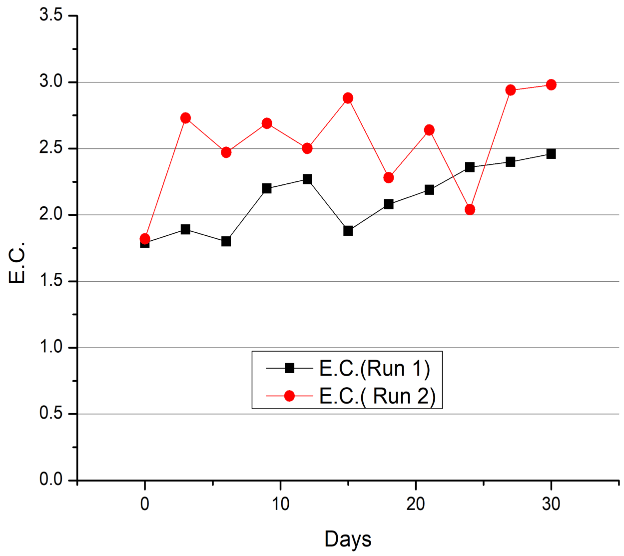

Fig. 2: Variations in E.C. in Run 1 and Run 2 during composting.

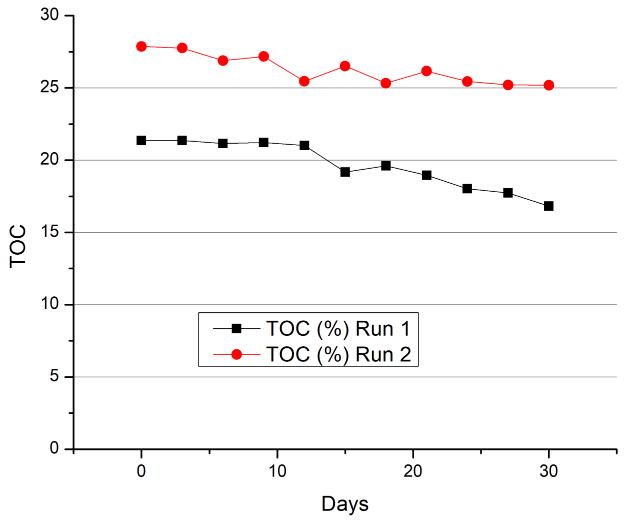

Fig. 3: Variations in TOC in Run 1 and Run 2 during composting.

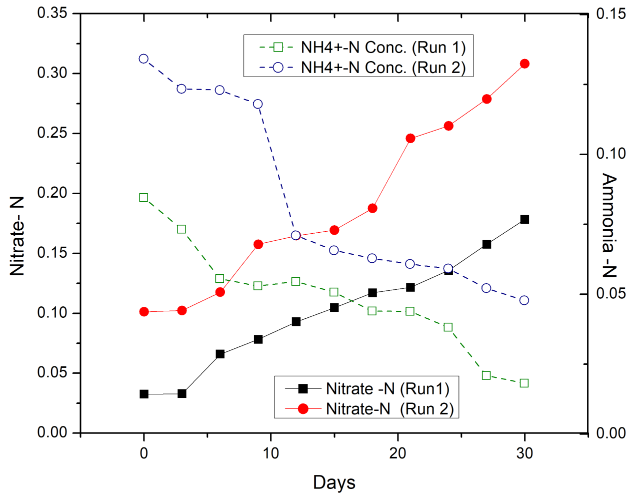

Fig. 4: Variations in Nitrate-N and Ammonia-N in Run 1 and Run 2 during composting.

increase in composting time as shown in graph (Fig. 6). There was 8.1 % increment of ash content in Run 1, and 4.78 % in Run 2. So, Run 1 showed greater rate of volatilization and simultaneous increase in ash content than Run 2. During initial to 5 days, Run 1 shows slow rate of volatilization, but after fifth day volatilization rate increases, and hence, ash content also increases. But Run 2 showed gradual increment in ash content, and hence, volatilization. Similar observations have also been reported by Singh et al. (2005).

Phosphorus: Phosphorus is a macronutrient important for plant growth and maintenance, so it is important in compost. Kalamdhad et al. (2012) suggested that phosphorus in organic matter is released by mineralization process by the microorganisms. Inorganic phosphorus is negatively charged and after the reaction with positively charged iron (Fe), aluminium (Al) and calcium (Ca) ions forms relatively insoluble complexes. When this happens, the phosphorus is considered fixed or immobile. In this context, phosphorus does not behave like nitrate, which is also negatively charged, but does not form insoluble complexes. In Run 1, phosphorus concentration varied from 2.38 g/kg to 8.63 g/kg. In Run 2, phosphorus concentration varied from 3.59 g/kg to 12.02 g/kg. There was 37.19 % increased in phosphorus concentration in Run 1, and 59.08 % in Run 2. So, Run 2 performed

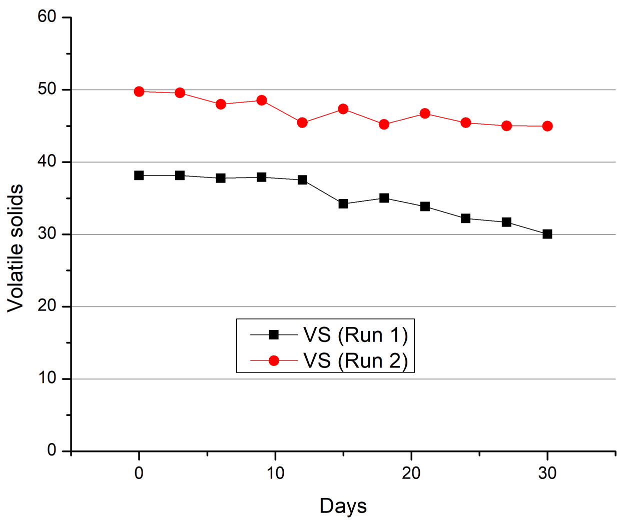

Fig. 5: Variations in volatile solids in Run 1 and Run 2 during composting.

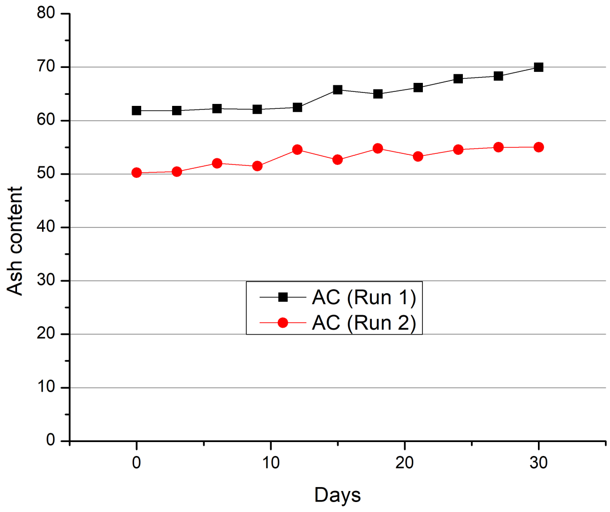

Fig. 6: Variations in ash content in Run 1 and Run 2 during composting.

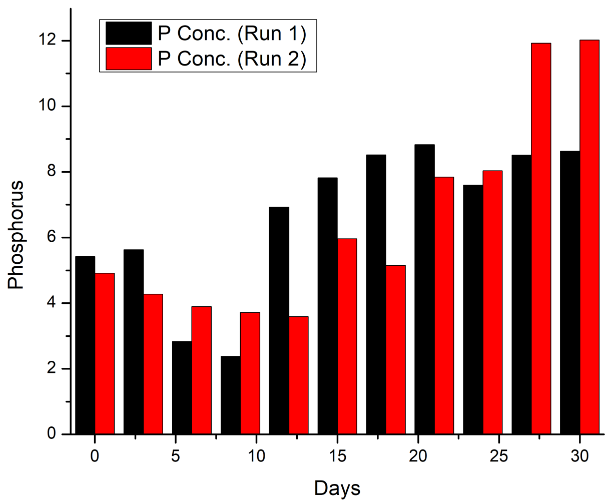

Fig. 7: Variations in phosphorus in Run 1 and Run 2 during composting.

better than Run 1 as greater increase in phosphorus was observed in Run 2, and hence, greater mineralization (Fig. 7).

CONCLUSIONS

The results of the study clearly indicate that rotary drum composting technique can transform the sludge produced from common effluent treatment plants (CETPs) into suitable compost. Physico-chemical analysis of compost from the view point of parameters like temperature, pH, ash content, volatile solids, ammonia nitrogen, nitrate nitrogen, electrical conductivity and phosphorus agreed with recommended levels. The physico-chemical parameters suggest rotary drum composting method as suitable waste management option. In produced compost, level of phosphorus substantially increased, whereas the level of TOC substantially decreased. The composting of CETP sludge produced a good quality compost with pH (neutral though slightly acidic or alkaline pH), electrical conductivity (avg. 2.12 mS/cm in Run 1 and avg. 2.54 mS/cm in Run 2) and final total organic carbon of 9.02 % in Run 1 and 11.25 % in Run 2. pH and electrical conductivity were observed in suitable range, but TOC was less in both the runs as per recommendation by Official Journal of the European Community (Organic carbon 20 %). Gradual decrease in ammonia-N and simultaneously rise in nitrate-N was observed during composting suggest maturity of compost. Mineralization in terms of phosphorus content recommended the use of produced compost for plant growth. So, it was observed that based on physico-chemical parameters, nutrient and trace element analysis, and stability parameters, the performance of Run 2 (summer run) is better than Run 1 (winter run). In comparison to traditional composting, the rotary drum composting is more efficient way due to fast and mixing through rotating the drum.

ACKNOWLEDGEMENTS

Authors would like to thank Director, MNIT for providing research laboratory and necessary resources.

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