Composting of Effluent Treatment Sludge

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ABSTRACT

Approximately 0 15–0 20 ton of sludge is generated from the effluent treatment plant per ton of paper produced. Traditionally, most of this sludge has been landfilled, but environmental concerns, governmental resolutions, and scarcity of land will make landfills much harder and more expensive option to operate. For these reasons alternative methods of sludge management are currently being evaluated Composting of ETP sludge is one of various alternatives that may find increased use in the future since it could reduce sludge mass and also yield a material suitable for horticultural applications.

A composite, primary and secondary sludge from effluent treatment plant from one of the small pulp and paper mill using non-woody raw material and producing kraft paper was composted at CPPRI using static pile, windrow and forced aeration processes. Various plants were grown using the composted sludge and the growth observed was found comparable to that obtained by using a sheep dung market manure amended medium. It was observed that ETP sludge can be rapidly composted into a material suitable for safe use in agricultural and horticultural application The results of the trial, method of composting and various variables affecting the process and quality of compost are being presented herein.

Introduction :

The process of composting is familiar to many people as a relatively simple means of converting garden debris, food scraps and other organic wastes into a rich organic humus, But the process was not widely used at large scale due to associated problems. Sustained research has been going on in this area to modify the process so as to produce good quality compost by an environmentally safe method In 1974, US Department of Agriculture developed an improved method of composting known as forced aeration method or Beltsville method (4) The process works by mechanically drawing air through the pile of composting material. In recent years, this process has received increasing attention as a method for transforming municipal sludge to agricultural and landscaping use In particular many municipalities in advanced countries have adopted composting as a cost effective method of disposal.

To examine the potential applicability of static pile composting to the waste (ETP sludge) from the paper industry, work had been carried out but to a limited extent and the detail of which is available in the literature elsewhere (1, 2, 5–8). The quality of compost and time of biodegradation or completions time would depend on quality of waste, climatic conditions, and particularly on monitoring of process conditions. Work has been carried out at CPPRI by composting ETP sludge from one of the small paper mills using non-woody raw material. The purpose was to examine its suitability, affect of climatic conditions on biodegradation and to study the associated problems.

Composting systems :

The nature of the ancient process of composting is such that a clear cut definition is difficult. It has been

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defined as 'the microbiological degradation of organic material to a stable product under conditions which will allow the achievement of thermophilic temperatures Because the micro-organisms responsible for the composting reaction are facultative, the process can work under aerobic or anaerobic conditions.

Aerobic decomposition by micro-organisms leads to the formation of oxidized end products such as carbon dioxide, water, sulfates etc. alongwith generation of heat. These compounds are stable and relatively less offensive, odour and nuisance free. On the other hand the anaerobic composting process yields partly oxidized compounds and reduced chemicals such as carbon dioxide, water, methane, ammonia, hydrogen sulfide, organic acids and aldehydes. These products are unstable and result in serious nuisance effects. The traditional method for composting of waste sludge is anaerobic. However, the anaerobic composting is associated with the following shortcomings.

— slow reaction rate
— very less heat generation
— less reliable and less uniform
— results in serious nuisance effects.

Due to these reasons, most of the composting systems in use to date are aerobic and hence only this system is being discussed here.

Aerobic system can be of two types viz. In-vessel methods or mechanical systems and non-vessel method. In in-vessel methods composting occurs inside some type of a vessel (reactor) specifically equipped with and designed for that purpose. While in a non-vessel method, composting proceeds in the open air, outside of any containment vessel.

In–vessel systems are typically proprietary and are stationary or rotary, horizontal or vertical bed reactors. Provision is made to adjust the moisture content and air flow to material inside and the compost material may or may not be agitated during its residence time.

The main advantages of an in-vessel system are that it requires a minimal time and land area for composting and achieves complete odour control. Its disadvantages are the high capital cost and inherently complex mechanical nature.

Non–reactor methods can be classified as windrow or aerobic static pile method. In windrow method, a pile of material with or without bulking agent is formed and periodically turned either manually or mechanically for uniform aeration While in aerated pile method, aeration is carried out by forcing air into the pile by blowers. This method of aeration ensures more reliable and more uniform composting than the windrow. Following a composting, the pile is broken down and the mixture of compost and bulking agent is moved to another site and cured for an additional one month This step may or may not be required depending upon material and conditions.

After curing, bulking agent is separated from the compost and recycled while compost is put into use.

A modification of the aerated pile method is the aerated extended pile method in which sludge delivery of each day mixed with bulking agent and placed in a pile which utilizes the shoulder (lengthwise dimension) of the previous day's pile forming a continuous or extended pile. The extended pile reduces the extended area by 50% Moreover, the amount of blanket material required for insulation and odor control is also decreased.

Variables affecting composting process :

The important variables affecting the composting process are :

— moisture content
— C/N ratio
— oxygen/aeration
— temperature
— pH
— porosity of the pile.

These variables govern the rate and extent of composting and must be within specific optimum range for rapid stabilization of the organic materials to yield good quality product.

There must be sufficient moisture to soften the organic material to permit the micro–organisms, to hydrolyze complex organic compounds into simple molecules. However, too much moisture will promote anaerobic conditions and will reduce the temperature of pile. The optimum moisture content is between 40 to 70%.

C/N ratio must be between 30 to 40·1- The higher C/N ratio increases the composting time and the lowering of the same results in increased losses of nitrogen in the compost.

To maintain a desirable aerobic condition, a sufficient amount of air/ O_2 (5–15%) must be assured by some external means.

Composting rate increases with elevation in temperature upto some limit (75–80°C), beyond which it declines. Temperature of 60–65°C can be considered sufficient to destroy pathogens and compost thus obtained can be used without fear of any disease to the plants.

Satisfactory results, however, can be obtained over a wide pH range but extreme values limit the function of the microbes responsible for composting. The pH should be between 5.5-8 0 with 6.5 as an optimum value.

There must be sufficient porosity in the pile constructed to ensure proper airation but at the same time pile must have structural integrity. Some bulking agent is usually added to maintain proper porosity and at the same time to provide structural integrity.

Final ripe compost should have C/N ratios between 10/1 to 20/1 and is ready in 2 months to one year depending upon the quality of material and conditions maintained and process followed. If sludge of high C/N ratio will be applied for plantation then N-mineralisation will be delayed because aerobic microorganisms that decompose organic matter will consume nitrogen and will tie it up in their organic biomass. This process is called immobilisation. As decomposition proceeds, ultimately nitrogen will be liberated. In the mean time the plants will not receive enough nitrogen for growth. The following immobilisation period have been indicated for sludges of different C/N ratio.

C/N ratio	Immobilisation Period
30–35:1	2–4 Weeks
50:1	> 3 months
40–70:1	2–11 months
230:1	21 years

To avoid negative crop growth response a special application strategy will be needed to minimise the problem of N–immobilisation. The ripe compost will definitely provide the advantages in this regard and will work both as a soil conditioner and N–fertilizer.

Work done at CPPRI :

First, the samples of effluent sludge and other organic wastes like pith and straw were analyzed for Carbon and Nitrogen values. Table–1 shows these values alongwith the C/N ratio. Pulp and paper mill ETP sludges generally have high C/N ratio and thus some Nitrogen compound has to be added to reduce the same to 30–40:1. Experimental work was initially performed on very small amount (about 65 Kg., 62.12% moisture) of sludge obtained from one of the small paper mills using non woody raw material. This sludge had high C/N ratio (~120), therefore small amount of urea was added to maintain optimum C/N ratio (~35). After adjusting moisture content, the sludge was placed in the from of a heap. Temperature of the heap was noted regularly and turning was done from time to time for aeration purpose and proper mixing. Moisture was also maintained at around 50% Results obtained were encouraging i.e. the final C/N reduced to about 10:1 within 2 months and temperature was recorded upto 70°C. But the amount of compost was very less. Therefore, a large amount of sludge was obtained from the same mill. Two heaps measuring about 1.5 m × 1.5m × 1 5m each were made after adjusting C/N ratio by adding minor quantity of urea, one for manual turning (Windrow process) and another for forced aeration (aerated pile process). Rice straw was added to provide sufficient porosity. In the windrow pile some cow dung was also mixed. For aerated pile process, heap was made on top of a grid of perforated pipes connected to a blower(figure 1). First a loop of perforated drainage pipe was laid on the site surface according to sludge quantity. Then a thin layer of wood chips was put on pipes grid followed by a one inch thick layer of rice straw to avoid plugging of holes with sludge. Over the straw layer, pile was formed in trapezoidal shape. The perforated pipe network was connected to a blower through a section of solid pipe. The capacity of blower was 1.5m^3/min of air. The air was sucked from the heap. The blower was controlled by a programmable timer. Initially, the cycle time of blower was set to 20 min with 5 min on & 15 min off time. But this was making the heap cool due to winter season & temperature was not rising above 40–45°C. Therefore the blower was set to operate for sixty seconds in every 20 minutes. The temperature at the center of the heap was now around 55°C. The other pile was turned manually. The variation in temperature is shown in figure 2. The tempera'ure of windrow pile was noted by thermometer thus the temperature shown is about 1° below surface while in case of Aerated pile temperature was noted by putting thermocouple. This reading of temperature was from the centeral point. The composting operation was considered complete after the temperature dropped to near about the ambient and C/N reduced to around 10/1. The total stabilizing time was about 2 5 months for aerated pile method and about 3 month for windrow method. The properties of sludge compost and market manures of cow dung and sheep dung are given in table 2. Various plants (Sugarcane, chili, Tomato, Brinjal) were grown by applying the sludge and market manure in equal amount to the soil. In fact on dry weight basis, the amount of sludge compost applied was less than market manure because sludge compost was having higher moisture.

Results and Discussion :

It was observed that the sludge was composted readily (in 2 months) in the first experiment which was run in summers as compared to the second experiment run in winter. Thus climatic conditions can affect the time period of completion because in winter. There was lot of heat energy loss and so temperatures were not rising above 55°C. In aerated pile method, on-off time of the blower has to be optimized and it would be better to insulate the heap by some manure or ripe compost to avoid heat loss. In the present case there was no ignificant difference in completion time period by either method because some cow dung manure was added in the windrow method initially. Because the bacteria are the work horses in the decomposition process, so materials that contains higher bacterial population such as animal and poultry manure and slaughter wastes will hasten decomposition So it is better to add some market animal or poultry manure or ripe compost for fast composting. No unusual environmental problems such as odours, flies or leachate was noted at either site. If sludge is having higher moisture content then other solid waste material like pith, straw dust or straw waste from storage can be mixed.

Table 2 shows that the properties (C/N ratio, macro and micro nutrients, and regulated metals) of sludge compost are comparable to market manure In fact sludge compost is having higher organic matter which contains humic acid, a group of compounds which help in retaining moisture in soil and improves soil tilth.

In an experiment, growth of brinjals was compared by using raw sludge and compost. It was observed that the leaves of the plant grown in the former were infected which might be due to presence of pathogens which get destroyed in the latter.

Growth of sugarcane plants for soil amended with composted sludge improved with time and was comparable to a market manure of sheepdung.

Advantages of Composting :

Composting of organic wastes particularly of effluent treatment plant sludge offers several advantages which are listed hereunder.

1. It converts a waste into a valuable material that can be marketed and used in a variety of applications.
2. The process requires little capital investment and is environmentally sound.
3. The operation can be rapidly implemented.
4. The process requires little energy.

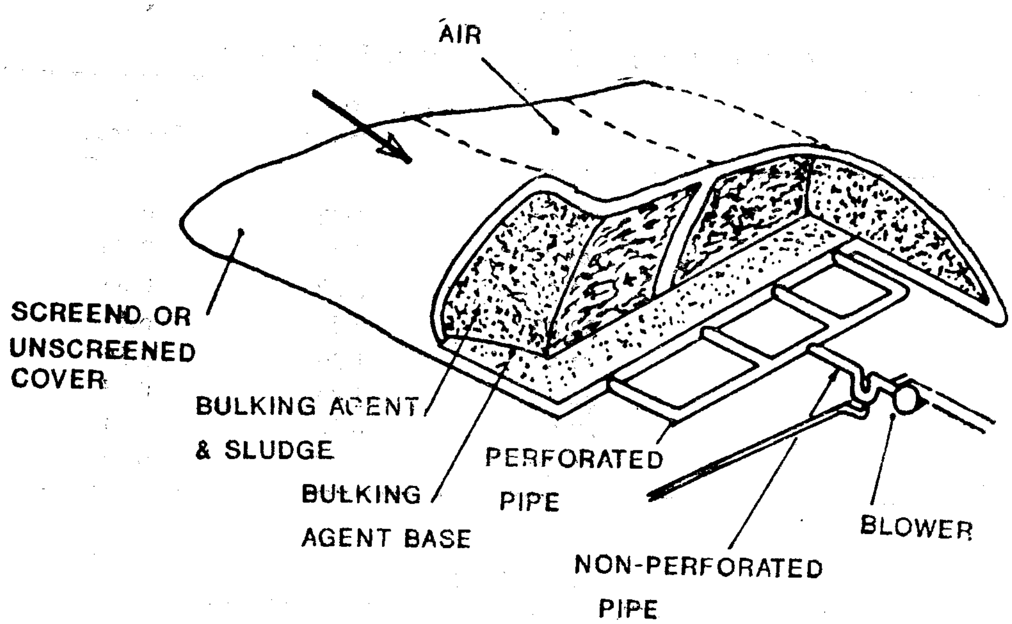

FIG. 1: SCHEMATIC DIAGRAM OF THE FORCED AERATED PILE METHOD FOR COMPOSTING

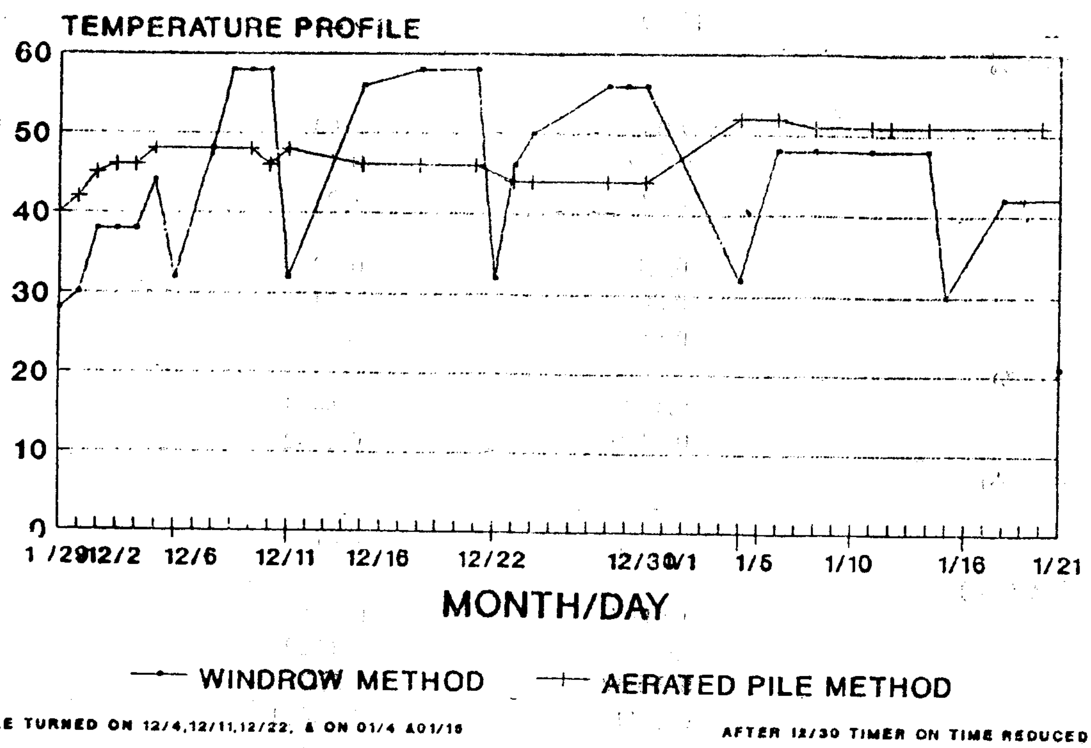

FIG.2 : TEMPERATURE PROFILE DURING TWO MONTHS PERIOD IN WINDROW AND FORCED AERATED PILE COMPOSTING

TABLE—1

C, H, N & C/N Values of Different Solid Wastes

	C	H	N	C/N
		values in % on OD basis		
1. Effluent sludge				
Mill A	39.95	5 68	0 30	118 86
	44 40	4 35	0.70	63 49
Mill B	40 28	6.28	0.35	115 09
Mill C	38.89	6.54	0.61	63 75
Mill D	43 37	4 80	0 54	80.31
Mill E	32.75	5.86	0.52	62 98
2. Pith	47.92	6.30	0.63	76 06
3. Rice straw dust	37.00	5.41	0 67	55.22

TABLE—2

Comparison of Sludge Compost and Market Manure (Sheep and Cow Dung)

	Sludge Compost	Market Manure (Sheep Dung)	Market Manure (Cow Dung)
Moisture, %	50	35	45
Ash	36.5	51 6	47
pH	5.3	—	—
Final C/N	17.09	13.25	17 9
Macro Nutrients %			
Primary			
N	2 06	2 03	1 64
P	0.142	0.150	0 138
K	0.29	1.54	0.48
Secondary			
Ca	0.25	0 59	0.63
Mg	0.34	0.34	1.015
S	0 616	—	—
Micronutrients (%)			
Fe	0.678	0.6454	0.379
Mn	0.0186	0.0242	0 0161
Other Elements (%)			
Al	7.662	—	—
Na	0 295	1.54	0.48
Regulated Melals (%)			
Cr	0.0047	0 003	0.00067
Cu	0.0012	0.0023	0.00125
Pb	0.00067	ND	0.00062
Ni	0.00118	0 00054	0.00174
Hg	ND	0 0132	ND
Zn	0.0171	0.0109	0.0045

ND : NOT DETECTED

5. Finished compost is relatively odor free and has an earthy smell since the readily decomposable organics are destroyed during the course of the process,

6. Elevated temperatures in the process reduce the concentration of pathogenic organisms and destroy weed seeds and insect eggs.

7. If a sludge contains toxic organics, many of these will degrade during composting thus producing an environmentally acceptable product.

In addition to this paper mill sludge with its fibrous textures aids in the flowability and spreading capability of finished compost. Also, the sludge is an excellent source for carbon and very probably humic acid as well. The presence of calcium, clay, phosphorus or lime in the sludge may enhance the product value.

Marketing of Compost :

Compost can be sold to farmers, nurseries, green houses, landscaper, farm supply distributor, fertilizer manufacturer or individual customers. The important factors which will govern the market value of compost are :

- Distance of shipment
- Volume of compost produced
- Potential for in-house utilization.
- The support of agricultural authorities particularly ministry of agriculture
- A price of product which is acceptable to most of farmers
- A net disposal cost (plan cost minus income from sales) which can be sustained
- Quality of compost

In general, compost will provide the following benefits

- increase in water holding capacity
- improvement in permeability and soil aeration.
- enhance aggregation
- increase in water retention time
- Increased infiltration
- Reduced surface crusting.

The calculations pertaining to economics of composting of sludge are given in table 3.

TABLE—3

Economics of Composting of Sludge

Basis : 1 Ton OD Sludge Per day

	Aerated Pile Method (Cost in Rupees)	Windrow Method
1. **Land and Equipment Cost**		
Cost of Land	26,600	40,000
Cost of Blower	13,000	—
Interest on Capital[1]	12	18
Depreciation Cost[2]	4	—
2. Operating Cost		
Waste Raw Material Cost	350	350
Electrical Power Cost[3]	14	—
Manpower Cost[4]	12	12
Maintenance Cost (20%)	3	—
Cost of Urea Added to Adjust C/N Ratio	75	75
	———	———
Total Cost of Converting One Ton O D. of Sludge To Compost	470	455≈500
Average Cost of Market Manure	= 650	
Profit Per Ton Sludge	= 150	
Profit Per Day For 30 TDP Plant (ETP Sludge Generated 0.2 T/T Paper)	= 900	
Profit Per Annum	= Rs. 2.97 Lakhs/Year for 30 TPD Paper Mill.	

Note

1. Assuming Interest on Capital 15%
2. Assuming Equipment and Accessories Life 10 Years
3. 0.25 KW Blower with 6 min on and 18 min off Time Will be Required for About 45 days.

4. Assuming About one hour Working Per day Per man

5. Assuming C/N Ratio of Sludge [$(45/0.3) \approx 150$]
1 Year = 330 Working days

It has been reported that the benefits from the utilization of an organic waste will always be higher than the revenues, if any, derived from their sales (3) because organic manure elicit yield responses from succeeding crops. Organic materials degrade in the soil much more slowly than inorganic fertilizer and thus invoke yield responses over a longer period than inorganic fertilizers. It is also reported that the largest crop response is for the first few units of organic material applied and thereafter the response to each additional unit is less. Thus, the value of the first years crop and an succeeding crops must be aggregated to determine the economic value of organic material after considering time factor of money. But this is not the case generally and these total benefits can not be expected to be captured as revenues to the waste management authority A mill may consider following points for operation of the compost.

* Use the 'turnkey' approach for operation and marketing of the compost. This approach will result in lower annual operating cost due to competitive bidding by contractors. A private contractor will have an incentive to produce a good quality product, as he will be responsible for marketing the product. Another alternative is to sell the sludge to farmers who can compost it . Other alternative is to sell ETP sludge to farmers who can make compost themselves.

* Conduct a public education program demonstrating sludge compost as a valuable, free of chemical hazards and environmentally friendly resource material.

* Encourage the public to carry out first hand trials by applying ETP sludge compost to plantations and kitchen gardens.

Conclusion :

Composting of ETP sludge provides an environmentally desirable, technologically sound and cost efficient means of utilizing this waste. Composting successfully counters the need for more land for disposal of sludge and also converts an industrial liability into an environmentally desirable asset. Composting is by far the most responsible technical solution where waste is wet and highly organic, climate is arid and soil is in serious need of organic suppliments ETP sludges from pulp and paper industry in particular have proven to be highly suitable for rapid biodegradation through composting. The heavy metal content of the sludges will not affect the composting Process. However, sludge compost has to be restricted to non-agricultural uses if it contains high levels of heavy metals. The presence of calcium, clay, phosphorus or lime in the sludge may actually enhance the products value

However, it is important to note that sludge compost does not represent a replacement for commercial fertilizer. It is an economically and environ mentally justified adjunct to the farmers existing program. It is a product that provides organic matter which contains humic acid and thus conditions the soil and also contains small amount of other nutrients for plant growth. It contains most of the nitrogen in organic form. Thus it can be considered as a slow release nitrogen fertilizer.

If implemented sucessfully, composting may constitute a major step in the direction of total resource recovery for the pulp and paper making industry.

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