

Response of Anaerobic Digester Sludge for Activator Aided Rapid Composting and its Effects on Compost Quality

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Abstract

The anaerobic treatment is in growing demand as an advanced methodology rendering sustainable treatment option for organic wastes. The Anaerobic digester sludge (ADS) is the product of anaerobic digestion of organic matter by microbial activity in an oxygen-deficit environment. It is a good supplement to soil as it enriches soil with nutrients, increases the availability of minerals to plants and helps in soil conditioning. Though ADS is frequently used in agriculture, there are opinions supporting the fact that ADS contains more recalcitrant than its nutritional components. Hence, there is a need for the post-processing of ADS to make it compatible for soil application. In the present study, an attempt has made to assess the response of ADS for CA aided composting and to study the effectiveness composting on the quality of finished compost.

Keywords: Anaerobic digested sludge; Compost activator; Recalcitrant; C/N ratio

Introduction

Anaerobic digestion (AD) is the process to convert organic waste into biogas. AD generated considerable quantities of sludge, which are normally used in agriculture or disposed into soil after drying considering its nutritional value [1,2]. Anaerobic Digester Sludge (ADS) contains good amount of organic matter, essential minerals and nutrients such as N, P and K. Direct discharge of sludge to the plough layers is mostly practiced in developing countries [3]. However, there is paucity of data to justify direct application ADS into the plough layer.

Contrary to the benefits of ADS, there are also views as regards to nature and composition ADS, and its effects on the plough layers. There are opinions suggesting that ADS contains only recalcitrant stuffs such as lignocellulose and its nutrition quality is poor [4-6]. Prolonged application of ADS might concentrate hazardous secondary metabolites along with heavy metals that are otherwise harmful for soil microbes and rhizosphere environment. The AD sludge can also release unpleasant odour containing corrosive and noxious gases such as H₂S and NH₃ [7]. Therefore, it is required that the ADS is evaluated for its compatibility before its application into the plough layers. The Kyoto agreement also emphasises on sustainable handling of organic wastes with pre and post treatment technologies for AD sludge [8].

There are several factors, which regulate the fate and mineralization of the organic residues in soil and the process depends on the physico-chemical, microbiological and soil vegetation those need to be ascertained to determine suitability of the organic residue for such purposes [9,10]. ADS if found enriched with recalcitrants can be further processed into a compost using selective microorganisms along with necessary additives. Conventional means of composting

recalcitrants would take more time due to non or reduced availability of effective microorganism and other necessary ingredients such as essential minerals and nutrients in ADS. However, if provided with effective microorganisms along with other necessary ingredients, composting of recalcitrant stuffs can be facilitated. As the expected recalcitrant stuffs are mostly cellulose and lignin the cellulolytic and lignolytic microbes can be employed along with necessary additives to rapid compost ADS. Composting of lignocellulosic materials using compost activators has already been documented [11]. In recent years, ADS composting has been performed far and wide with changing variables and different types of co-substrates [12]. Composting aims at improving the mineralization and humification of ADS to ensure enhanced supply of organic carbon, essential nutrients and macronutrients such as N, P and K into the rhizosphere.

Having in mind, in the present investigation, an attempt has been made to characterize ADS and to assess its compatibility for composting using compost activators. The effectiveness composting on ADS was assessed through compost quality parameters and its nutritional signature.

Materials and Methods

Collection and processing of anaerobic digester sludge

The ADS used in the present investigation was a dry sludge collected from the open air-drying bed of sewage treatment plant of Nagpur Municipal Corporation, Bhandewadi, Nagpur. The sludge samples brought in closed containers and segregated off for inorganic contaminants during the initial screening process. The sludge sample then pulverized to a size of 25-30 mm in order to carry out further experiments. Some amount of the sample was used for the proximate

and ultimate analysis of ADS as presented in Table 1 and the remaining used in the rest of the experiments.

Sr. no.	Parameters	Anaerobic digested dry sludge
1	pH	7.72 (± 0.38)
2	Conductivity (µS)	327.1 (± 18.1)
3	TDS (mg/kg)	211.6 (± 10.1)
4	Salinity (mg/kg)	167.1 (± 8.5)
5	Na (mg/kg)	9.26 (± 2.62)
6	P (mg/kg)	2.02 (± 0.35)
7	K (mg/kg)	5.6 (± 8.3)
8	Nitrogen (%)	1.49 (± 0.06)
9	C/N ratio	14.42 (± 0.24)
10	Organic carbon (%)	21.49 (± 0.07)
11	Ash content (%)	62.94 (± 0.01)

Table 1: Composition analysis of anaerobic digested dry sludge.

Preparation of compost activator (CA)

The fungal cultures used in the present experiment consisted of *Trichoderma reesei* NCIM (1052), *Trichoderma viride* NCIM (1053) and *Phanerochaete chrysosporium* NCIM (1197) species procured from National Collection of Industrial Microorganisms-NCL, Pune, INDIA and maintained at the National Environmental Engineering Research Institute (CSIR-NEERI) lab under controlled conditions. Each culture were grown in 500 ml Erlenmeyer flask containing 200 ml potato dextrose broth in aseptic condition and incubated in rotator shaker at 200 r.p.m. for 7 days at 30°C. For achieving 1% compost activator dosage, 0.830 µl from each culture were collected and prepared a mixed fungal inoculum using 12.5 g (w/w) of Jaggery and 1.25 g (w/w) of Polyethylene Glycol (PEG). Similarly for 5% and 10% dosage, 4.16 ml and 8.33 ml of each culture were taken along with other ingredients.

Experimental setup

Experiments were carried out in plastic pots of 0.5 kg capacity 250 g of dried and powdered sludge sample was taken and mixed with different (1%, 5% and 10 %) concentrations of CA. The Control (C) setup contained only sludge without CA. All the experiments were replicated thrice. The pots were irrigated as and when required. Samples were collected at regular intervals for further analysis.

Physico-chemical analysis of the compost

Samples were taken from both C and CA experimental setups for physico-chemical analysis. The pH of the compost measured in double distilled water with 1:5 (w/v), compost: water ratio using a pH meter (Model: EUTECH PC-300 probe). The temperature during composting process was monitored using digital thermometer. The CHNS analyzer (Model ELEMENTAR CHNS-O analyzer) measured carbon, nitrogen, hydrogen and sulphur content of the compost. The cellulose and lignin content of the samples were determined by HNO₃-ethanol method and 72% (v/v) H₂SO₄ method, respectively according to [13]. The

concentration of sodium and potassium was estimated using flame photometer. Phosphate content of the sample was determined by stannous chloride method using UV spectrophotometer at 690 nm (4500 P Standard methods US-EPA). The heavy metal content of the sample was estimated by acid digestion with concentrated nitric acid (AR), followed by ICP-OES analysis.

Estimation of microbial population

The total microbial population of the composting samples were estimate by counting the Colony Forming Units (CFU) plated on specific media (Potato Dextrose Agar and Nutrient Agar) after overnight incubation at 37°C. The samples were serially diluted in autoclaved distilled water and plated, then the microbial colonies were calculated by CFU method and expressed in CFU /g unit.

Results and Discussion

Changes in temperature during composting process

Figures 1 and 2 depicts the changes in temperature as observed in control C and activator added CA composting experiments. The results showed an increase in temperature of CA composting trials compared to the control. On evaluating 10% and 5% dosage treatment, the temperature of the reaction system increased to 39°C and 35°C respectively during the initial 7 days, then attained a stationary temperature range of 37°C and 35°C upto 15 days, which further declined to 32°C and 27°C respectively within 21 days of the experiment. However, control treatment did not show any significant increase in temperature during composting. The amount (5% and 10 %) of CA added positively correlated to the increase in temperature during composting process that the increase in temperature was the highest in case of 10% of (CA) addition than at 5%. The increase in temperature during composting process is a normal phenomenon of thermophilic phase [14]. The significant increase in temperature as observed in CA experiments was due to the increased metabolism of substrates by activator [15].

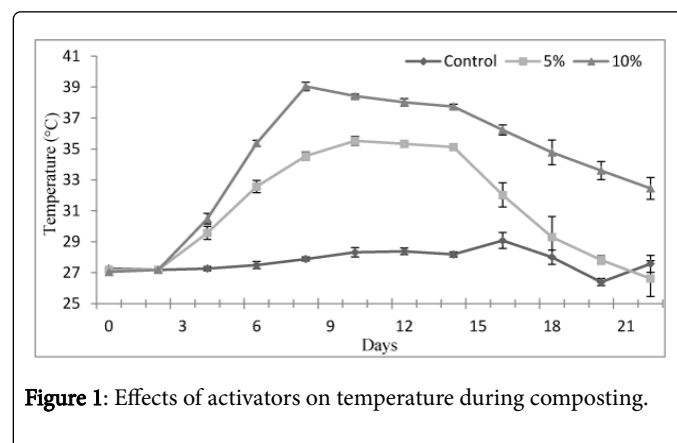


Figure 1: Effects of activators on temperature during composting.

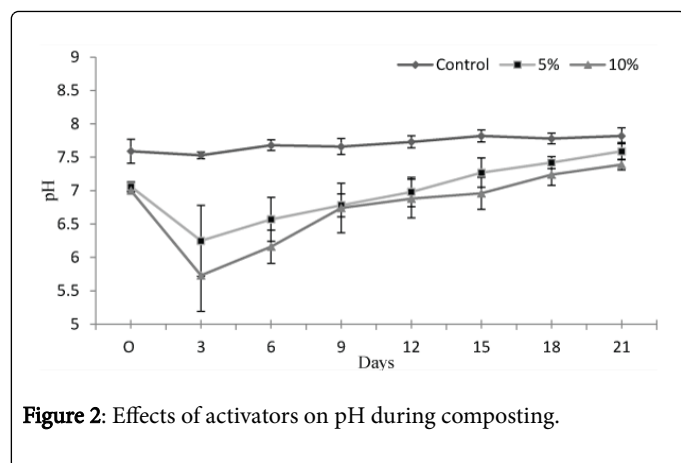


Figure 2: Effects of activators on pH during composting.

Changes in pH during composting process

The change in pH over time tested in both C and CA experiments. The control experiments showed no significant change in pH, however, CA experiments recorded significant changes in pH throughout the duration of composting. There was a sudden drop in pH in case of CA experiments within the first 3 days of the experiment followed by an increase in pH towards neutrality until 21 days. The impulsive drop in pH could be due to the action of extracellular ligno-cellulosic enzymes, which causes breakage in ligno-cellulose structure leading to release of organic acids and volatile fatty acids via acidogenesis making the environment acidic by reducing the pH. On further passing days, the pH reaches to neutral range indicating alkalization of substrate through the release of exchangeable bases and the reduction of organic acids [16].

Changes in C, N, C/N ratio during composting process

The effect of activator aided composting on Carbon, Nitrogen, and C/N ratio was illustrated in Figures 3-5, respectively.

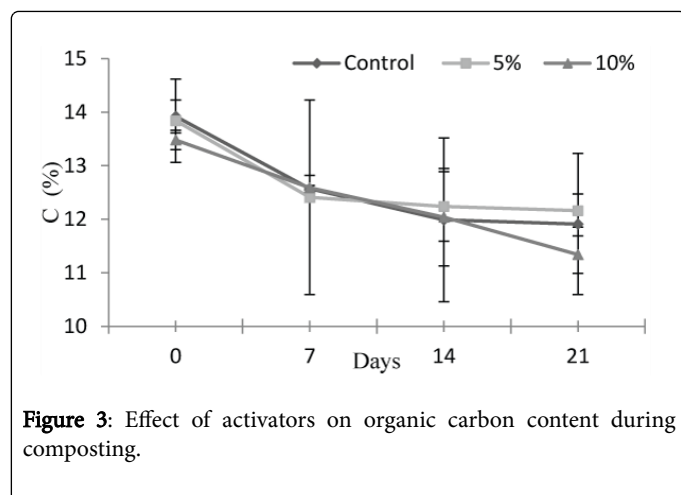


Figure 3: Effect of activators on organic carbon content during composting.

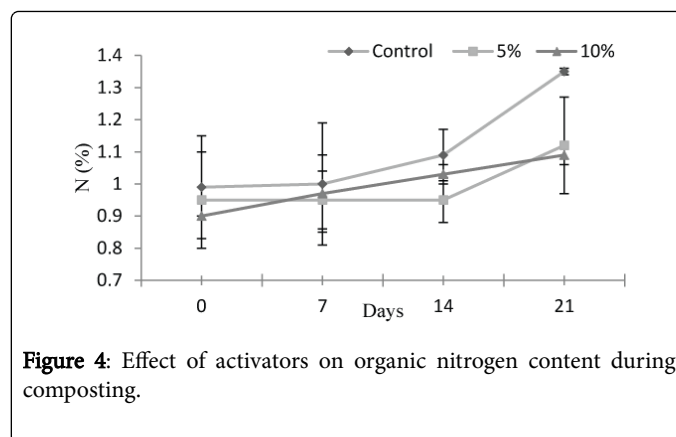


Figure 4: Effect of activators on organic nitrogen content during composting.

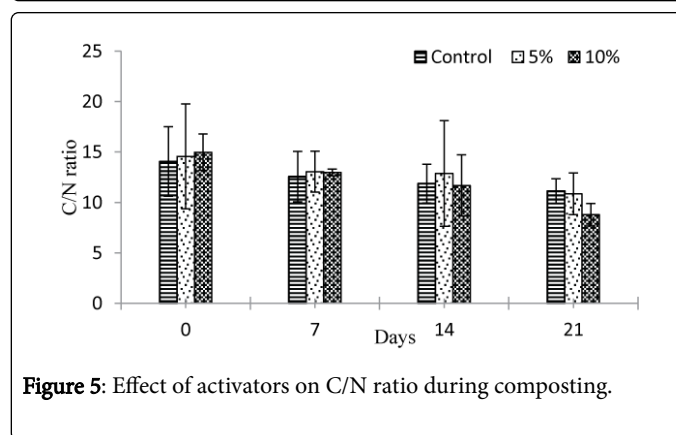


Figure 5: Effect of activators on C/N ratio during composting.

The C/N ratio is an essential parameter for determining the extent of composting with the degree of maturity [17]. The organic carbon content of both C and CA composting experiments declined sharply from 0 to 7 days and thereafter attained a stationary phase. Conversely, the nitrogen content showed a static linear graph illustrating no change in concentration with time till 14 days for both control and additives, which thereafter rose drastically for 10% CA and moderately for 5% CA till 21 days. Compared to the control, CA experiments displayed significant increase in nitrogen content. The initial and final changes in the C/N ratio during composting process can be accounted in terms of percentage as in C the change was only 20.84% and in 5% CA treatment the difference was 25.47% whereas in 10% CA treatment it varies with 41.59% supporting rapid composting with in 21 days. The increase in the total nitrogen during composting was caused by the decrease of substrate carbon resulting from the loss of CO₂ [18]. Further decomposition leads to the transformation of organic matter into stable compounds [19]. As a result, the C/N ratio of the finished compost at the end of 21 days composting cycle showed significant reduction in CA experiments compared to C experiment.

Changes in ligno-cellulosic concentration during composting

The reduction in cellulose concentration during composting is mainly due to the cellulolytic action of microbes [20,21]. A decrease in cellulose concentration suggests the breakdown and recovery of cellulose after cellulolytic action.

Figure 6 illustrates that the reduction in cellulose concentration was due to increased cellulolytic activity where the heterotrophic fungus acts on carbonaceous materials in case of both 5% and 10% CA

treatment catalyzing degradation of insoluble high molecular weight organics into simpler form [22]. The cellulose concentration in the present study decreased from 76 % to 63 % in C. Among the CA treatments, the cellulose concentration dropped from 58% - 34% within the first 7 days in case of 5% fungal inoculum treatment, which thereafter became static and slightly dropped until the end of experiment. As compared to the 5% CA treatment, in 10% treatment the cellulose concentration reduced till 7th day and was consistent until the end.

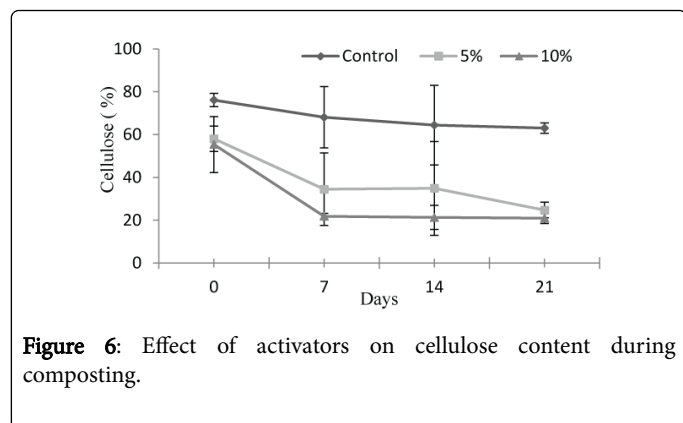


Figure 6: Effect of activators on cellulose content during composting.

The CA additives contained Jaggery and PEG (Polyethylene Glycol) which serves as a substrate for the microbes to feast on thereby leading to an increase in cellulolytic activity and the rate of cellulose degradation. On the contrary, the lignin concentration in Figure 7 has increased in case of control and sample containing 5% fungal inoculum of the experimental setup for the first 7 days followed by a drastic drop in the concentration till 14 days and then a stationary phase is attained upto 21 days. However, treatment containing 10% fungal inoculum showed decrease in concentration during the first 7 days then a slight increase followed by steady phase till the end of the experiment.

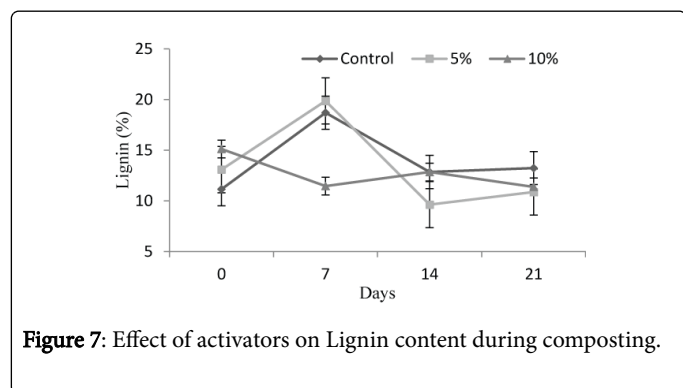


Figure 7: Effect of activators on Lignin content during composting.

Changes in microbial profile during composting

Figures 8 and 9 show the changes in microbial biomass during ADS composting. It was observed that the microbial biomass of the treatments decreased with time notably till the end of the experiment. The CA composition not only aids the growth of fungal but also the bacterial population during the experiment. In case of the sample containing 10% fungal inoculum, there is a drastic decrease in the biomass over time till 21 days of the experiment. However, in the C, a marginal decrease in the microbial biomass observed.

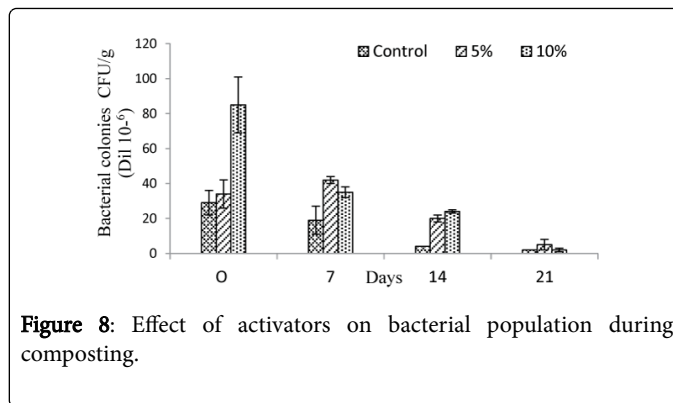


Figure 8: Effect of activators on bacterial population during composting.

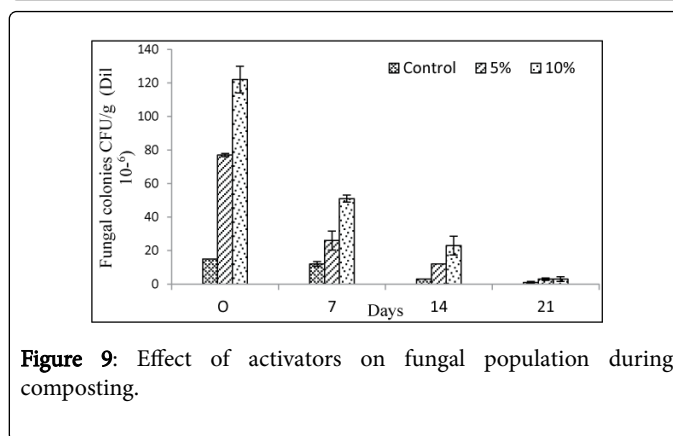


Figure 9: Effect of activators on fungal population during composting.

Both the fungal colonies and the bacterial colonies of the microbial biomass have decreased in case of control and additives from the beginning to the end of the experiment. It is interesting to note that the treatment where fungal cultures (5% and 10% inoculum) added, the microbial biomass decreased significantly. The cause may be behind this was the CA consist of Jaggery as a carbon source aiding microbial population in initial days but as duration increased carbon supply in the form of Jaggery depleted that led to the decrease in microbial population. This also indicates that as the primary source of carbon lessens, the possible secondary source viz. the ADS does not have enough essential nutrients or organics that supports microbial population.

Effects of CA aided composting on the mineral nutrient and heavy metal content of ADS.

The speciation of minerals and heavy metals depends on its chemical content during anaerobic digestion followed by adsorption, precipitation and stabilization in sludge and later on humification process on the chemical form of metal during composting. The analysis of mineral nutrients such as sodium, potassium and phosphorous (Figures 10-12) showed the availability of these elements in varied concentrations. The elements sodium and potassium has produced a similar type of graph, which shows stationary phase in early 14 days and with a slight deviation till the end of experiment in case of C and the both CAs during their initial 7 days drops down, and in the next 14 days attends a stationary range of concentration. On the other hand, in case of 10% fungal inoculum treatment, phosphorous levels have initially decreases (day 0) and stabilize throughout the experiment (day 21). However, the control and 5% fungal inoculum contained treatments have varyingly decreased in their levels until the experiment completes.

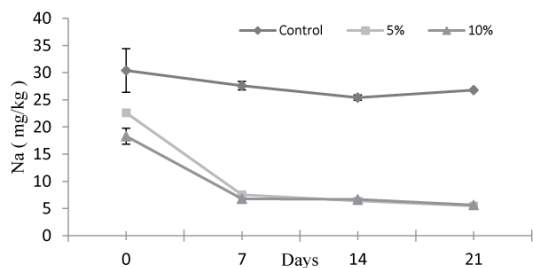


Figure 10: Effect of activator on Sodium concentration during composting.

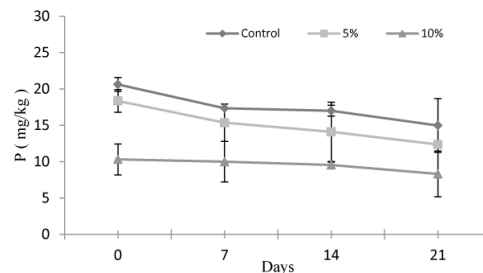


Figure 12: Effect of activator on phosphorus concentration during composting.

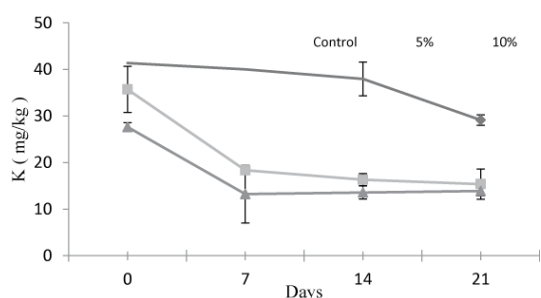


Figure 11: Effect of activator on Potassium concentration during composting.

Many authors have described the availability, role and importance of heavy metals in different composts [23-26]. Table 2 shows the different heavy metals that are analyzed in the compost by detecting them through ICP-OES. It was clear from the results that the heavy metals are within the permissible limit. The concentration of Cd, Cr, Ni, Pb and Zn and have decreased in case of control and the sample containing 5% fungal inoculum for 7 days of the experiment and then shows constancy in their concentration till 21 days whereas in case of the treatment with 10% fungal inoculum the heavy metal concentration was maintained at a stationary phase throughout. The final compost renders in an acceptable form for agricultural use as the total concentration of Cd, Cr, Ni, Pb and Zn is low.

Days	Control				5% treatment						10% treatment				
	Cd	Cr	Ni	Pb	Zn	Cd	Cr	Ni	Pb	Zn	Cd	Cr	Ni	Pb	Zn
0	0.26 ±0.14	2.08 ±1.30	1.44 ±0.98	6.42 ±3.02	25.10 ±7.72	0.23 ±0.10	1.70 ±0.95	1.25 ±0.49	5.68 ±2.13	24.16 ±6.52	0.14 ±0.05	0.77 ±0.5	0.82 ±0.49	5.68 ±2.13	19.10 ±3.96
7	0.10 ±0.02	2.14 ±0.90	0.53 ±0.07	2.47 ±0.28	12.55 ±1.58	0.12 ±0.01	0.95 ±0.49	0.65 ±0.07	3.01 ±0.27	15.34 ±1.47	0.10 ±0.02	0.84 ±0.09	0.58 ±0.08	2.71 ±0.33	13.48 ±1.54
14	0.11 ±0.01	0.84 ±0.09	0.60 ±0.09	2.97 ±0.28	14.18 ±1.98	0.10 ±0.02	0.79 ±0.35	0.55 ±0.10	2.54 ±0.39	12.72 ±1.98	0.10 ±0.01	0.80 ±0.41	0.56 ±0.05	2.65 ±0.26	12.91 ±1.17
21	0.09 ±0.01	0.73 ±0.39	0.53 ±0.04	2.69 ±0.22	12.80 ±1.04	0.09 ±0.00	0.74 ±0.36	0.53 ±0.01	2.55 ±0.02	12.38 ±0.24	0.10 ±0.01	0.72 ±0.35	0.54 ±0.03	2.66 ±0.17	12.63 ±0.57

Table 2: Heavy metal concentration in different treatments of ADS during composting.

Conclusion

In context of ADS utilization, it is important to assess its characteristics and compatibility for soil application. The results of the present study indicated that ADS consisted of recalcitrants that were degraded through CA aided composting process. This will leads in empowering the utilization of ADS as eco-friendly manure aids to soil conditioning and availability of essential nutrients for plant growth and eco-capital build up. Thus, it is essential to post treat the ADS in order to utilize it as soil enrichment in a sustainable approach.

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