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Research Paper

BIO-COMPOSTING OF LATEX ETP SLUDGE AND EFFECT OF LATEX COMPOST ON COWPEA

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Abstract
Latex ETP sludge is an industrial by-product with a high nutrient content (N-1.9%, P-9.12%, K-12.89%), which is eventually biodegradable. Since there are few alternatives for its practical use, its utilization as an agricultural fertilizer is proposed. Thus, this paper studies composting as treatment method for latex sludge and the use of compost obtained as growing media for cowpea. For this six treatments were prepared using sludge, bulking agents [saw dust (SD), cow dung (CD) and coir pith(CP)] and microbial inoculum, Streptomyces sp. in different ratios for 120 days. The treatments prepared were T1(S+SD), T2(S+CD), T3(S+CP), T4(S+SD+CD), T5(S+CP+CD), T6(S+CP+SD) and a control for each treatment was maintained. The finished compost showed adequate physico- chemical properties and maturity. Among the treatments T2 and T5 showed the best results. Therefore, composting can be a suitable method not only for the management of these wastes but also for adding value to them as a manure for crop production.
Key words: Latex Sludge, bulking agents, microbial inoculum, compost, C:N ratio.

INTRODUCTION

In Kerala, HLL Lifecare Limited (formerly known as Hindustan Latex Limited) is one of the largest consumer of rubber in the form of latex for the manufacture of male condoms. HLL also manufactures other health care products like Blood collection bags, Surgical Sutures, Hydrocephalus shunts, tissue expanders etc. The annual production capacity of HLL is 1.316 billion pieces. In this factory, the latex ETP Sludge is an semi solid part by-product obtained after effluent treatment in the effluent treatment plant (ETP). About 750 tonnes of sludge is produced every year. Landfill is the disposal method practised in HLL, which may not be viable in the long run as land is getting scarce and land cost is becoming more expensive. Moreover landfill disposal of sludge has many drawbacks like high cost of transportation, heavy metal contamination of land, emission of foul gases etc. Incineration is yet another treatment method which presents environmental impacts like emission of SO_2, NO_x, Co_x, dioxins and heavy metals (Zorpas et al.,2008).

The eco-friendly management of these type of industrial sludge and solid waste are major challenging issue for industries, scientist and society (Gautam et al.,2010). Among all disposal options, composting can be considered to be the most economic and environmentally sound option. Composting is the process of bacterial conversion of organic solid and semisolid waste in to compost which can be handled, stored and transported without any adverse environmental effect and can be used as organic manure for improvement of soil quality and fertility. Composting can be aerobic and anaerobic. Different species of bacteria are responsible in each case, different chemical changes takes place and different temperatures are reached (Hussain and Naser,2013).There are few main factors which may be able to affect the composting process; temperature, carbon to nitrogen ratio, aeration(percentage of oxygen), moisture content, porosity and pH(Table 1)

Sludge could not be composted alone because of their lack of physical structure. Hence they had to be mixed with bulking agents (Huet et al.,2012). The addition of bulking agents for composting optimises substrate properties such as air space, moisture content, C:Nratio and pH affecting positively the decomposition rate(Neves et al.,2009).Co-composting of more than one type of waste can be more suitable management process of solid waste. Sawdust, rice husk bark cow dung can be added as additives to absorb excess moisture as well as to achieve the optimum C:N ratio(Kubota et al.,1984). Coir pith is yet another bulking agent most commonly used. Several authors have been reported composting using different bulking agents(Gautam et al.,2010;Rosazlin et al.,2011;Tripetchkul et al.,2012;Harrison et al.,2014). Recently adding microorganisms to speed up composting and increase the nitrogen content in the waste to improve the microbiological degradation is actively investigated(Vargas-Garcia et al.,2007;He et al.,2008;Ridha et al.,Li et al.,2011). Actinomycetes such as *Streptomyces* sp. also have the capacity to attack and degrade lignins (Crawford,1978, Phelan et al., 1979). Besides this utilization of various forms of additives combined with microbial consortium for the decomposition of different kinds of solid wastes/biowastes has been also reported by some researchers (Kithome et al.,1999;Abrusci et al.,2007;Echeverria et al.,2012).Bellamy et al.,(1995) reviewed 10 years research programme on the use of various industrial sludges as a soil amendment and found decrease in yield of crops during the early stage of the crop. However the slowly increased 10 months after incorporation, which might be due to biodegradation of the industrial sludge. Meanwhile, Reji (2005) studied the composting of Latex sludge and coir pith in different ratios along with microbial inoculums (Phanerochaetae, Pseudomonas and Streptomycetes) and concluded that the microorganisms have the capacity to utilize biodegradable portion of sludge under a set of environmental conditions. Studies on bio-composting of latex sludge are limited. Therefore, the aim of this work was to examine the efficacy of composting of Latex sludge with bulking agents like saw dust, coir pith and cow dung in different ratios along with inoculation. The study was conducted to determine the physico-chemical characteristics of composted latex sludge and effect of composts on plant growth performance.

MATERIALS AND METHODS

Materials and bulking agents

The main material for composting was Latex sludge(S).The sludge(S) was collected from effluent treatment plant of HLL Lifecare Limited Peroorkada,Thiruvananthapuram. The collected sludge was air dried under shade, powdered and sieved. The bulking agents used were sawdust(SD),coir pith(CP) and cow dung(CD).Fresh sawdust was collected in large polythene bags from a sawmill near Chirayinkeezhu. Coir pith was collected from coir industry near Chirayinkeezhu and cow dung was collected locally from Kariavattom. The physico-chemical characteristics of latex sludge(S) and selected bulking agents are presented in Table 2.

Inoculum preparation

The inoculants used in this study was a kind of actinomycete,Streptomycetesp.Mother culture of Streptomycete sp. was purchased from Kerala Agricultural University Vellayani,Thiruvananthapuram. Mother culture of *Streptomyces* sp. was subcultured and broth was prepared. The growth medium used for preparing the *Streptomyces* sp. was potato dextrose agar(Cappuccino and Shermann,1999).

Composting experiment design and physico-chemical analyses

Composting treatment was done in Department of Environmental Sciences, Kariavattom Campus, Thiruvanathapuram. Composting was carried out using plastic troughs 35cm in diameter and 30cm height provided with holes to hasten aerobic decomposition. Plastic troughs was filled with sludge cow dung, saw dust and coir pith as per experimental design:

T1:2kg Sludge(S) +2kg Saw dust(SD) (1:1)
T2:2kg Sludge(S) +2kg Cow dung(CD) (1:1)
T3:2kg Sludge(S) + 2kg Coir pith(SD) (1:1)
T4:2kg Sludge(S) +1kg SD +1kg CD (2:1:1)
T5:2kg Sludge(S) +1kg CP+ 1kg CD (2:1:1)
T6:2kg Sludge(S)+1kgCP +1kg SD (2:1:1)

Latex sludge was mixed with bulking agents in different ratios on dry weight basis to prepare six different treatments. The sludge and raw materials were mixed thoroughly and adequate moisture content (60-70%) of the mixture was maintained by spraying water using a spray can. The mixture was kept undisturbed for one day and the next day microbial culture of *Streptomyces* sp.(20ml) was added. Periodic turning once a week was done with a spatula. Temperature was monitored on 15 days intervals using soil thermometer inserted at different locations and depths in container (Bhoyar et al, 1979).The mean of the temperature at three points is reported.

To analyse the physico-chemical changes during the composting process, compost samples were drawn right after each turning at various stages of composting 15,30,45,60,75,90,105 and 120 days. pH ,EC and moisture content was analysed on the day of sample collection. The collected samples were air-dried and properly grounded and stored in sterilized plastic air tight bags for analysing other chemical parameters. All analysis was performed in triplicates. pH and EC were measured in an extract of10g of fresh sample in 100ml distilled water. The pH was measured using a pH meter and EC using a conductivity meter(Jackson,1973). Moisture content of fresh compost samples was determined after drying to a constant weight at 105°C in a forced air oven. Organic carbon was determined by wet oxidation method of Walkley and Black (Saxena et al,1996).Total nitrogen was determined by microkjeldahl method(Trivedy and Goel,1997). Total phosphorous was determined using spectrophotometric method and total potassium was determined by flame photometry(Trivedy 1984). Calcium and magnesium was determined by titrimetric methods(Jackson 1973).

Pot culture experiment was carried out to study the effect of compost prepared in different ratios by cultivating bush type cowpea, *Vigna unguiculata* against control. The seeds of *Vigna unguiculata* were procured from Kerala Agricultural University. The compost was mixed with garden soil in 1:3 ratios and then filled in pots. Seeds were sown in pots and two plants were maintained in each of the pots. The set ups in triplicates were kept under natural sunlight and watered regularly. Measurements were made on 30th,60th and 90th day. Observations on height of the plant(measured with a tailor's tape),number of branches per plant, number of leaves were counted manually during 30th and 60th day. After fruiting, the harvested pods were taken and assessed for parameters needed to calculate the yield such as number of pods, length of pods, number of seeds per pod and finally weight of seeds per pod was noted (Adeoye et al.,2011).

Statistical analysis

The data on all parameters were collected in triplicates and calculated the mean and standard error by one-way analysis of variance(ANOVA); Simple linear regression of the form y=ax+b was carried out in order to find significant relationship between y(physico-chemical parameters and x different time periods). Estimates of the slope parameter(a) and intercept parameter (b) were obtained using principle of least squares method. The significance of these parameters were tested using t-test. The coefficient of determination (R^2) was calculated for testing goodness of fit of the model. The Pvalue<0.05 is considered to be statistically significant.

RESULTS AND DISCUSSION

Characteristics of latex sludge(S) and bulking agents

The physico-chemical properties of latex sludge and bulking agents are shown in (Table 2).The latex sludge (S) was alkaline in nature(7.2).The C:N ratio of latex sludge was low(4.74) and a high nitrogen content of 1.95% was noticed. The phosphorous and potassium content was also high(9.12 and12.89%). The selected bulking agents showed high C:N ratios *ie,* CP(83.39),SD(201.6) and CD(29.64)respectively. The C:N ratios of latex sludge(S) was not sufficient for composting. Therefore the selected bulking agents especially coir pith and sawdust with high C:N ratios were used for composting.

Physico-chemical parameters of compost

All the compost samples appeared dark brown in colour with an earthy smell,deemed necessary for mature compost(Epstein 1997).

Changes in pH, EC, moisture content and temperature during composting.

In general,the result showed that compared to control groups, the treated groups showed an increase in mean values of all parameters. Since the beginning of the process, the pH tend to move towards acidic. This may be due to the incomplete oxidation and formation of organic acids from composting mixtures (Goyal et al.,2005;Karak et al.,2013). Microorganisms are reported to produce organic acids and hence the pH value of the composts decreases slowly at the initial stage (Li and Zhang 2000).During maturation (120th day), all the treated groups attained a neutral pH. Liu et al.,(2011) explained that the increase of pH from acidic to neutral in later stages could be due to the production of nitrogenous compounds and decomposition of organic acids. Similar results was obtained by Awasthi et al.,(2016)and this was due to the degradation of sludge-borne proteins and the accumulation of ammonium nitrogen(Wong et al.,2009;Villasenor et al.,2011).Results of Anova showed that significant difference were observed between treated groups compared to control groups(p<0.05).The simple linear regression analysis revealed that pH value significantly increased with time. The R^2 values were 0.9074,0.9641,0.9827,0.9943,0.9785 and 0.9968 for treatments T1 toT6 respectively.

EC indicates the mineralization rate and availability of total soluble salts in compost, which is negative effect on plant growth.EC values increased gradually irrespective of treatments throughout the composting period except T1(S+SD) on 30thday.Several authors had reported the increasing trend of EC(San-chez-Monedero et al.,2001;Wong et al.,2009;Villasenor et al.,2011;Wang et al.,2016). They have stated that the production of extractable ammonia, nitrate and nitrite may be responsible for increasing trend of EC. On analysing the results by ANOVA, EC values varied significantly between the treatments ($p<0.05$). All the six treatments gave a good match and the R^2 values were greater than 0.8.

Temperature profile during composting is one of the most frequently reported indexes to understand the progress of composting. In this study, it was observed that compost did not reach the thermophilic stage(>38°C).This may be due to heat dissipation because of it's small volume(Kala et al.,2009).The factors affecting temperature rise in a compost pile are type of micro organisms present, materials used for composting, amount and height of compost and moisture content (Rosalin et al.,2011).Moreover the moisture content was also high in all the six treatments. The relative low levels of rise in temperature was due to the fact that high amount of moisture content (80%) was present initially and moisture content also increased due to hydrolysis reaction(Manjula and Meenambal 2012).Generally the temperature of all treatment groups showed similar pattern. This similarity in temperature could be as a result of the balancing of C:N ratio of the substrates before being subjected to biodegradation process. Hence there is the possibility that the micro organisms resident in the substrates would exhibit similar metabolic activities(Itelima 2015).It was observed that there was significant difference in temperature between the treatments($p<0.05$).The R^2 values were 0.896,0.801,0.868,0.831,0.906,0.879 for treatments from T1 to T6($R^2>0.8$)

During composting the moisture content is important for transporting the dissolved nutrients required for the physiological and metabolic activities of microorganisms (Liang et al.,2003). Initially the moisture content was between 70-80% and as composting proceeded the moisture content dropped to 58-69%.On analysing the results by Anova, the decrease in moisture content were significant($p<0.05$).The R^2 values were 0.943,0.960,0.927,0.894,0.941,0.994 for treatments from T1 to T6($R^2>0.8$) respectively. The moisture content was not found to be within an acceptable range of 50-60%(Table 1) during maturation. Therefore, the compost should be dried in natural environment before the application to agricultural field.

The total organic carbon is usually used as energy sources for microorganisms during composting process (Chan et al.,2016)and the degradation of total organic carbon could be used to illustrate the level of compost maturity (Vargas-Gracia et al.,2010).Initially the TOC was high in all the treatments and this may be due to the ligno cellulose materials present in coir pith and saw dust. The content of organic carbon decreased in all treatments as the decomposition progressed. The results of Anova showed that there exist significant decrease in TOC between the treatments($p<0.05$).The R^2 values were 0.971,0.956,0.986,0.990,0.977 and 0.948 for the treatments from T1 to T6 ($R^2>0.9$).The TOC is not an important parameter but some researchers reported that TOC is directly involve to maintain C/N ratio which is an important parameter to determine the degree of compost maturity (Kithome et al.,1999a;Wong et al.,2009;Karak et al.,2014;Awasthi et al.,2015;Chan et al.,2016).

Nitrogen is one of the most important factor to assess the nutrient level(Li et al.,2011).Figure 1 presents the dynamics of concentrations of TN of the six treatments. In this study, there was a steady increase in TN for all the treatments until the end of experiment except T1(S+SD).An increase was observed for T1 around 30th day, afterwards sudden drop was noticed until 120th day. Results also indicated that treatments with cow dung combinations observed higher final nitrogen content compared to other treatments. The maximum mean value of 1.61±0.01 was observed in T5(S+CP+CD) on 120th day. Significant differences in total nitrogen were observed between the treatments ($p<0.05$).

Total phosphorous and potassium in different modes of composting are encapsulated in Fig(2) and (3) respectively. In the case of phosphorous, the sludge when combined with sawdust and coir pith showed a decrease in phosphorous content until the 120th day. There was an increase in phosphorous content when sludge was combined with cow dung throughout the composting period. In T6(S+CP+SD), an increase in phosphorous content was noted up to 60th day. On 75th day onwards there was a decline in the mean value up to 120thday.A salient feature observed was all the cow dung combinations showed a steady increase in phosphorous content throughout the composting period. The maximum mean value of 4.57±0.01 was observed in T5(S+CP+CD) on 120thday. On analysing the results by ANOVA the total phosphorus values varied significantly between the treatments ($p<0.05$).The total potassium content increased the end of composting period irrespective of the treatments. Among the treatments, those with cow dung combinations reported the highest mean values compared to other treatments.T4(S+SD+CD) reported the maximum mean value of 3.36±0.01 on 120th day. The increase in potassium content may be due to the addition of structural materials, which provided a better nutritional balance. Significant differences in total potassium were observed between the treatments ($p<0.05$).It has been reported that appreciable amount of nitrogen and potassium are needed for good crop yield(Scalenghe,2012). Somida (2002) states that potassium is a essential plant nutrient and it plays an important role in growth, yield and quality of crops.

Carbon and nitrogen ratio is one of the most widely utilized important parameters to confirm the rate of composting process as well as end product maturity(Pagans et al.,2006;Singh et al.,2013;Awasthi et al.,2015;Chan et al.,2016).In general, a decreasing trend of C/N ratio were found in all treatments and similar trend of C/N ratio reduction was also reported by Awasthi et al.(2015).Initial high C/N ratio (Fig 4) in the treatments indicated the presence of lingo cellulose materials(Wei et al.,2014).On 30th days of composting, C/N ratios significantly decreased irrespective of the composition. An interesting feature noticed was those treatments with cow dung showed a drastic decrease in C/N ratio during the composting period. All the cow dung combinations reported a final C/N ratio which was within the acceptable range(Table.1).At curing stage (120thday),C/N ratios were found between 33.60 and 12.35,with the minimum value in T5(S+CP+CD) and the maximum in T1(S+SD).As the decomposition progressed, due to the loses of carbon mainly as CO_2,the carbon content of the compostable material decreased with time and nitrogen content per unit material which resulted in the decrease of C/N ratio(Karak et al.,2013).The C/N ratio being an important parameter to judge the maturity of compost. In this experiment the treatments with cow dung showed low C/N ratio. The decreased C/N ratio is regarded as a criterion of maturity of compost. On analysing the results by Anova, C/N ratio varied significantly between the treatments($p<0.05$).

The prepared composts showed low concentrations of calcium and magnesium from the initial day. A slight increase in calcium levels were noted in all treatments except T1(S+SD).In T1 a decrease in mean value was noted throughout the composting till 120th day. The R^2 values were 0.659, 0.953, 0.927, 0.979, 0.975 and 0.732 for treatments from T1 to T6 respectively. The magnesium levels were totally unstable during the composting period. The R^2 values were 0.202, 0.260, 0.001, 0.173, 0.990, 0.616 respectively for treatments T1 to T6. The low values of R^2 indicate that the magnesium levels depend not only on time but also on other factors. The treatment T5(S+CP+CD) showed a gradual increase from initial to final day. All the other treatments were totally unstable till the end of composting. Significant differences in macronutrients were observed between the treatments ($P<0.05$).

The pot culture experiment carried out to study the effects of composts prepared with different amendments in different ratios by cultivating cowpea, *Vigna unguiculata* against control showed that plants grown by the application of composts showed efficient growth than control (soil alone).All the growth parameters were affected by the compost application. Among all the treatments, T2(S+CD) and T5(S+CP+CD) showed maximum growth parameters. This may be due to the nutrient content of the compost.

There was a noticeable increase in plant height over the control was noted in T2 (107.90 cm) and T5(106.47 cm) on 90th day. The maximum increase in number of branches, number of leaves, number of pods, length of pods, number of seeds and weight of seeds per pod were also noted in T2 and T5. During decomposition, the release of nutrients increased and this is the reason for maximum significant increase in yield of cowpea. This result is in accordance with the studies of Natarajan (2001) who reported that compost was superior in nutrient content and gave significant increase in yield. This result is also in agreement with Itelima, (2015) who reported that bio-fertilizer , prepared from saw dust, cow dung and poultry droppings inoculated with a fungus when applied on cowpea gave the best yield.

Table 1.Factors affecting composting process (Alexander 1994)

Factors	Acceptable range
Temperature	54-60°C
Carbon to Nitrogen Ratio(C:N)	25:1-30:1
Aeration(Percentage of oxygen)	>5%
Moisture content	50-60%
Porosity	30-36%
pH	6.5-7.5

Table 2. Nutrient content of Raw materials.

Samples	**Ph**	**EC**	**Organic Carbon**	**Nitrogen**	**Phosohorous**	**Potassium**	**C/N Ratio**
		(mS/m)	(%)	(%)	(%)	(%)	
Latex Sludge	7..2	2.17	9	1.9	9.12	12.89	4.74
Coir pith	7	1.97	56.67	0.68	1.98	0.84	83.39
Sawdust	6.9	1.58	50.4	0.25	0.2	0.06	201.6
Cowdung	7.1	1.89	32.6	1.1	0.52	0.89	29.64

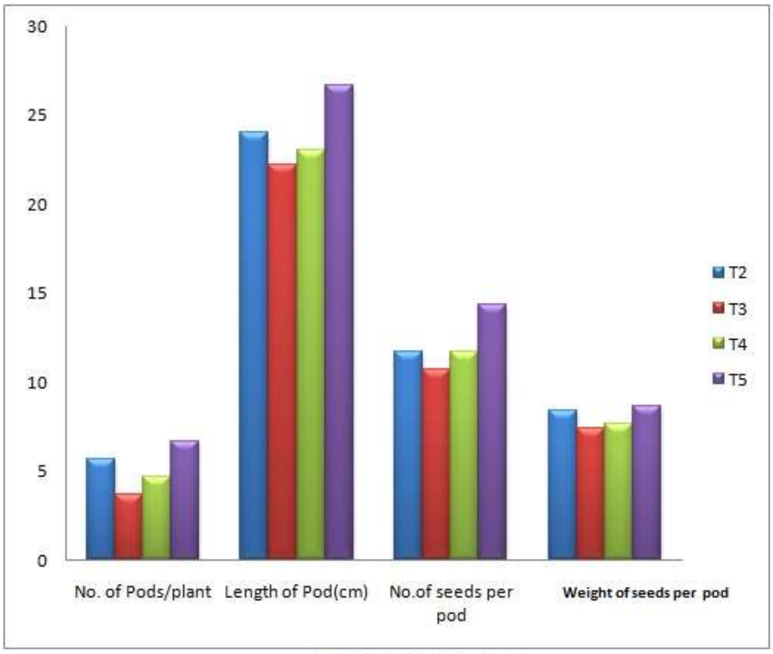

Fig.5 Yield parameters on cowpea

CONCLUSION

The results from this study indicated that thorough mixing of the compost by turning and inoculation increased the decomposition process. The matured compost showed adequate physico chemical properties. The C:N ratio decreased drastically in all the treatments throughout the composting period. The treatments T2 and T5 showed an ideal C:N ratio good growth parameters on the yield of cowpea. Sludge management should be developed towards great environmental utilization and this is possible with a gradual decrease of storage on municipal dumping sites. Taking in to account environmental and economic factors, for tropical countries like India composting can be considered as a viable option.

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