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COMPOSTING OF TANNERY SLUDGE

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LIST OF SYMBOLS & ABBREVIATIONS

BCS	:	Basic Chromium Sulphate
CETP	:	Common Effluent Treatment Plant
CHN analyser	:	Carbon, Hydrogen, Nitrogen analyser
C/N	:	Carbon / Nitrogen ratio
CTC	:	Centre Technique Cuir
^{o}C	:	Degree Celsius
ETP	:	Effluent Treatment Plant
FYM	:	Farm Yard Manure
INR	:	Indian Rupees
kg	:	Kilogram
kg/d	:	Kilogram per day
m	:	Meter
m^3	:	Cubic meter
m^3/d	:	Cubic meter per day
mg/l	:	Milligram per litre
mg/kg	:	Milligram per kilogram
ppm	:	Parts per million
%	:	Percentage
RePO	:	Regional Programme Office of UNIDO at Chennai
TKN	:	Total Kjeldahl Nitrogen
tpd	:	Tonne per day
UNIDO	:	United Nations Industrial Development Organization
w/w	:	Weight/weight

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EXECUTIVE SUMMARY

At a water consumption rate of 30-40 m^3 per tonne of raw material processed in a tannery, treating 1 m^3 of effluent in a waste water treatment plant generally yields 3 to 4 kg of sludge (dry weight basis). The sludge invariably consists of 50 – 60% of solids, the remainder being moisture; and organic matter accounts for 35-60% of the solids. This large amount of organic matter present in the sludge makes it suitable for composting with other organic wastes.

In many countries tannery sludge is classified as hazardous mainly on account of the presence of chromium in it. In the United States of America and some European countries, tannery sludge has been deleted from the list of hazardous wastes. Following this, the Government of India too has deleted this from the list of hazardous wastes if the trivalent chromium present in it is less than 5000 mg/kg and the hexavalent chromium, less than 50 mg/kg. It is expected that similar relaxation may follow in other countries of South East Asia. This development may result in a substantial quantity of tannery sludge falling outside the definition of hazardous waste.

The cost of disposal of sludge in a secure landfill is 40 – 50% of the total operational cost of the tannery effluent treatment plant in many European countries.

UNIDO, under its Regional Programme, has been exploring avenues for utilisation of sludge not falling in the category of hazardous waste. In this context, in cooperation with selected tanneries and CETPs, some trials of composting tannery sludge were undertaken by combining it with other organic wastes available in the same locality. The objectives were to first verify the compostability of sludge with appropriate admixtures and then to evaluate its effectiveness as a manure vis-à-vis other comparable organic manures.

Early trials in 1998 in CETP, Melvisharam, Tamilnadu, confirmed the compostability of tannery sludge with other organic wastes such as coir pith, vegetable waste and cow dung. As the increase in temperature during the thermophilic phase was not satisfactory, further trials were done using other wastes such as green or limed fleshings, green bio mass and tertiary coir pith. The efforts were to find admixtures that were available locally at affordable cost and at the same time helped the composting process effectively. The initial emphasis had been on maintaining the Carbon / Nitrogen (C/N) ratio above 14. Different modes of building the heap – laying the ingredients layer by layer or pounding and chopping the ingredients to uniform size, mixing these thoroughly and then laying a big heap – were tried. The heaps were turned over at regular intervals to facilitate good mixing and natural aeration. The ambient temperature and the temperature of the heap were measured daily and recorded. The moisture of the heap was maintained at around 60%. The duration of the composting was noted and the quality of final compost meticulously monitored and recorded. The compost was applied to edible and inedible plants and its impact was positive on growth and yield of the plants.

Based on the lessons of these trials, large scale trials were carried out in two tanneries – SSC Ambur and MAKH Ranipet – in Tamilnadu, India. The detailed data concerning 60 heaps in each location, including daily temperature of each heap, date of turning over, the final yield, etc. has been recorded. The duration of composting process was between 70 and 90 days. The effect of mechanical aeration of heaps was studied at one location but due to difficulties in practical implementation it did not yield more favourable results.

The results of trials carried out by RePO, UNIDO, Chennai, were reviewed by an international expert, Mr. Warren Bowden of BLC, UK. While he found the results interesting, Mr. Bowden impressed on the need to have a proper density of the pile to be able to induce satisfactory high temperature of about 70^0C in the thermophilic phase, which lasts for 35 to 60 days from the day the pile is set up, followed by the mesophilic phase of below 45^0C when the temperature of the heap gradually falls in about 40 to 60 days to eventually reach the ambient temperature. He felt that turning over could be avoided by building the heaps on a platform of gravel and natural aeration would be further aided by mixing wooden chips and twigs in the heap. Reducing the ingredients to uniform particle size by pounding or chopping, mixing these well and then building heaps would ensure uniformity. Mr. Bowden visited the two sites in Tamilnadu and under his guidance, seven heaps were built, four of these on gravel platform and three on the floor. The results were found to accord with expectations and the quality of compost achieved was quite good.

The results of composting trials carried out until now can be summed up as follow:

- Affordable organic wastes such as green or limed fleshings, green bio mass, tertiary coir pith and paddy straw available locally, can be used as admixtures. Cow dung, a costly input, can be dispensed with as compost heaps built without cow dung have yielded positive and satisfactory results.
- The ingredients should be pounded/chopped/cut to uniform particle size before being mixed and piled up. This, as against piling the ingredients layer by layer, provides uniform density. Adding wooden chips and twigs will aid natural aeration. Undigested wooden chips and twigs can be recycled in successive heaps.
- Building heaps on gravel platform obviates the need of turning over the same.
- The density of the heap should be between 0.4 and 0.6 t/m^3.
- The C/N ratio of 15 to 35 is generally appropriate.
- In order to achieve the desired density and C/N ratio, based on the data collected during the experiments, as rule of thumb, 1 tonne of sludge can be combined with fleshings (250 to 350 kg), green biomass (200 to 300 kg), paddy straw (200 to 300 kg) and coir pith (200 to 300 kg).
- The moisture level of 60 – 65% is essential to aid effective composting. Sprinkling of water on the heap once a day in the morning is adequate to maintain the required moisture level. However on warm days, sprinkling may be done both in the morning and the evening.
- The temperature of the heap rises to above 70^0C within the first 10 to 20 days. The thermophilic phase, when the temperature remains above 45^0C, lasts until 35 to 60 days from the day the compost pile is set up. Thereafter the mesophilic phase, when the range of temperature is 45^0C to 15^0C, lasts for about 40 to 60 days. During this phase the temperature of the heap gradually falls to reach the ambient temperature, when the composting process is completed.
- Dewar flask helps measure the self heating temperature of the heap accurately.
- Duration of composting varies depending on admixtures, anywhere between 80 and 110 days.

The option of composting of sludge is ideally suited for tanneries that practise effective chrome management and when the level of chromium in the sludge from their treatment plant is well within the norms prescribed.

One crucial question is whether the product will have a market or not, if produced in large volume. The other, of course, is its acceptability to the regulatory authorities. These will have to be discussed with potential users and concerned authorities before large scale composting of tannery sludge is encouraged.

A separate report has been published on some trials of vermi-composting of tannery sludge carried out at CETP-SIDCO, Tamil Nadu, India.

1. INTRODUCTION

1.1 Generation of sludge

About 30 – 40 m^3 of wastewater is generated when processing one tonne of raw hide/skin to finished leather. The wastewater is treated either in individual or common effluent treatment plants to meet standards prescribed for discharge to different recipients. Suspended solids in the wastewater, generally in the range of 2000 to 5000 mg/l, are precipitated by application of chemicals such as alum, lime and/or polyelectrolyte, at the stage of primary treatment. Though sludge is separated at different stages of treatment in a treatment plant, it is the primary sludge, which accounts for the bulk of it. While factors such as the nature of the effluent, method of treatment employed and effectiveness of equipment used for clarification / settling are responsible for the quantity of sludge generated, it is generally in the range of 300 – 350 kg at 30-40% dry solids per tonne of raw hide/skin processed. Sludge thus is yet another solid waste of the tanning industry requiring appropriate utilisation or safe disposal.

1.2 Legislative aspects of sludge disposal

In many countries, tannery sludge is categorised as hazardous mainly because it contains chromium, though in its trivalent form. In the United States of America and many European countries tannery sludge has been deleted from the list of hazardous wastes. Following this, the Government of India has issued a notification (January, 2000) deleting the tannery sludge from the list of hazardous wastes if the level of trivalent chromium in sludge is less than 5000 mg/kg (dry weight basis), and hexavalent chromium, less than 50 mg/kg. This has made composting of sludge an interesting option for low-chrome sludge, especially for tanneries that process semi-processed hides / skins to finished leather.

1.3 Safe disposal of sludge

For the disposal of tannery sludge containing chromium beyond permissible levels, a properly designed and operated safe landfill is the best option. This option, where unavoidable, does require vast area of land and leachate from the landfill requires treatment. In some European countries, the cost of sludge disposal has been estimated as 40-50% of the operational cost of effluent treatment.

1.4 Utilisation of sludge

Generally 35-60% of the total solids in tannery sludge is organic matter. As the organic matter in the sludge is amenable for biomethanation, sludge can be mixed with wet limed fleshings and treated in a digester to generate biogas. Another option, the subject of this report, is composting.

2. PRINCIPLE OF COMPOSTING

Composting is defined as the breaking down of organic matter by microbes in a moist, warm, aerated environment. The microbes take oxygen from the air and food from the organic material. Carbon is the principle source of energy and nitrogen is used to promote cell synthesis. Part of the energy released by the organisms is in the form of heat. As a result of these activities, the compost heap passes through warming up, attaining a gradual peak in temperature, cooling and maturing phases. The aerobic decomposition of organic matter results in a humus-like material of beneficial quality.

3. PILOT TRIALS

3.1 Trials – Phase I

Initial trials on composting tannery sludge by combining it with other organic wastes such as vegetable waste, coir pith (waste of coconut coir industry), cow dung, etc. were carried out at the CETP-Vishtec, Melvisharam, India in 1998. These trials established the possibility of producing a compost with nutrient values comparable to those of commonly used organic manures such as urban / rural compost and Farm Yard Manure (FYM).

The ingredients were arranged layer by layer with sprinkling of cow dung slurry on each layer. A ratio of 1:1 was maintained between sludge and admixtures (w/w). Turning over of the heap was done when the temperature was observed to fall. Moisture level in the heap was maintained at 60-65%. It was observed that the temperature build up in the heap was very poor and not more than $50^{o}C$.

3.2 Trials – Phase II

The temperature build-up during Phase 1 was considered to be inadequate for effective composting though the composting itself was found to be satisfactory. This was considered to be on account of poor C/N ratio of the compost heap. In order to improve the C/N ratio, during the second phase of composting trials in 1999, green biomass (freshly cut green leaves) and paddy straw were used as admixtures in the place of coir pith. This resulted in a better C/N ratio and much higher temperature build up (> $60^{o}C$). It was observed that the digestion of green biomass was faster than of paddy straw.

The harvested compost was analysed for presence of chromium. The chromium level in the harvested compost corresponded to its level in the sludge composted.

The compost was applied to okra and radish plants grown in pots and their performance in terms of overall growth - height, surface area of leaves, vegetable yield, etc.- was found to be much better than that of control plants. The pot trials established that sludge compost was suitable for application as manure in agriculture.

4. LARGE SCALE TRIALS

Against this background, it was decided to carry out industrial scale composting trials using (i) sludge containing trivalent chrome at levels lower than 5000 mg/kg and (ii) sludge containing little or no chrome. Accordingly, two counterparts namely, Shafeeq Shameel & Co. (SSC), Ambur and MA Khizar Hussain & Sons (MAKH), Ranipet were identified.

The objectives of the trials were:

- To establish that the option of composting sludge can be applied to take care of sludge generated in the effluent treatment plant of a medium scale tannery.
- To try different organic wastes as admixtures and arrive at an ideal combination, yielding a product with acceptable nutrient qualities at an affordable cost.
- To study the effect of mechanical aeration and the techno-commercial feasibility of its application.
- To train the personnel of the two identified counterparts in the composting process.
- To demonstrate to interested tanners how sludge, under certain given conditions, could be composted with other organic wastes.

4.1. Shafeeq Shameel &Co (SSC), Ambur

This tannery practises predominantly chrome tannage. The processing activity includes raw to finishing (goat skins) and wet blue to finishing (cow hides and cow calf skins). The tannery has a fairly well established chrome management system. Improved conventional chrome tanning method is practised in the tannery. There is a chrome recovery unit and spent chrome tan liquor from the main tannage is treated to recover chrome. The chrome level in the sludge is therefore always < 5000 mg/kg. A flow diagram of the ETP is enclosed at Annex 1. The sludge characteristics are in Table 1.

Table 1: Characteristics of sludge from ETP of SSC, Ambur

#	Parameter	Detail	
		Sample 1 (July 2000)	Sample 2 (March 2001)
1.	Moisture	82.39 %	95.54%
3.	Solids	17.61 %	4.46%
4.	Organic matter	57.68 %	55.46%
5.	Total chromium	4164 mg/kg	3979 mg/kg

4.1.1 Preparation of site for composting

Three segments of currently unused solar evaporation pans, each measuring 25 m x 12 m and at an elevated level were selected for carrying out composting trials. These solar evaporation pans have hard flooring of granite and cudappah stones. A water delivery point was provided by the tannery near the site.

4.2. MAKH & Sons, Ranipet

This tannery processes wet salted buffalo calf skins to vegetable tanned leather and then to finished leather. In addition, a small quantity of wet blue calf skins is processed to finished leather. The finished product is predominantly burnishable upper leather for the shoe industry. The tannery has an ETP with 800 m^3/d capacity. The sludge generation in the tannery is estimated at 1600 kg/d (dry weight). A flow diagram of the ETP is at Annex 2. The sludge characteristics are in Table 2.

Table 2: Characteristics of sludge from ETP of MAKH & Sons, Ranipet

#	Parameter	Detail		
		Sample 1 April 2000	Sample 2 October 2000	Sample 3 October 2000
1.	pH	8.9	8.9	8.7
2.	Moisture	76.5 %	34.8%	29.5%
3.	Solids	23.5 %	65.2%	70.5%
4.	Organic matter	44.37 %	45.7%	38.1%
5.	Total chromium	199 mg/kg	2572 mg/kg	1756 mg/kg

4.2.1 Preparation of site for composting

An area of about 1200 m^2 beyond the ETP was earmarked for the purpose of setting up compost heaps. The area was cleared of vegetation and levelled. A shed with thatched roofing was constructed by the tannery management to carry out sieving of harvested compost and its storage.

5. ADMIXTURES USED

As use of green biomass, paddy straw and cow dung as admixtures in the second phase of the composting trials carried out at Melvisharam helped achieve a temperature build up of more than 60^{o}C, essential to achieve effective composting, it was decided to follow this system in the trials at Ambur and Ranipet. While paddy straw was available in the market, cow dung and green biomass had to be procured through unorganised channels. Both SSC and MAKH & Sons engaged contractors to supply the required quantity of green biomass and cow dung.

Fig. 1 - Compost and admixtures being laid layer by layer

5.1 Cost of admixtures

The cost of admixtures may be seen in Table 3:

Table 3: Cost of admixtures

#	Material	Price / tonne	Availability
1.	Paddy straw	INR 1500	Easy
2.	Green biomass	INR 800	Quantity larger than 1 tpd is difficult to obtain.
3.	Coir pith	INR 350 (This waste is available free of cost. The cost incurred is only towards transport)	Easy
4.	Cow dung	INR 500	Easy

5.2 Fleshings as an admixture

As the tannery management found the efforts and expenditure incurred towards procuring the required quantity of admixtures high, it wanted to ascertain the feasibility of using wet limed fleshings as an admixture. Mr. Sultan Ismail, UNIDO Consultant during the earlier phases of composting trials, on being consulted, suggested that fleshings could be used. The C and N values of fleshings are tabled below:

Table 4: Analysis of tannery fleshings using CHN analyser (IIT Madras)

#	Parameter	Unit	Sample source				
			Ranipet Buffalo	Ranipet Cow	V'Badi Sheep	M'Visharam Buff calf	M'Visharam Cow calf
1.	Nitrogen	%	10.09	6.48	9.01	9.07	8.67
2.	Carbon	%	32.85	27.45	37.07	30.77	40.07
3.	Hydrogen	%	5.31	4.36	5.85	4.97	6.38

6. RATIO BETWEEN SLUDGE AND ADMIXTURES

The quantity of sludge and the different admixtures to be used in a heap were worked out to get a C/N ratio of > 14. A ratio of 1:1 (wet weight basis) was maintained between sludge and admixtures initially. Details of a few combinations, which have been tried in Ambur and Ranipet, are given in table 5:

Table 5: Different combinations between sludge and admixtures

Ingredients	Combinations (weight in kg)				
	1	2	3	4	5
Sludge	1000	1000	1000	1000	1000
Green biomass	450	300	250	125	400
Paddy straw	450	300	150	125	200
Fleshings	-	300	300	400	300
Coir pith	-	-	200	250	-
Cow dung	100	100	100	100	100
Ratio (wet weight) Sludge/admixtures	1:1	1:1	1:1	1:1	1:1

As the temperature build-up was observed to be satisfactory, different sludge / admixture ratios were tried. After a few trials, heaps built using ratios such as 1:1, 3:2 and up to 2:1 (dry weight basis) were observed to yield good temperature build-up.

6.1 C/N ratio of ingredients

While maintaining a quantitative ratio of 1:1 or 3:2 or 2:1 between sludge and admixtures, care was taken to ensure that the C/N ratio of the composting heap was > 14.

Details showing C/N ratio for two different combinations, both in the ratio of 1:1 (sludge and admixtures), are in Tables 6 and 7.

Table 6: C/N ratio = 15.13

#	Ingredients	Qty kg	% moisture	Qty. - Dry matter (kg)	%C	%N	Quantity in kg	
							C	N
1.	Sludge	1000	50	500.00	38.20	2.75	191.00	14.00
2.	Green biomass	125	70	37.50	40.00	1.50	15.00	0.56
3.	Paddy straw	125	12	110.00	48.00	1.00	52.80	1.10
4.	Wet lime fleshings	400	80	80.00	33.64	8.66	26.90	6.93
5.	Cow dung	100	60	40.00	59.45	1.78	23.78	0.71
6.	Coir pith	250	50	125.00	49.50	1.00	61.88	1.25
						Total	371.36	24.55

Table 7: C/N Ratio = 16.81

#	Ingredients	Qty kg	% moisture	Qty Dry matter-kg	%C	%N	Quantity in kg	
							C	N
1.	Sludge	1000	50	500.00	38.20	2.75	191.00	13.75
2.	Green biomass	300	70	90.00	40.00	1.50	36.00	1.35
3.	Paddy straw	300	12	264.00	48.00	1.00	126.72	2.64

4.	Wet lime fleshings	300	80	60.00	33.64	8.66	20.18	5.20
5.	Cow dung	100	60	40.00	59.45	1.78	23.78	0.71
						Total	397.68	23.65

7. PREPARATION OF HEAPS

Fresh sludge removed from sludge drying beds was used initially (till end of May 2000). The presence of branches and twigs in green biomass was considered useful for facilitating better natural aeration. Sludge and admixtures were arranged layer by layer with sprinkling of cow dung slurry on each layer while building a heap. Normally, heaps built using 1000 kg of sludge and 1000 kg of admixtures (wet weight) were of the following size:

Length : 2.50 m – 3.00 m
Width : 1.50 m – 2.00 m
Height : 1.25 m – 1.50 m

8. PARAMETERS MONITORED

The moisture level in the heap was maintained at 60-65%. A soil moisture-measuring meter was used to measure the moisture level. Temperature in the heap was measured using a temperature probe which could be inserted into the heap to reach a depth of 40-50 cm. Temperature was measured at five different points in a heap and the mean value of the five readings taken as the temperature of the heap for the day. The ambient temperature at the time of measuring the heap temperature was also noted. The temperature was measured every day and recorded along with ambient temperature in the log sheet.

Fig. 2- Temperature in the interior zones of the heap being measured and entered in the log sheet

Fig. 3 - Water being sprayed on compost heaps to maintain moisture level at 60 – 65%

The oxygen level in the heaps could not be measured and monitored in the absence of a suitable oxygen meter.

9. TURNING OVER OF HEAPS

The heaps were turned over when the temperature was observed to be dropping. Each heap was turned over three to five times during the entire process of composting. In SSC, Ambur, turning over of a few heaps was done once in 10 or 12 days irrespective of the level of temperature. This variation was tried to observe the efficiency of digestion of admixtures if the heaps were turned over at regular frequency.

10. TEMPERATURE BUILD-UP

A temperature build-up of more than 60^{o}C was observed in almost all the heaps. While rise in temperature was observed in some heaps within 3-10 days of setting up, in the case of some others, the build-up was slow. The quantity and the type of admixtures were responsible for the temperature build-up.

Two typical combinations tried out in Ambur and Ranipet and the temperature build-up in these heaps are shown in Tables 8,9 and 10 and figures 4 and 5.

Table 8: Heaps with sludge and admixtures in 2:1 and 1:1 ratios on dry weight basis

#	Ingredient	Weight in kg					
		MAKH & Sons Heap # 53			SSC Heap # 40		
		Wet wt.	% Moisture	Dry wt.	Wet wt.	% Moisture	Dry wt.
1.	Sludge	2500	41	1475	1800	40	1080
2.	Green biomass	1000	74	260	700	70	210
3.	Paddy straw	350	10	315	300	10	270
4.	Fleshings	-	-	-	1400	80	280
5.	Coir pith	450	70	135	400	70	120
6.	Cow dung	250	60	100	250	60	100
7	Total	4550		2285	4850		2060
8	Ratio (approx.) Sludge: admixtures	2:1			1:1		

Table 9: Temperature build up in the heap # 53 at MAKH & Sons, Ranipet (Date of set-up: 01 July 2000)

Day	Temperature °C		Remarks
	Inside heap	Ambient	
1	38.8	33.0	
5	53.0	30.2	
6	56.4	31.4	
7	66.1	32.0	
8	64.2	27.0	
9	67.1	31.2	
10	68.3	31.6	
11	63.7	31.2	
12	62.9	31.0	
13	68.7	31.3	
14	65.5	33.5	
15	63.2	32.4	
16	62.5	32.3	
17	62.4	31.6	
18	57.2	32.3	
19	58.5	31.9	
20	57.7	30.3	
21	46.5	28.2	I Turn over
22	52.5	28.9	
23	62.8	31.9	
24	58.1	28.2	
25	64.1	28.6	
26	57.7	30.1	
27	62.3	33.7	
28	59.5	31.1	
29	59.7	26.8	
30	65.1	30.1	

Note: Turning over of heap was done only after drop in temperature.

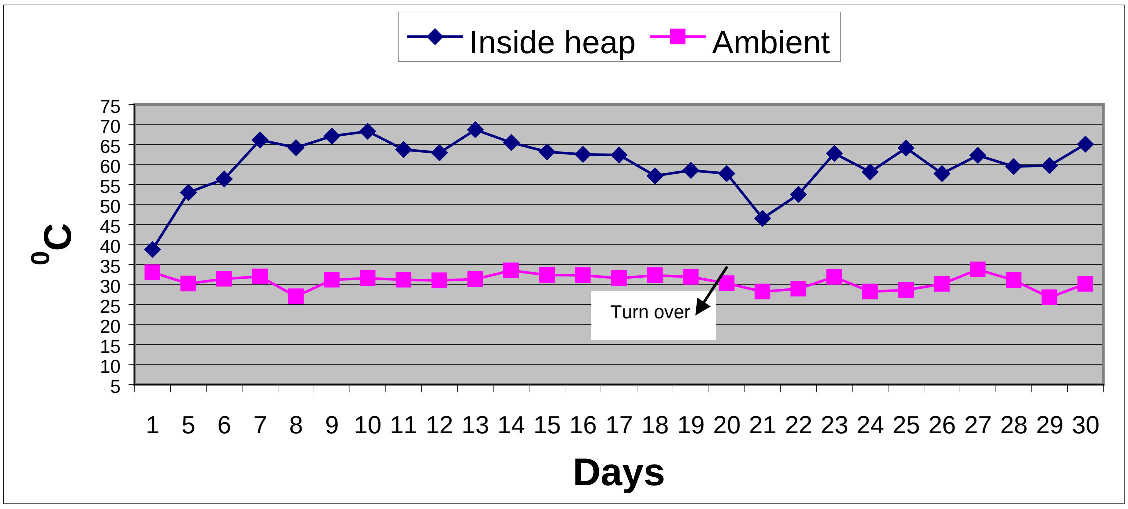

Fig. 4: Temperature build-up in Heap # 53 at MAKH & Sons, Ranipet

Table 10: Temperature build up in Heap # 40 at SSC, Ambur
(Date of set-up: 22 June 2000)

Day	Temperature ^{o}C		Remarks
	Inside heap	Ambient	
2	50.4	32.5	
3	58.1	32.8	
4	63.0	32.4	
5	65.3	32.5	
6	66.7	32.8	
7	67.4	32.5	
9	61.2	33.2	I Turn over
10	54.2	33.5	
11	68.4	34.1	
12	67.1	31.5	
13	69.2	30.5	
14	74.9	30.8	
16	77.0	31.5	
17	75.7	31.8	
18	73.8	31.5	
19	74.3	30.7	II Turn over
20	47.6	31.7	
21	63.3	32.2	
23	65.0	32.5	
24	69.5	32.7	
25	67.8	31.6	
26	71.6	31.7	
27	67.9	33.5	
30	67.3	32.8	III Turn over
31	51.7	32.5	
32	55.9	32.5	
33	53.1	32.3	
34	52.1	31.5	
35	52.5	32.0	
37	63.5	31.8	IV Turn over
38	67.3	32.4	
39	47.5	32.2	

Note: Turning over of heap was done once in ten days (approximately) irrespective of temperature status.

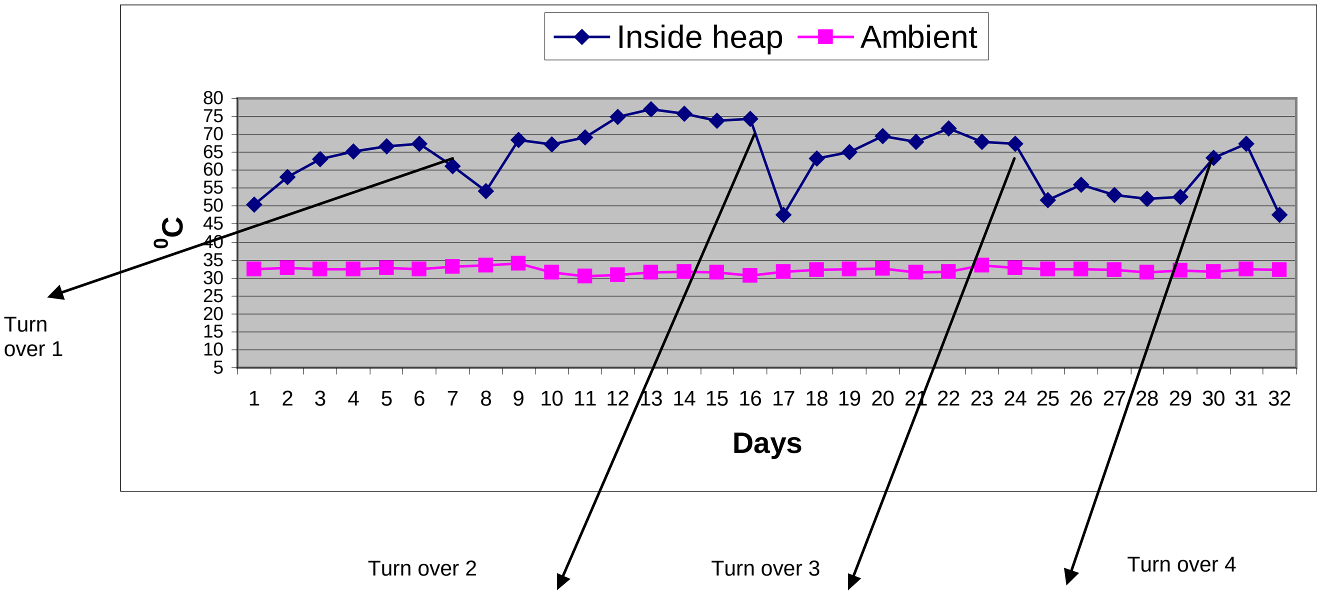

Fig. 5: Temperature build-up in Heap #40 at SSC, Ambur

11. DURATION OF COMPOSTING PROCESS

After the second phase of trials at Melvisharam, it was thought that the duration of composting of sludge with admixtures such as green biomass, straw, etc. would be about 45 days. However, it has been practically seen in trials carried out in Ambur and Ranipet that heaps are not ready for harvest at the end of 45 days. In almost all the heaps, the temperature in the interior zones were found to be much higher than the ambient temperature even after 45/60 days. To cite a few examples:

Table 11: Temperature after 45 days

#	Location	Heap No.	Temperature °C		
			Heap	Ambient	Difference
1.	SSC, Ambur	04	54.2 (64th day)	32.7	21.5
2.	SSC, Ambur	10	51.8 (47th day)	31.5	20.3
3.	SSC, Ambur	15	50.7 (45th day)	32.7	18.0
4.	SSC, Ambur	21	48.6 (51st day)	32.5	16.1
5.	SSC, Ambur	29	52.0 (59th day)	33.0	19.0
6.	SSC, Ambur	34	47.4 (48th day)	33.0	17.4
7.	MAKH & Sons, Ranipet	07	62.1 (45th day)	33.4	28.7
8.	MAKH & Sons, Ranipet	09	69.9 (49th day)	32.6	37.3
9.	MAKH & Sons, Ranipet	15	60.8 (56th day)	31.0	29.8
10.	MAKH & Sons, Ranipet	35	43.1 (47th day)	30.5	12.6
11.	MAKH & Sons, Ranipet	49	49.8 (49th day)	31.3	18.5
12.	MAKH & Sons, Ranipet	52	50.6 (48th day)	30.1	20.5

As high temperature in the interior zones of the heap (> 10°C over the ambient) indicated ongoing microbial activity, it was decided to wait till the temperature dropped to more or less the ambient level. It was observed that the temperature of the heap got closer to ambient temperature only after 60 days and therefore it was concluded that it took 65-70 days for the composting process to be completed.

Detailed data such as date of set up, composition – quantity of sludge and different admixtures, temperature – peak and as observed after 45 days of setting up heap, dates of turning over the heap, and the number of days taken for completion of composting process, with respect to 60 heaps set up in each of the two locations are at Annex 3.

12. HARVESTING

Heaps, when ready for harvest, were disturbed, dried and screened through sieves of mesh size 6 mm to separate fine compost from the coarse.

Fig. 6: Harvested compost being screened through mesh

The following observations were made during harvest and sieving of compost:

- While leaves were fully digested, branches and twigs of the green biomass remained undigested.
- As fresh sludge was lifted from drying beds and laid with admixtures in heaps, some large lumps of sludge remained as such without any disintegration through the process. Apparently, turning over of heaps had also not helped break the large lumps to smaller particles.
- The final product was fluffy and light and had a fine soil aroma.

Fig. 7: Weighing out fine compost for packing

Fig. 8: Fine compost packed in bags

The yield details – fine and coarse quality – with respect to 60 heaps in the two locations are shown in the Tables 12 and 13.

Table 12: Harvest details – MAKH & Sons, Ranipet

Heap #	**Compost yield**				
	Fine		**Coarse**		**Total**
	Qty-kg	**%**	**Qty- kg**	**%**	**Quantity- kg**
1	680	79.5	175	20.5	855
2	910	48.8	955	51.2	1865
3	650	56.0	510	44.0	1160
4	970	52.7	870	47.3	1840
5	870	46.5	1000	53.5	1870
6	1020	49.8	1030	50.2	2050
7	1080	88.9	135	11.1	1215
8	1185	97.5	30	2.5	1215
9	1240	83.8	240	16.2	1480
10	960	88.9	120	11.1	1080
11	880	89.8	100	10.2	980
12	760	87.4	110	12.6	870
13 & 14	2030	90.6	210	9.4	2240
15 to 20	6795	93.3	490	6.7	7285
21 to 22	1935	94.2	120	5.8	2055
23 to 26	3930	96.6	140	3.4	4070
27 to 28	1600	93.8	105	6.2	1705
29 to 36	6320	86.5	990	13.5	7310
37 to 38	1320	75.9	420	24.1	1740
39 to 40	1720	81.5	390	18.5	2110
41 to 44	3600	94.0	230	6.0	3830
45 to 46	2440	96.1	100	3.9	2540
47 to 48	2360	94.8	130	5.2	2490
49 to 50	2360	94.4	140	5.6	2500
51	1400	92.7	110	7.3	1510
52	1160	93.5	80	6.5	1240
53	3160	90.8	320	9.2	3480
54	2460	90.8	250	9.2	2710
55	2320	83.5	460	16.5	2780
56	2440	88.7	310	11.3	2750
57	2320	87.9	320	12.1	2640
58	2360	92.9	180	7.1	2540
59	2440	94.6	140	5.4	2580
60	2360	94.8	130	5.2	2490
Total	**70035**	**86.4**	**11040**	**13.6**	**81075**
% Range		**46 – 98%**		**02 – 54%**	
Average	**84.5%**		**15.5%**		

Table 13: Harvest details – SSC, Ambur

Heap #	Compost yield – kg				
	Fine		Coarse		Total
	Qty - kg	%	Qty - kg	%	Quantity- kg
1	570	60.0	380	40%	**950**
2	583	59.3	400	40.7	983
3	590	55.9	465	44.1	1055
4	565	57.9	410	42.1	975
5	658	61.0	420	39.0	1078
7 to 14	4176	59.7	2814	40.3	6990
15	505	58.2	362	41.8	867
16	495	58.9	345	41.1	840
17	510	59.2	351	40.8	861
18	521	59.1	360	40.9	881
19	526	60.2	348	39.8	874
20	535	58.5	380	41.5	915
21	541	58.0	391	42.0	932
22	515	58.1	372	41.9	887
23	520	56.0	408	44.0	928
24	545	58.1	393	41.9	938
25	530	56.4	410	43.6	940
26	505	54.9	415	45.1	920
27	516	55.0	422	45.0	938
28	523	56.2	408	43.8	931
29-30	1300	66.7	648	33.3	1948
31	550	56.8	418	43.2	968
32	565	58.4	402	41.6	967
33	530	57.2	395	42.8	925
34	545	56.5	420	43.5	965
35	570	57.5	422	42.5	992
36	551	56.2	430	43.2	981
37	584	61.2	370	38.8	954
38	560	58.8	392	41.2	952
39	525	55.9	415	44.1	940
40	1311	61.6	817	38.4	2128
41 (Mechanical aeration – blowing)	2850	65.7	1490	34.3	4340
42	1851	63.0	1089	37.0	2940
43	1917	63.2	1115	36.8	3032
44	1750	57.2	1310	42.8	3060
45	972	60.0	648	40.0	1620
46	1905	61.1	1215	38.9	3120
47	795	60.0	530	40.0	1325
48	760	59.6	515	40.4	1275
49	785	60.9	505	39.1	1290
50	936	62.0	573	38.0	1509
51	721	60.9	462	39.1	1183

52	1014	65.0	546	35.0	1560
53	945	65.0	508	35.0	1453
54	875	70.0	375	30.0	1250
55	845	65.0	455	35.0	1300
56	910	67.4	440	32.6	1350
57	920	67.9	435	32.1	1355
58	915	68.5	420	31.5	1335
59	905	68.3	420	31.7	1325
60	915	69.6	400	31.4	1315
61 (Mechanical aeration – suction)	2684	66.0	1384	34.0	4070
% Range		**54 - 70**		**30 – 46**	
Average		**60.5%**		**39.5%**	

13. BEHAVIOUR PATTERN OF ADMIXTURES

13.1 Recycling of coarse particles

While the focus should be on reducing the coarse particle content to the barest minimum (<5%) in the final product by reducing the particle size of the ingredients before piling in a heap, it may be noted that the entire coarse material is recycled in the next fresh heap.

13.2 Admixtures

The time required for the digestion of admixtures used and the influence of admixtures on the temperature build up in the heaps were studied. Both wet limed and green fleshings require the least time for digestion. Fleshings are fully digested within ten days. During the first turning over of heaps, no trace of undigested fleshings could be seen. Also, use of fleshings as an admixture did not result in emanation of foul odour.

Next in the order is the green biomass. The leaf content of the green biomass is found digested within 30/40 days. However, twigs and branches remain undigested even after 75 days.

While cow dung added as slurry is digested quickly, the digestion of cow dung added as lumps is very slow. Partially digested lumps of cow dung could be seen during the screening of harvested compost.

The coir pith used during trials at Melvisharam was the primary and secondary waste of coir industry. The fibre content of the primary waste is quite high. Fibres are hard to digest and not much of decaying could be seen after 45 days. As a result of this, the temperature build up was very poor. Therefore, though this waste is available free of cost, it could not be considered for use as one of the main admixtures. The cottage sector coir industry has a big presence in the Ambur – Pernambut belt. Interaction with the coir industry personnel revealed that the tertiary waste of coir had low fibre content. Therefore, it was decided to use this tertiary waste as a partial replacement of paddy straw / green biomass. Also, as the temperature build up was quite high (65 to 70^{o}C) with green biomass and paddy straw, it was felt that coir pith which is a carbon-rich material could be tried even if it resulted in a slow or a lower temperature build up. The trials have established that the tertiary waste coir pith can be used up to 200/250 kg for 1000 kg of sludge. Addition of coir pith as an admixture slows down the temperature build up and increases the duration of the composting process.

Paddy straw takes the longest time to digest. Even in the “fine compost” yellow particles of paddy straw can be seen. This, however, helps to generate a good temperature build up.

The experience in SSC, Ambur and MAKH & Sons, Ranipet has clearly brought to light the need to reduce the particle size of both the sludge and the admixtures. Chopping of green biomass and paddy straw, dissolving lumps of cow dung in water to get a thick slurry and pounding of sludge to reduce the particle size quicken the process of composting and more importantly improve the yield of fine compost.

To do this, a few tools and implements and perhaps a small mechanical device are necessary. In MAKH & Sons, an unused coal-breaking machine is being used for grinding sludge. However, in SSC, Ambur pounding of sludge is done manually. This process is labour-intensive. To obtain 2500 kg of pounded sludge, a gang of four workers has to be deployed for a day.

14. MECHANICAL AERATION

14.1 Aeration using blowing technique

A mechanical aeration system was set up to aerate the compost heap in SSC, Ambur. A sketch showing details of the system is enclosed at Annex 4.

The size of the platform is 5 m x 3 m. The platform has a wall of height 0.3 m on all the four sides. The chamber is provided with a bed of pebbles. Perforated PVC pipes of 100 mm diameter are placed on the pebble bed. The source of air supply is a blower with a capacity to deliver air @ 45 m^3 per hour. Air from the blower is conveyed to the heap through pipeline. A geonet mat is placed above the PVC pipe. Compost heap is built on this mat.

The aeration required is about 10 m^3/h per tonne of sludge (dry weight) to maintain oxygen level of 5-15% inside the heap.

Heap # 41 of the following composition, as in Table 14, was set up on the platform and aerated mechanically using the blower:

Table 14: Mechanical aeration using blower technique - Heap # 41 in SSC, Ambur

#	Material	Wet wt. kg	Moisture	Dry wt.	Carbon		Nitrogen	
					%	Qty-kg	%	Qty-kg
1.	Sludge*	4000	40%	2400	38.20	916.80	2.75	66.00
2.	Green biomass	1600	70%	480	40.00	192.00	1.50	7.20
3.	Paddy straw	600	10%	540	48.00	259.20	1.00	5.40
4.	Fleshings	1600	70%	480	33.64	161.47	8.66	41.57
5.	Coir pith	560	50%	280	49.50	138.60	1.00	2.80
6.	Cow dung	600	60%	240	59.45	142.68	1.78	4.27
						1810.75		127.24

** Pounded and screened*

$$C/N = \frac{1810.75}{127.24} = 14.23$$

The size of the heap as measured at the time of setting up was 5 m x 3 m x 1.8 m.

The blower was operated for 10 minutes each hour from 0800 hours to 2000 hours every day. In other words, the blower was run for a total duration of 2 hours in a day (12 hours @ 10 minutes per hour). As the capacity of blower is 45 m^3 per hour supply of air to the heap was about 90 m^3 per day. The details of temperature build up in the heap are given in Table 15.

Table 15: Temperature build up in Heap # 41 – Mechanical aeration by blowing

Day	Temperature in ^oC		Day	Temperature in ^oC	
	Heap	Ambient		Heap	Ambient
1 (05 July)	38.3	30.5	32	57.6	33.0
2	48.0	30.8	33	56.6	32.8
4	54.7	31.5	34	48.8	32.8
5	63.9	31.8	35	54.1	32.5
6	65.0	31.5	36	51.7	32.7
7	65.5	30.7	37	45.4	32.0
8	64.9	31.7	39	66.5	32.0
9	63.8	32.2	40	68.4	32.2
11	64.3	32.5	41	64.8	32.5
12	64.7	32.7	43	65.0	32.2
13	63.1	31.6	44	61.7	32.0
14	63.4	31.7	46	62.7	32.5
15	59.8	32.5	47	59.8	33.4
16	56.3	33.5	48	57.0	32.6
18	54.8	32.8	49	56.8	32.6
19	56.0	32.5	50	51.1	30.8
20	60.0	33.0	51	59.9	31.8
21	62.0	32.5	53	55.3	32.0
22	62.6	32.8	54	52.9	32.5
23	63.2	33.0	55	49.9	33.3
25	64.9	32.8	56	48.4	32.8
26	63.0	32.5	57	51.0	33.0
27	60.7	33.0	58	50.9	32.1
28	64.7	32.8	60	56.2	32.5
29	62.2	32.8			
30	58.7	33.2			

On the 33rd day, the heap was taken off the platform and put on the ground for curing. This amounted to turning over the heap. The temperature began to rise as shown above. Thereafter the heap was allowed to remain in the ground until the composting was completed on the 60th day.

The heap was left in curing for five more days and on the 65th day it was harvested. As the heap was mechanically aerated, it was not turned over. As against 4 to 5 turn overs done to naturally aerated heaps within a duration of 60 days, this heap was given only one turn over on the 33rd day when it was removed from the platform and put on the ground. This resulted in a fresh build up of temperature and the temperature inside the heap was > 50^o C against an ambient air temperature of about 33^o C indicating ongoing microbial activity.

14.2 Aeration using suction technique

After effecting suitable modifications, the blower was made to suck air. Heap # 61 of the following composition, as in Table 16, was built on the platform.

Table 16: Mechanical aeration by suction - Heap # 61

C/N = 16.97

#	Material	Wet wt. kg	Moisture %	Dry wt. kg	Carbon		Nitrogen	
					%	Qty. kg	%	Qty. kg
1.	Sludge*	6300	70	1890	38.2	722	2.75	52
2.	Straw	555	10	500	48	240	1.00	5
3.	Green leaves	850	70	255	40	102	1.50	4
4.	Fleshings	725	85	109	33.6	37	8.66	9.5
5.	Coir pith	300	30	210	49.5	104	1.00	2.1
6.	Cow dung	225	60	90	59.5	54	1.78	1.6
						1259		74.2

**** Wet sludge was weighed out, dried and pounded***

The suction was observed to be too powerful. Water droplets could be seen coming out at the suction outlet. The suction was so powerful that about 20 litres of water was sucked off the heap in 10 – 15 minutes making it dry and necessitating sprinkling of water to maintain moisture at 60-65%. The air coming out of the suction outlet was warm and the temperature of the sucked out air 3 to 8 ^{0}C more than that of the ambient air. Details of temperature recordings are given in Table 17.

Table 17: Temperature build-up in the heap aerated mechanically using suction technique

Day	Temperature in ^{0}C		
	Inside heap	Ambient air	Suction end
02	48.3	30.4	31.0
03	55.7	31.5	32.4
04	57.6	28.8	34.2
05	57.8	29.4	32.3
06	45.5	24.1	32.0
07	46.7	21.5	31.5
09	44.8	26.5	33.1
10	44.6	32.6	33.4
11	43.7	28.4	32.7
12	44.0	33.3	33.8
13	43.8	32.5	32.8
14 - The heap was turned over			
16	50.3	25.4	29.3
17	59.5	23.7	31.1
18	62.9	21.5	30.1
19	65.5	30.5	31.5
20	63.2	30.4	32.3
21	59.2	32.1	33.5
23	50.4	34.6	32.6

24	53.9	31.6	32.6
25	57.4	24.6	31.7
26	52.7	27.1	34.3
27	50.9	32.1	34.5
28	51.2	31.5	32.6
29	48.7	30.3	31.8
30	48.3	26.4	32.5
32	48.7	31.4	33.6
33	49.2	28.5	31.6
34	44.9	26.1	31.5
37	44.4	21.5	28.1
37 - The heap was turned over			
38	45.8	30.4	34.4
39	46.6	32.5	35.4
40	52.7	30.6	33.3
41	53.4	31.4	33.6
42	50.7	26.7	33.1
44	55.5	29.1	32.3
45	55.4	30.7	33.5
46	54.7	29.3	32.8
47	53.3	26.5	31.7
48	49.5	31.5	32.8
49	49.2	28.1	32.2
51	46.7	27.3	32.0
53	46.8	28.1	32.3
54	47.8	29.3	31.8
55	46.7	26.4	31.4
56	46.9	29.6	32.3
58	The heap was removed from platform and put on ground for curing		

After ten days, the heap was split open, contents dried and screened through a sieve.

In both the cases of mechanical aeration- using blowing and suction techniques – it was observed that intermediate turning over of heaps was necessary to facilitate steady build-up of temperature and in turn a good level of microbial activity. Also, the duration required to complete the composting process was found to be 60-70 days, the same as in the case of naturally aerated heaps.

15. MEASURES TO PROTECT COMPOSTING YARD FROM RAIN

During rains, the heaps are covered with gunny cloth and woven coconut leaf mats. This protects the heaps from disintegrating. However, harvested compost has to be spread in the open on hard stone flooring to dry the matter and make it suitable for sieving. The tannery managements were advised to construct a shed for carrying out the following activities:

- Sieving, weighing and packing
- Storage of final product

MAKH & Sons constructed a shed. SSC had been motivated to make a similar arrangement. A shed had been constructed over the mechanical aeration system at SSC.

During monsoon, when heavy down pour is experienced for three or four weeks, composting activity may have to be suspended. However, this may not be unusual as work in tanneries slows down during monsoon as most of the operations, particularly, airing off of set/vacuum dried leathers and drying of sludge in conventional drying beds will suffer too.

16. ANALYSIS OF HARVESTED COMPOST

Samples of harvested compost collected from SSC and MAKH & Sons were analysed for nutrient values - N, P and K. The results are in Table 18.

Table 18: Analysis of harvested compost – NPK values on dry weight basis

#	Nutrient	% on dry weight basis (Range)
1.	Nitrogen as TKN	1.1 to 2.0 %
2.	Potassium as K_2O	0.70 to 2.60 %
3.	Phosphorous as P_2O_5	0.70 to 0.90 %

Similarly samples of harvested compost were analysed for the presence of chromium too. The results are in Table 19.

Table 19: Total chromium in the harvested compost

Sample #	Total chromium (dry weight basis)
1	3286 mg/kg
2	1603 mg/kg
3	1315 mg/kg
4	2005 mg/kg

17. COST OF PRODUCT & MARKET POTENTIAL

17.1 Cost of product

The cost of composting sludge for two typical compositions has been arrived at as shown in Table 20 on the following assumptions:

- Sludge and admixtures mixed in approximately 1:1 ratio (dry weight).
- Composting is done using natural aeration technique.
- The moisture content of fine compost is about 25%.
- The yield of fine compost is 70% of the harvested compost.

Details of quantity, unit price and cost of different materials used in composting with respect to two models – Model 1 and Model 2 – are given in Table 20.

Table 20: Cost of material input

#	Material	Wet weight (kg)		% moisture	Dry weight (kg)		Price / tonne (INR) (wet wt.)	Cost (INR)	
		Model 1	Model 2		Model 1	Model 2		Model 1	Model 2
1.	Sludge	1800	2000	50	900	1000	-	-	-
2.	Green biomass	700	1000	70	210	300	800	560	800
3.	Paddy straw	300	350	10	270	315	1500	450	525
4.	Fleshings	1400	-	70	420	-	-	-	-
5.	Coir pith	400	400	70	120	120	350	140	140
6.	Cow dung	250	250	60	100	100	500	125	125
	Total				2020	1835		1275	1590

17.1.1 Calculation of yield of fine compost

The calculation of yield of fine compost is given in Table 21.

Table 21: Yield of fine compost

#	Detail	Weight in kg	
		Model 1	**Model 2**
1.	Total input – wet wt.	4850	4000
2.	Total input – dry wt.	2020	1835
3.	Yield of fine compost @ 70% - dry wt.	1414	1285
4.	Yield of fine compost with 25% moisture	1885	1713

Cost of fine compost (final product) is arrived at as shown below:

Model 1

4850 kg of inputs (wet weight) valued at INR 1275 yields 1885 kg of fine compost that can be marketed.

Therefore, cost of material/tonne of fine compost : INR 676
Cost of labour and overheads @ 50% of direct material cost : INR 338
Total cost / tonne of fine compost : **INR 1014**
Rounded off to : INR 1000

Model 2

3600 kg of inputs (wet weight) valued at INR 1590 yields 1713 kg of fine compost that can be marketed.

Therefore, cost of material/tonne of fine compost : INR 928
Cost of labour and overheads @ 50% of direct material cost : INR 464
Total cost / tonne of fine compost : **INR 1392**
Rounded off to : INR 1400

Average cost of fine compost = (1000 + 1400) ÷ 2 = INR 1200 per tonne

17.2 Market potential

The market for sludge compost is rural India where the primary occupation is agriculture. Presently, FYM and compost prepared by town/city administration from domestic waste are used by farmers. It has been reported that in India in order to rejuvenate agricultural land exposed to intensive chemical fertilizers, the sellers of such fertilizers have been advised to also sell at least 20% of the total quantity sold in the form of organic fertilizer.

18. APPLICATION OF SLUDGE COMPOST AS FERTILISER

18.1 Pot trials

During the first two phases of composting trials, Mr. Sultan Ismail, National Consultant had established through trials carried out in pots that plants fertilised with sludge compost performed better than those grown in similar conditions without application of sludge compost. The growth performance of the plants in terms of foliage – number of leaves and surface area of leaves, girth of stem, height of plant and yield – size and weight of vegetables was monitored closely and the plants fertilised with sludge compost were found to outperform the control plants. However, the chromium present in the compost was found to enter the plants.

18.2 Field trials

During the large scale composting trials, the harvested sludge compost was applied as manure both as basal and top dressing to the following plants in fairly large sized plots:

a. Lady's finger
b. Tomato
c. Radish
d. Cluster beans

In all the cases, the plants fertilised with sludge compost were observed to be very healthy with dense chlorophyll. The vegetable yielded by these plants were dried and analysed for the presence of chromium.

Fig. 9: Radish fertilised with sludge compost

Fig. 10: The yield of okra plant fertilised with sludge compost was remarkably better – both in number & size

Table 22 – Analysis of vegetables: Chromium

Sample	Chromium as Cr
Lady's finger	Below detectable limit[1]
Radish	Below detectable limit
Cluster beans	Below detectable limit

Sludge compost was applied as manure to inedible crops too. The species tried include cotton, ornamental plants such as zenia, balsam, etc. Plants fertilised with sludge compost have shown remarkable results.

In SSC, Ambur, cotton has been grown in two plots of identical soil. While sludge compost was applied as manure to one plot, the other plot was maintained as 'control plot' to study the effect of sludge compost application. Since the beginning, the plants fertilised with sludge compost outperformed those in the control plot. The yield of plants fertilized with sludge compost was 60% higher than that of the control plot.

Fig. 11: Cotton crop fertilised with sludge compost

[1] ***Detection limit is 0.028 ppm***

In SSC, Ambur, in two plots of land each measuring 50 cents (0.5 acre), saplings of silk cotton trees and caster seeds have been sown in March 2001. Basal application of sludge compost has been done and the plants will be fertilised with sludge compost regularly.

The yield from both these species – cotton from silk cotton trees and caster seeds from caster plants – are readily saleable. While cotton from silk cotton is used in making mattresses and pillows, the oil extracted from caster seeds is inedible but has extensive industrial application, which includes use as fat liquor in the tanning industry.

In MAKH & Sons, Ranipet sludge compost is being used as a soil conditioner in the development of a green belt in a 7-acre plot of land adjoining the tannery. *Casuarina, Eucalyptus, Accacia mangium, Neem* and a few other species of plants have been raised.

19. INTERVENTIONS OF MR. W. BOWDEN OF THE BLC, UK

19.1 Review of RePO's report by the consultant

A report containing the details of trials carried out in SSC, Ambur and in MAKH & Sons, Ranipet was sent to Mr. Warren Bowden of the BLC Leather Technology Centre, U.K. for review. Though Mr. Bowden found the general results interesting he identified the following as the main drawbacks:

- The temperature of the heaps tended to rise after every turning over. As a result there was no distinction between the thermophilic and the mesophilic phases, resulting in needlessly extended process duration.

- Measuring the temperature of the heap directly was not fool-proof. Self heating temperature measurement (Dewar) is the proper mode of assessment of composting.

- While C/N ratio can be between 15 and 35, the more important factor influencing composting is the density of the pile. It had not been taken into account in the previous trials.

- The sludge and admixtures have to be reduced to smaller particles and mixed well before building the heap. Piling the admixtures layer by layer introduces differential density and in turn non-uniform aeration. Also, the moisture content will be different in different layers.

- Building the piles on a gravel platform would eliminate the requirement of turning over the heap.

Accordingly, Mr. Bowden suggested building some model heaps under his supervision taking into account the following essential parameters:

- The resultant density of the piled materials should ideally be between 0.4 and 0.6 t/m^3. The lower the density the greater the porosity and air space.

- The ratio between sludge and admixtures may be suitably adjusted to achieve the desired density. Wooden chips and twigs could be added to increase porosity and reduce cost of admixtures. Undigested wooden chips and twigs can be recycled in successive heaps.

- Cow dung, a costly input, can be dispensed as its C and N contents are similar to sludge.

- The heap will have C/N ratio of 15 to 35 and moisture content of about 60%.

- Sludge and admixtures have to be pounded/chopped/cut to reduce these to uniform particle size and mixed thoroughly before heaping. This will ensure uniform C/N ratio, moisture level and porosity throughout the heap.

- Determination of self-heating temperature using the DEWAR flask is necessary as it conclusively establishes the status of the material in a pile – whether it is in thermophylic or mesophylic phase or has become a stable product. Self-heating temperature is the only reliable means of assessing different stages of composting, namely, activity, maturity and completion. Self-heating temperature during the active stages of thermophilic and mesophilic phases should be in the range of 20 – 40^0C. The process of checking self-heating temperature normally starts from the 3^{rd} day of setting up of heap and is continued till the end of composting process at an interval of 10 days between two successive measurements. When the self-heating temperature is < 10^0C, it indicates that the matter in the compost pile is stable and that the process of composting is complete.

- Duration of the composting process for tannery sludge and admixtures may vary but is not longer than 120 days.

- Piles built on gravel bed do not require turning over. Piles built on stone floor have to be turned over once in 3-5 days over a period of 40-60 days during the mesophillic phase.

At UNIDO's initiative, Mr. Bowden visited Tamil Nadu, India in July 2001 and helped set up a few compost heaps, eliminating perceived drawbacks of the earlier procedure.

19.2 Trials under Mr. Bowden's guidance

Three gravel platforms were erected in SSC at Ambur and one in MAKH & Sons at Ranipet. The gravel was of about 50 mm diameter. The height of the gravel beds was 200 mm.

In SSC, five heaps were built. The main guiding factor was the density. The density of each ingredient was determined and heaps were so built as to achieve a resultant density of 0.4 – 0.6 t/m^3. The density of heaps set up by Mr. Bowden was generally < 0.5 t/m^3. The other ingredients used were coir pith (tertiary waste), fleshings, green biomass and paddy straw. Three of these heaps were built on gravel beds and two on hard stone floor. Paddy straw and green wastes were chopped prior to mixing. Of the three heaps built on gravel bed, one was built to achieve a density less than the range 0.4 to 0.6 t/m^3 and this was considered an ideal combination. The other four heaps were prepared to achieve a density within the 0.4 to 0.6 t/m^3 range. It is apparent that the lower the density of the heap the lower the volume of sludge that can be used for composting and the higher the requirement of other inputs some of which come with a cost.

Fig. 12: Compost heaps built on gravel bed and hard stone flooring in SSC, Ambur

In a similar manner at MAKH & Sons two heaps were set up one on gravel platform and the other on hard stone floor. The procedure adopted was the same. However, in MAKH & Sons coir pith was not used.

It should be mentioned here that while the heaps in SSC were made in the open yard, those in MAKH were set up under roof.

Fig. 13: Compost heaps built under shelter on gravel bed and cement flooring in MAKH & Sons, Ranipet

It may also be pointed out here that because the contents were chopped, mixed and then the heaps were built, some pieces of fleshings came on top of the heap emitting a bad odour for a day or two. It was found that by spreading paddy straw atop the heap this could be minimised.

A statement containing details of the heaps such as ingredients, moisture content, density, C/N ratio, cost of inputs, sludge and admixture ratio, etc. is at Annex 5.

The moisture level in the heaps was maintained at about 60% by sprinkling water as required. The temperature in the interior zones of the heaps was measured at 08 00 hours everyday using a thermo probe. The ambient air temperature too was measured at the same time. Samples of matter drawn from different heaps were assessed for self- heating temperature using DEWAR flask.

Normally, the temperature in the heap was found to reach a peak in about 3-10 days of setting up. A maximum temperature of 74^{0}C was recorded on the 4^{th} and 5^{th} days in the heaps at set up in MAKH & Sons at Ranipet. At Annex 6, is a table containing details of temperature measured in the seven heaps during the period 10 July – 28 October 2001. Interestingly, in MAKH, the distinction between the thermophilic (22 to 31 days) phase and the mesophilic phase was quite clear. This was not quite so in SSC possibly because the heaps were in the open yard, exposed to rain and different combinations of admixtures. Nevertheless, the overall trend observed in the data relating to temperature at both the sites clearly indicate a distinction between the thermophilic and the mesophilic phases. Though Mr. Bowden had indicated 120 days as the maximum limit for composting process to be completed, it was observed that these heaps were ready for composting between 86 and 110 days.

19.3 Key parameters in Mr. Bowden's trials

In Table 23, a summary of key parameters observed in all the seven heaps built under Mr. Bowden's guidance is provided.

Table 23: Key parameters in heaps built under Mr. Bowden's guidance

Description	Shafeeq Shameel & Co., Ambur					MAKH & Sons, Ranipet	
	Pile 1 On gravel	Pile2 On gravel	Pile3 On gravel	Pile 1 On floor	Pile2 On floor	On gravel	On floor
Density, t/m^3	0.399	0.417	0.457	0.417	0.457	0.452	0.452
Quantity of the heap, tonne	2.5	2.5	1.8	2.5	1.8	2.47	2.47
Dry matter input, tonne	1.15	0.8	0.64	0.8	0.64	1.04	1.04
Sludge: Admixture (Dry matter)	5:18	5:3	5:8	5:3	5:8	1:2	1:2
C : N ratio	38	23	28	23	28	31	31
Peak temperature / reached on N^{th} day	65^{0}C / 9	67^{0}C / 7	63^{0}C / 3	62^{0}C / 3	58^{0}C / 6	74^{0}C / 5	74^{0}C / 4
Thermophilic phase	1 – 68	1 - 70	1 – 62	1 – 68	1 – 62	1 – 22	1 – 30
Mesophilic phase	69 - 110	71 - 105	63 - 103	69 – 97	63 – 108	23 – 86	31 – 90
No. of days taken for completion of the process	110	105	103	97	108	86	90
Quantity of fine compost as produced[1], tonne	1.15	0.8	0.87	0.82	0.88	0.96	1.04

Quantity of coarse matter as produced, tonne	0.09	0.3* 0.26#	0.05	0.295* 0.26#	0.06	0.131* 0.031#	0.187* 0.047#
Yield of fine compost, % on total produced (excluding wooden chips)	93	95	95	96	94	91	88
Material cost / tonne compost, INR	1,152	219	477	213	471	1,052	971

* including wood, recyclable matter
# Quantity of wood
[1] The fine compost contains moisture content of about 25%

The comparison of main parameters and results obtained in Mr. Bowden's trials with the previous trials is given Table 24.

Table 24: Comparison of previous trials and Mr. Bowden's trials

S.No.	Parameters	Previous trials	Mr. Bowden's trials
1.	Peak temperature	55 to 77^{0}C	58 to 74^{0}C
2.	Duration	68 to 90 days	86 to 110 days
3.	Fine compost, on total compost	55 to 97%	88 to 96%
4.	Material cost / tonne compost	Rs.676 to Rs.928	Rs.213 to Rs.1,152
5.	Turning over	Necessary	Not necessary

19.4 Application of sludge compost

Mr. Bowden felt that compost, whether obtained from municipal wastes or from industrial wastes containing organic matter, was suitable for use as land conditioner. Compost prepared from 'clean' wastes such as vegetable market wastes, paddy straw, etc. is sold at fancy prices. However, the market for such product is very small. In view of this, composting should be viewed as an alternate route for the safe disposal of an otherwise difficult-to-dispose industrial solid waste, namely sludge. In the industrialised countries where laws governing disposal of industrial wastes are stringent and enforced strictly, this option provides an alternate disposal route. The option of disposal in landfills, apart from being an expensive one, may not be available for long as the availability of land shrinks.

Tannery sludge compost can be applied as soil conditioner. When applied as soil conditioner, it has been found to:

- improve moisture retention property
- provide resistance to pests & diseases
- prevent soil erosion
- marginally help in the rejuvenation of soil

Typical areas of application of compost in the UK are:

- As topsoil in the development of golf courts. It helps in the growth of grass.

- As cover over closed landfills. This is done to facilitate growth of grass and provide a green top layer to closed & covered landfill sites.
- As support material on either side of asphalt highways. Applied with grass seeds, the compost supports growth of grass and this prevents erosion of soil.
- Soil conditioner to land where non-food crops are grown.

20. LESSONS LEARNT

From the industrial-scale trials of composting of tannery sludge in Ambur and Ranipet and especially the trials done under the guidance of Mr. Bowden, the following lessons have been learnt:

- Affordable organic wastes such as green or limed fleshings, green bio mass, tertiary coir pith and paddy straw available locally, can be used as admixtures. Cow dung, a costly input, can be dispensed with as compost heaps built without cow dung have yielded positive and satisfactory results.
- The ingredients should be pounded/chopped/cut to uniform particle size before being mixed and piled up. This, as against piling the ingredients layer by layer, provides uniform density. Adding wooden chips and twigs will aid natural aeration. Undigested wooden chips and twigs can be recycled in successive heaps.
- Building heaps on gravel platform obviates the requirement of turning over the same.
- The density of the heap should be between 0.4 and 0.6 t/m^3.
- The C/N ratio of 15 to 35 is generally appropriate.
- In order to achieve the desired density and C/N ratio, based on the data collected during the experiments, as rule of thumb, 1 tonne of sludge can be combined with fleshings (250 to 350 kg), green biomass (200 to 300 kg), paddy straw (200 to 300 kg) and coir pith (200 to 300 kg).
- The moisture level of 60 – 65% is essential to aid effective composting. Sprinkling of water on the heap once a day in the morning is adequate to maintain the required moisture level. However on warm days, sprinkling may be done both in the morning and the evening.
- The temperature of the heap rises to above 70^0C within the first 10 to 20 days. The thermophilic phase, when the temperature remains above 45^0C, lasts until 35 to 60 days from the day the compost pile is set up. Thereafter the mesophilic phase, when the range of temperature is 45^0C to 15^0C, lasts for about 40 to 60 days. During this phase the temperature of the heap gradually falls to reach the ambient temperature, when the composting process is completed.
- Dewar flask helps measure the self heating temperature of the heap accurately.
- Duration of composting varies depending on admixtures, anywhere between 80 and 110 days.

Based on the results of the trials conducted until now, it would be safe to state that this option offers a promising avenue for utilisation of sludge containing trivalent chrome at less than 5000 mg/kg and meeting the other disposal standards specified.

One crucial question is whether the product will have a market or not, if produced in large volume. The other of course is its acceptability to the regulatory authorities. These will have to be discussed with potential users and concerned authorities before large scale composting of tannery sludge could be encouraged.

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2. Mr. Warren Bowden, BLC, UK
3. Management and staff of SSC, Ambur, India
4. Management and staff of MAKH & Sons, Ranipet, India
5. Management and staff of CETP-Vishtec, Melvisharam, India

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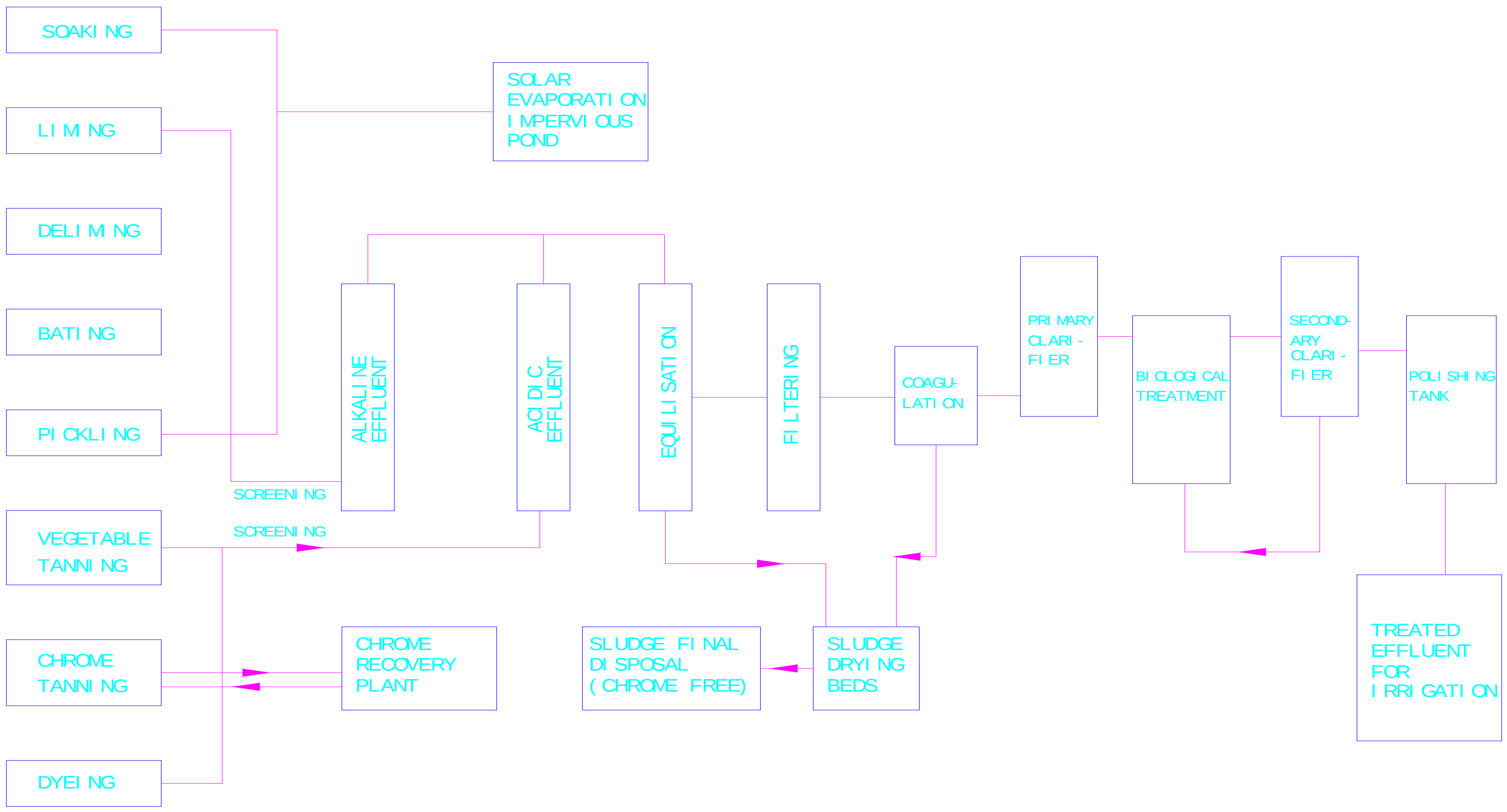
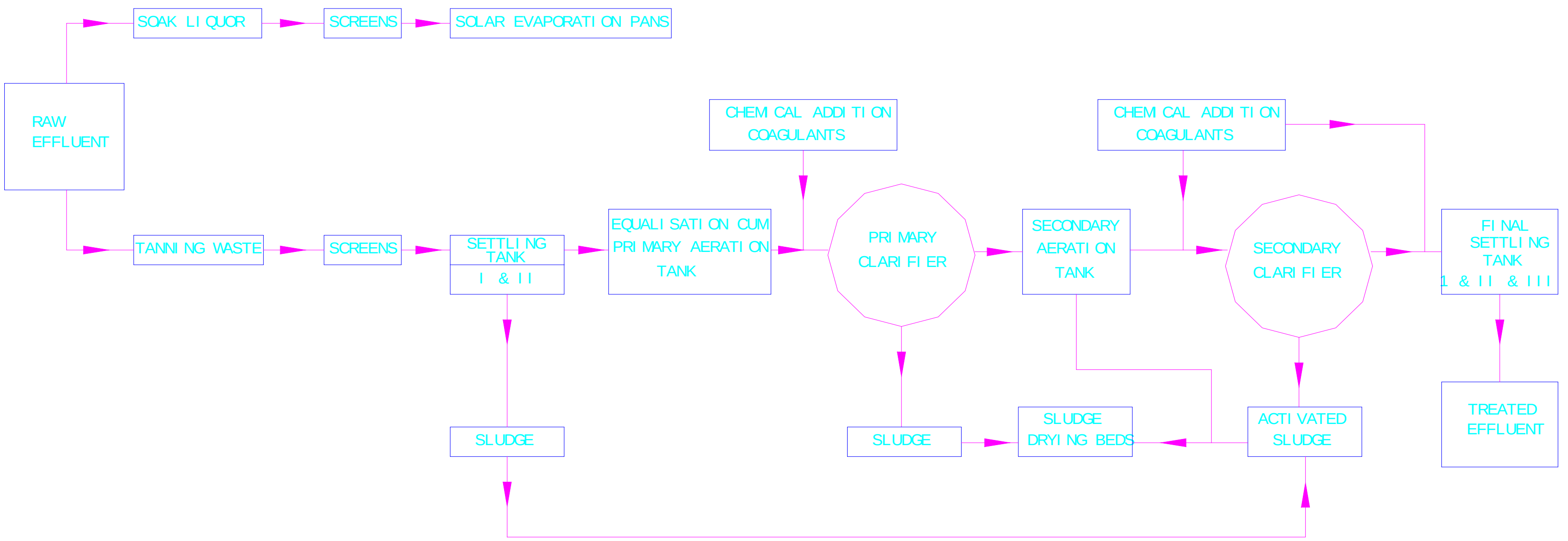
1. 'The Science of Composting' by Eliot Epstein.
2. Report on 'Composting Manual for the Execution of Composting Tests in Xuzhou Tannery' – Ulrich Fringgs (US/CPR/92/120).
3. Reports of Mr. Warren Bowden, BLC, UK of May & September 2001.

ANNEX-1 FLOW DIAGRAM OF ETP IN SHAFEEQ SHAMEEL & CO, AMBUR.



ANNEX -2 FLOW DIAGRAM OF ETP IN MA KHIZAR HUSSAIN & SONS, RANIPET.



Annex 3

Detailed data on composting trials – Composition, temperature, turn over, etc.

Location: SSC, Ambur

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					No. of days taken for completion	*Remarks*
		Sludge	GB	Straw	Flesh	Coir	C/dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	day	Date	^{0}C	Date		
1	29/03/2000	1000	450	450	-	-	100	23/4	18/5	-	-	-	70.9	8	05/4	61.3	10/5		
2	06/04/2000	1000	400	400	-	-	200	03/5	18/5	-	-	-	69.1	5	11/04	46.1	18/05		
3	06/04/2000	1000	400	400	-	-	200	18/4	17/5	23/5	08/6	-	67.3	5	11/04	44.2	29/05		
4	08/04/2000	1000	300	600	-	-	100	30/4	18/5	21/5	01/6	17/6	66.1	4	12/04	41.0	23/05	74	
5	11/04/2000	1000	450	450	-	-	100	25/4	20/5	25/5	08/6	17/6	64.2	7	18/04	49.2	27/05	74	
6	11/04/2000	-do-	-do-	-do-	-	-	100	02/5	20/5	27/5	08/6	17/6	68.2	15	26/04	48.9	27/05	75	Temp. on 6th day was 64.1^{0}C
7	12/04/2000	-do-	-do-	-do-	-	-	100	03/5	20/5	08/6	24/6		69.3	10	22/04	53.5	27/05	81	Temp. on 5th day was 68.7^{0}C
8	16/04/2000	-do-	-do-	-do-	-	-	100	09/5	21/5	10/6	24/6		69.6	10	26/04	48.2	31/05	74	Temp. on 4th day was 65.9^{0}C
9	17/04/2000	-do-	-do-	-do-	-	-	100	06/5	21/5	10/6	24/6		76.8	3	20/04	41.0	01/06	74	
10	19/04/2000	1000	300	300	300	-	100	17/5	01/6	10/6	24/6		70.5	6	25/04	50.7	03/06	74	

Note: Coarse particles resulting from sieving of harvested compost forms part of the sludge taken for building a heap

Location: SSC, Ambur

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	C/dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	Day	Date	^{0}C	Date		
11	20/04/2000	1000	300	300	300	-	100	17/5	28/5	10/6	04/6		71.2	18	08/05	45.7	04/06	74	Temp. on 6^{rd} day was 71.1^{0}C
12	23/04/2000	1000	300	300	300	-	100	18/5	24/5	10/6	25/6	01/7	72.4	15	08/05	47.9	07/06	71	Temp. on 3^{rd} day was 72.3^{0}C
13	24/04/2000	1000	600	300	-	-	100	21/5	01/6	11/6	25/6	01/7	66.9	10	04/05	45.7	08/06	72	Temp. on 2^{nd} day was 64.6^{0}C
14	25/04/2000	1000	300	300	300	-	100	18/5	01/6	11/6	25/6	01/7	71.4	8	3/5	49.0	10/6	71	
15	3/5/00	1000	250	150	300	200	100	20/5	3/6	14/6	25/6	03/7	70.6	6	9/5	50.7	14/16	72	
16	4/5/00	1000	125	125	400	250	100	20/5	3/6	14/6	25/6		65.1	6	10/5	38.2	18/6	73	
17	4/5/00	-do-	-do-	-do-	-do-	-do-	-do-	21/5	4/6	14/6	27/6		69.9	6	10/5	47.1	22/6	71	
18	8/5/00	-do-	-do-	-do-	-do-	-do-	-do-	19/5	27/5	15/6	27/6		61.7	7	15/5	47.9	27/6	70	Temp. on 2^{nd} day was 60.4^{0}C
19	10/5/00	-do-	-do-	-do-	-do-	-do-	-do-	22/5	5/6	15/6	27/6		64.9	8	18/5	49.8	27/6	75	
20	11/5/00	-do-	-do-	-do-	-do-	-do-	-do-	25/5	5/6	18/6	28/6	08/7	65.5	7	18/5	49.2	27/6	74	
21	11/5/00	-do-	-do-	-do-	-do-	-do-	-do-	22/5	29/5	18/6	28/6	08/7	64.2	23	3/6	50.1	28/6	72	Temp. on 6^{th} day was 62.8^{0}C
22	15/5/00	-do-	-do-	-do-	-do-	-do-	-do-	22/5	7/6	18/6	28/6	08/7	64.9	15	30/5	40.2	3/7	76	Temp. on 10^{th} day was 63.3^{0}C

* Number of days taken for completion of composting process

Location: SSC, Ambur

Heap #	**Set up on**	**Composition: weight in kg**						Turn over done on					**Temperature**					*	**Remarks**
		Sludge	**GB**	**Straw**	**Flesh**	**Coir**	**C/dung**	I	II	III	IV	V	**Peak**			***After 45 days***			
													^{0}C	**Day**	**Date**	**^{0}C**	**Date**		
23	16/5/00	1000	125	125	400	250	100	25/5	7/6	19/6	28/6	08/7	60.8	7	23/5	42.2	4/7	**70**	
24	16/5/00	-do-	-do-	-do-	-do-	-do-	-do-	3/6	7/6	19/6	28/6	08/7	63.4	9	25/5	44.3	3/7	**69**	
25	23/5/00	-do-	-do-	-do-	-do-	-do-	-do-	3/6	7/6	19/6	28/6	10/7	64.2	13	05/6	40.7	23/7	70	Temp. on 6th day was 63.2^{0}C
26	23/5/00	-do-	-do-	-do-	-do-	-do-	-do-	3/6	15/6	22/6	29/6	20/7	66.7	8	31/5	45.6	6/7	**72**	
27	24/5/00	-do-	-do-	-do-	-do-	-do-	-do-	4/6	17/6	26/6	09/7	20/7	67.4	4	28/5	46.7	09/7	**71**	
28	24/5/00	-do-	-do-	-do-	-do-	-do-	-do-	7/6	17/6	26/6	09/7	20/7	66.6	8	01/6	49.2	09/7	**69**	
29	29/5/00	-do-	-do-	-do-	-do-	-do-	-do-						65.2	7	05/6			68	Forced aeration
30	30/5/00	1000	100	100	400	300	100						52.9	4	03/6			**68**	”
31	31/5/00	1000	125	125	400	250	100	10/6	26/6	2/7	09/7	20/7	64.2	14	14/6	40.2	17/7	70	Temp. was between 50 and 60^{0}C during 3rd to 13th day
32	5/6/00	-do-	-do-	-do-	-do-	-do-	-do-	19/6	26/6	2/7	09/7	29/7	55.6	8	13/6	39.3	24/7	**75**	
33	5/6/00	-do-	-do-	-do-	-do-	-do-	-do-	19/6	26/6	2/7	09/7	29/7	55.0	6	11/6	42.6	24/7	**74**	
34	6/6/00	-do-	-do-	-do-	-do-	-do-	-do-	20/6	29/6	3/7	09/7	29/7	55.0	7	13/6	47.4	24/7	**75**	

* Number of days taken for completion of composting process

Location: SSC, Ambur

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	C/dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	Day	Date	^{0}C	Date		
35	7/6/00	1000	125	125	400	250	100	22/6	29/6	10/7	22/7	29/7	59.4	6	13/6	44.3	22/7	70	
36	13/6/00	-do-	-do-	-do-	-do-	-do-	-do-	22/6	3/7	10/7	20/7	06/8	61.6	4	17/6	45.0	02/8	75	
37	13/6/00	-do-	-do-	-do-	-do-	-do-	-do-	29/6	10/7	20/7	30/7	06/8	60.2	6	19/6	49.6	30/7	72	
38	14/6/00	-do-	-do-	-do-	-do-	-do-	-do-	29/6	10/7	20/7	30/7	06/8	67.3	8	22/6	45.6	01/8	73	
39	20/6/00	-do-	-do-	-do-	-do-	-do-	-do-	29/6	10/7	20/7	30/7	06/8	69.8	18	08/7	46.0	05/8	74	Temp. on 8th day was 64^{0}C
40	22/6/00	1800	700	300	1400	400	250	1/7	11/7	22/7	30/7	17/8	77.0	16	08/7	59.0	07/8	78	Temp. on 6th day was 65.3^{0}C
41	04/7/00	4000	1600	600	1600	560	600						65.5	7	11/7			60	Forced aeration
42	16/7/00	3000	375	375	1200	750	300	27/7	06/8	17/8	28/8	07/9	62.3	8	24/7	64.4	12/9	70	
44	19/7/00	-do-	-do-	-do-	-do-	-do-	-do-	01/8	10/8	19/8	-	-	63.6	13	1/8	62.0	07/9	72	Temp on 6th day was > 60^{0}C
45	27/7/00	2000	250	250	200	200	100	10/8	19/8	30/8	09/9	-	64.1	11	07/8	56.3	25/9	73	
46	07/8/00	-do-	-do-	-do-	-do-	-do-	-do-	16/8	27/8	06/9	18/9	28/9	70.4	5	13/8	42.1	25/9	74	

* Number of days taken for completion of composting process

Location: SSC, Ambur

Heap #	**Set up on**	**Composition: weight in kg**						Turn over done on					**Temperature**					*****	**Remarks**
		Sludge	**GB**	**Straw**	**Flesh**	**Coir**	**C/dung**	I	II	III	IV	V	**Peak**			**After 45 days**			
													^{0}C	**Day**	**Date**	**^{0}C**	**Date**		
47	21/8/00	3750	900	600	500	500	250	30/08	09/9	19/09	17/10	-	73.6	12	02/09	56.1	07/10	72	Temperature on 3rd day – 58.8^{0}C
48	08/9/00	1500	250	250	200	200	100	18/09	30/9	15/10	25/10	4/11	64.3	13	21/09	50.0	29/10	74	Temperature on 5th day – 63.9^{0}C
49	08/9/00	1500	350	350	250	150	250	16/09	28/9	03/10	16/10	25/10	63.6	04	12/09	50.1	24/10	75	
50	11/9/00	-do-	-do-	-do-	-do-	-do-	-do-	19/09	30/9	16/10	25/10	04/11	66.7	07	18/09	45.9	29/10	76	
51	11/9/00	1350	300	200	120	120	60	19/09	05/10	16/10	25/10	04/11	71.2	05	16/09	47.8	29/10	71	
52	26/9/00	-do-	-do-	-do-	-do-	-do-	-do-	15/10	25/10	04/11	15/11	20/11	67.2	14	10/10	39.7	11/11	72	Temp. on 4th day – 63.4^{0}C
53	05/10/00	-do-	-do-	-do-	-do-	-do-	-do-	15/10	26/10	07/11	16/11	26/11	64.1	07	12/10	50.7	20/11	73	
54	09/10/00	-do-	-do-	-do-	-do-	-do-	-do-	18/10	29/10	07/11	18/11	28/11	63.6	05	14/10	57.1	07/12	76	
55	15/10/00	-do-	-do-	-do-	-do-	-do-	-do-	25/10	04/11	14/11	25/11	06/12	61.6	04	19/10	63	13/12	78	
56	25/10/00	1500	350	350	250	250	150	04/11	14/11	25/11	05/12	14/12	69.3	40	04/12	58.3	22/12	79	Temp. build up was very slow
57	30/10/00	-do-	-do-	-do-	-do-	-do-	-do-	09/11	19/11	29/11	09/12	25/12	73.6	38	07/12	66.4	16/12	71	Temp. build up was very slow
58	05/11/00	-do-	-do-	-do-	-do-	-do-	-do-	16/11	26/11	06/12	14/12	30/12	66.3	32	06/12	60.5	25/12	75	

* Number of days taken for completion of composting process

Location: SSC, Ambur

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	C/dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	Day	Date	^{0}C	Date		
59	11/11/00	1500	350	350	250	250	150	2/11	2/12	12/12	22/12	02/01	69.2	26	06/12	51.9	31/12	71	Temp. build up was very slow
60	20/11/00	1890	600	220	400	200	150	02/12	11/12	09/01			67.5	10	30/11	41.1	06/01	72	

* Number of days taken for completion of composting process

Location: MAKH & Sons, Ranipet

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	C/dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	Day	Date	^{0}C	Date		
1	8/4/00	1000	300	200	300	-	100	21/4	5/5	11/5	19/5		74.1	12	20/4	44.9	24/5		
2	8/4/00	-do-	-do-	-do-	-do-	-do-	-do-	21/4	5/5	12/5	20/5		73.4	07	15/4	54.8	25/5		
3	11/4/00	-do-	-do-	-do-	-do-	-do-	-do-	22/4	6/5	12/5	22/5		74.3	03	14/4	45.9	25/5		
4	11/4/00	-do-	-do-	-do-	-do-	-do-	-do-	24/4	6/5	14/5	23/5		73.9	04	15/4	46.6	27/5		
5	12/4/00	-do-	-do-	-do-	-do-	-do-	-do-	25/4	7/5	21/5	23/5	3/6	73.2	04	16/4	51.2	27/5	70	
6	17/4/00	-do-	-do-	-do-	-do-	-do-	-do-	26/4	7/5	24/5	29/5	5/6	73.3	03	20/4	55.7	2/6	66	
7	18/4/00	-do-	-do-	-do-	-do-	-do-	-do-	26/4	7/5	25/5	1/6	14/6	73.2	04	22/4	62.1	3/6	70	
8	18/4/00	-do-	-do-	-do-	-do-	-do-	-do-	27/4	8/5	21/5	28/5	5/6	71.0	07	25/4	56.3	3/6	71	
9	19/4/00	-do-	-do-	-do-	-do-	-do-	-do-	3/5	8/5	24/5	1/6	15/6	70.1	06	25/4	69.9	7/6	73	
10	19/4/00	-do-	-do-	-do-	-do-	-do-	-do-	29/4	9/5	25/5	3/6	15/6	71.5	05	24/4	45.3	7/6	72	
11	21/4/00	-do-	-do-	-do-	-do-	-do-	-do-	28/4	19/5	27/5	3/6	15/6	72.4	03	24/4	48.5	8/6	70	

* Number of days taken for completion of composting process

Note: Coarse compost resulting from sieving of harvested compost forms part of the sludge taken for building a heap

Location: MAKH & Sons, Ranipet

Heap #	Set up on	Composition: weight in kg – Sludge	GB	Straw	Flesh	Coir	Cow dung	Turn over done on – I	II	III	IV	V	Temperature – Peak – ^0C	Peak – Day	Peak – Date	After 45 days – ^0C	After 45 days – Date	*	*Remarks*
12	22/4/00	1000	300	300	300	-	100	03/5	11/5	26/5	3/6	15/6	72.0	5	27/4	60.4	7/6	69	
13	23/4/00	-do-	-do-	-do-	-do-	-do-	-do-	06/5	9/5	26/5	3/6	15/6	70.9	5	28/4	49.0	7/6	68	
14	23/4/00	-do-	-do-	-do-	-do-	-do-	-do-	29/4	5/5	11/5	26/5	5/6	69.0	4	27/4	47.1	7/6	68	
15	24/4/00	-do-	-do-	-do-	-do-	-do-	-do-	04/5	14/5	17/5	28/5	7/6	70.1	4	28/4	50.8	7/6	70	
16	25/4/00	-do-	-do-	-do-	-do-	-do-	-do-	10/5	20/5	26/5	3/6	15/6	72.8	6	1/5	48.4	12/6	71	
17	26/4/00	-do-	-do-	-do-	-do-	-do-	-do-	10/5	22/5	28/5	3/6	15/6	72.3	7	3/5	50.3	11/6	75	
18	27/4/00	-do-	-do-	-do-	-do-	-do-	-do-	12/5	19/5	26/5	3/6	15/6	70.4	9	6/5	52.3	12/6	71	
19	28/4/00	1000	400	200	300	-	100	13/5	19/5	26/5	3/6	12/6	70.4	5	3/5	40.2	16/6	71	
20	29/4/00	1000	400	250	300	-	100	13/5	20/5	28/5	6/6	12/6	65.2	3	2/5	36.5	20/.6	73	
21	30/4/00	-do-	-do-	-do-	-do-	-do-	-do-	09/5	14/5	22/5	29/5	12/6	74.9	3	3/5	33.8	16/6	80	
22	30/4/00	-do-	-do-	-do-	-do-	-do-	-do-	16/5	21/5	28/5	3/6	7/6	70.7	3	3/5	43.0	15/6	78	
23	2/5/00	-do-	-do-	-do-	-do-	-do-	-do-	16/5	26/5	31/5	7/6	12/6	70.9	4	6/5	34.4	16/6	77	

* Number of days taken for completion of composting process

Location: MAKH & Sons, Ranipet

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	Cow dung	I	II	III	IV	V	Peak			After 45 days			
													^0C	Day	Date	^0C	Date		
24	3/5/00	-do-	-do-	-do-	-do-	-do-	-do-	16/5	25/5	31/5	12/6	21/6	64.9	3	6/5	47.7	25/6	77	
25	3/5/00	-do-	-do-	-do-	-do-	-do-	-do-	18/5	26/5	3/6	12/6	21/6	69.9	4	7/5	50.7	25/6	70	
26	4/5/00	-do-	-do-	-do-	-do-	-do-	-do-	18/5	25/5	2/6	12/6	21/6	65.8	5	9/5		25/6	77	
27	4/5/00	1000	400	250	300	-	100	17/5	21/5	29/5	6/6	11/6	72.7	3	7/5	50.6	26/6	76	
28	5/5/00	-do-	-do-	-do-	-do-	-do-	-do-	14/5	25/5	31/5	7/6	11/6	63.2	3	7/5	51.5	26/6	75	
29	6/5/00	-do-	-do-	-do-	-do-	-do-	-do-	14/5	25/5	31/5	7/6	11/6	65.0	3	9/5	55.8	26/6	73	
30	7/5/00	-do-	-do-	-do-	-do-	-do-	-do-	19/5	21/5	26/5	2/6	11/6	64.0	7	14/5	44.4	27/6	70	
31	8/5/00	1000	400	150	400	-	100	14/5	25/5	02/6	11/6	21/6	70.1	4	12/5	42.2	25/6	76	
32	9/5/00	-do-	-do-	-do-	-do-	-do-	-do-	14/5	21/5	28/5	6/6	11/6	61.5	5	14/5	52.4	26/6	72	
33	10/5/00	-do-	-do-	-do-	-do-	-do-	-do-	21/5	27/5	02/6	11/6	21/6	66.6	4	14/5	54.3	26/6	70	
34	11/5/00	-do-	-do-	-do-	-do-	-do-	-do-	27/5	01/6	05/6	11/6	21/6	69.9	13	24/5	53.9	26/6	72	Temp. on 2nd day was 62.2^0C
35	12/5/00	-do-	-do-	-do-	-do-	-do-	-do-	24/5	29/5	02/6	10/6	17/6	68.3	4	16/5	57.5	27/6	70	

* Number of days taken for completion of composting process

Location: MAKH & Sons, Ranipet

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
													Peak			After 45 days			
		Sludge	GB	Straw	Flesh	Coir	Cow dung	I	II	III	IV	V	^{0}C	Day	Date	^{0}C	Date		
36	13/5/00	1000	250	150	500	-	100	19/5	29/5	03/6	8/6	10/6	72.5	11	24/5		01/7	67	Temp. on 2nd day was 63.5^{0}C
37	15/5/00	-do-	-do-	-do-	-do-	-do-	-do-	26/5	03/6	05/6	10/6	19/6	70.5	4	19/5	39.0	01/7	70	
38	16/5/00	-do-	-do-	-do-	-do-	-do-	-do-	25/5	30/5	06/6	10/6	17/6	67.9	2	18/5	37.3	02/7	70	
39	17/5/00	-do-	-do-	-do-	-do-	-do-	-do-	25/5	30/5	05/6	10/6	19/6	65.7	3	20/5	37.6	01/7	70	
40	17/5/00	-do-	-do-	-do-	-do-	-do-	-do-	25/5	30/5	08/6	10/6	17/6	68.1	4	21/5	34.2	01/7	71	
41	18/5/00	-do-	-do-	-do-	-do-	-do-	-do-	27/5	01/6	07/6	10/6	19/6	67.9	3	21/5	32.2	09/7	70	
42	19/5/00	-do-	-do-	-do-	-do-	-do-	-do-	27/5	02/6	10/6	19/6	21/6	63.8	6	25/5	33.5	09/7	69	
43	20/5/00	1000	125	125	400	250	100	27/5	02/6	08/6	09/6	19/6	61.3	13	2/6	33.3	12/7	65	Slow build-up of temp.
44	21/5/00	-do-	-do-	-do-	-do-	-do-	-do-	31/5	07/6	09/6	19/6	06/7	67.0	13	3/6	42.6	17/7	70	Temp. on 6th day was 66.5^{0}C
45	22/5/00	-do-	-do-	-do-	-do-	-do-	-do-	30/5	09/6	19/6	04/7		70.5	5	27/5	39.0	11/7	69	
46	23/5/00	-do-	-do-	-do-	-do-	-do-	-do-	30/5	09/6	20/6	04/7		67.0	10	2/6	47.7	10/7	69	Temp. on the 10th day was 66.1^{0}C
47	24/5/00	-do-	-do-	-do-	-do-	-do-	-do-	03/6	08/6	20/6	04/7		70.5	14	7/6	48.8	10/7	70	Temp. on 3rd day was 62,2^{0}C

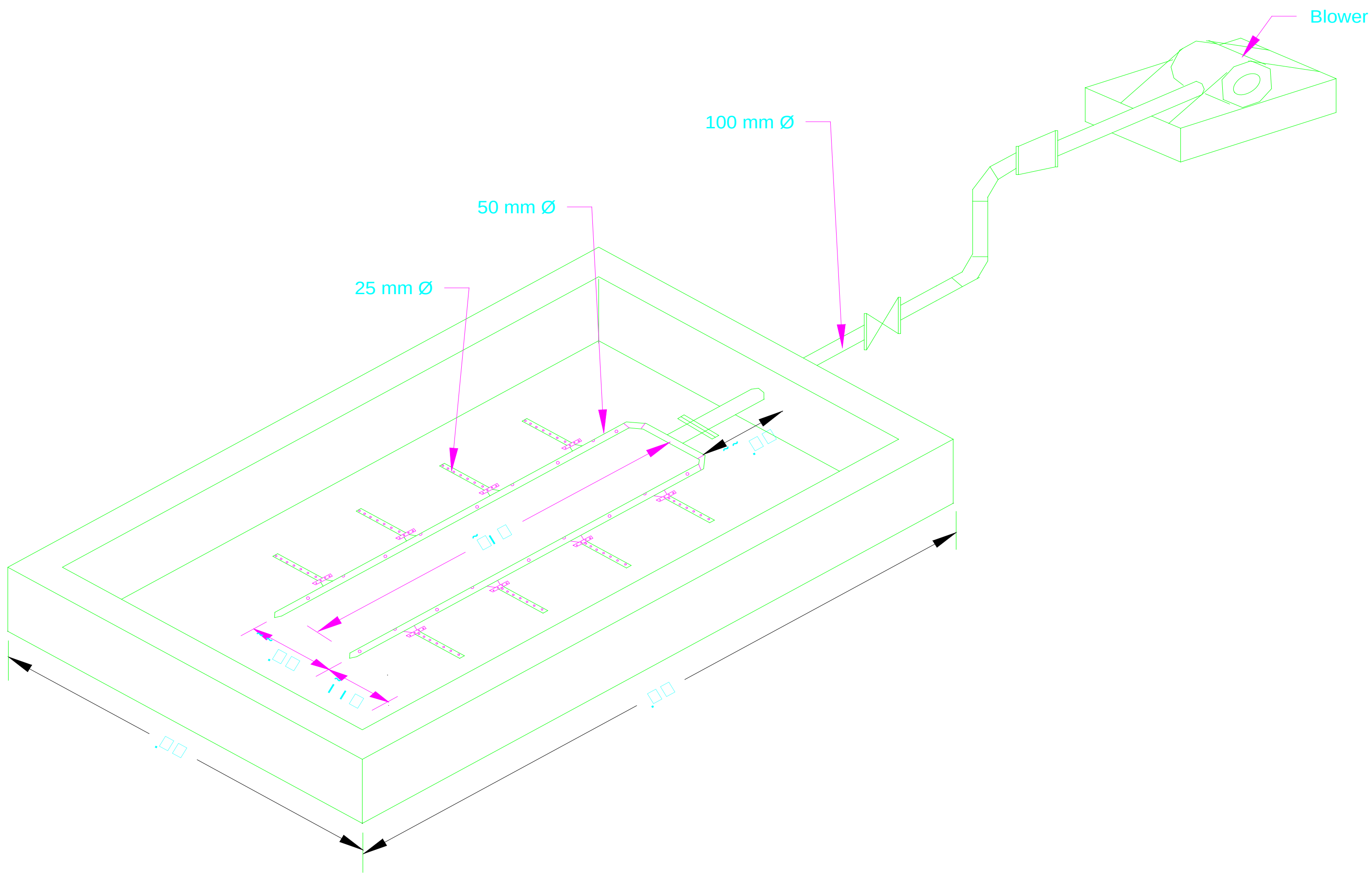
* Number of days taken for completion of composting process

Location: MAKH & Sons, Ranipet

Heap #	Set up on	Composition: weight in kg						Turn over done on					Temperature					*	Remarks
		Sludge	GB	Straw	Flesh	Coir	Cow dung	I	II	III	IV	V	Peak			After 45 days			
													^{0}C	Day	Date	^{0}C	Date		
48	26/5/00	-do-	-do-	-do-	-do-	-do-	-do-	08/6	09/6	17/6	04/7		68.5	8	3/6	43.5	12/7	71	
49	27/5/00	-do-	-do-	-do-	-do-	-do-	-do-	08/6	09/6	17/6	05/7		75.2	10	6/6	47.5	12/7	70	
50	28/5/00	1000	300	150	300	150	100	08/6	17/6	21/6	05/7		74.3	8	6/6	52.4	12/7	75	
51	13/6/00	1000	200/ 200	150	200	150	100	26/6	07/7	21/7	27/7	04/8	55.6	13	26/6			90	Sludge was pounded and screened before setting up heap
52	13/6/00	-do-	-do-	-do-	-do-	-do-	-do-	26/6	07/7	21/7	27/7	14/8	63.9	6	19/6	53.3	03/08	**90**	
53	01/7/00	2500	1000	350	-	400	250	21/7	04/8	24/8	11/9	22/9	68.3	10	11/7	52.3	05/09	**72**	
54	08/7/00	-do-	-do-	-do-	-do-	-do-	-do-	26/7	14/8	24/8	05/9	17/9	59.7	26	3/8	51.5	04/09	**70**	
55	10/7/00	-do-	-do-	-do-	-do-	-do-	-do-	28/7	20/8	05/9	25/9	6/10	65.0	22	1/8	51.9	29/08	**69**	
56	12/7/00	-do-	-do-	-do-	-do-	-do-	-do-	29/7	20/8	31/8	11/9	22/9	70.4	19	1/8	52.2	01/09	**88**	
57	16/7/00	-do-	-do-	-do-	-do-	-do-	-do-	03/8	25/8	11/9	26/9	10/10	63.7	4	20/7	53.6	05/09	**75**	
58	16/7/00	-do-	-do-	-do-	-do-	-do-	-do-	06/8	20/8	05/9	26/9	6/10	60.9	8	24/7	58.0	05/09	**71**	
59	19/7/00	-do-	-do-	-do-	-do-	-do-	-do-	06/8	20/8	05/9	22/9	6/10	60.8	5	24/7	52.7	11/09	**72**	
60	20/7/00	-do-	-do-	-do-	-do-	-do-	-do-	04/8	25/8	21/9	27/9	7/10	61.5	5	25/7	50.6	09/09	**71**	

* Number of days taken for completion of composting process

ANNEX - 4 COMPOSTING OF TANNERY SLUDGE - MECHANICAL AERATION SYSTEM



Annex 5

Details of compost piles set up under Mr. Bowden's guidance in Ambur & Ranipet

Ingredients	Moisture content, %	Density, t/m^3	C:N*	SSC, Ambur Quantity in tonne					MAKH & Sons, Ranipet Quantity in tonne	
				Pile 1 on gravel	Pile 2 on gravel	Pile 3 on gravel	Pile 1 on floor	Pile 2 on floor	On gravel	On floor
Sludge	50.0	0.9	20.0	0.5	1.0	0.5	1.0	0.5	0.7	0.7
Fleshings	70.0	0.7	7.0	0.5	0.5	0.5	0.5	0.5	0.7	0.7
Coir pith	70.0	0.3	50.0	0.5	0.5	0.5	0.5	0.5	-	-
Green Waste	70.0	0.3	50.0	0.5	-	0.3	-	0.3	0.7	0.7
Paddy straw	10.0	0.3	50.0	0.5	-	-	-	-	0.3	0.3
Wooden chips	10.0	0.2	-	-	0.5	-	0.5	-	0.07	0.07
Total				2.5	2.5	1.8	2.5	1.8	2.47	2.47
Density, t/m^3				0.399	0.417	0.457	0.417	0.457	0.452	0.452
C : N Ratio				37.87	23.19	28.2	23.19	28.2	31.22	31.22
Cost of material input, INR				1,325	175	415	175	415	1,010	1,010
Sludge : Admixture** (dry weight)				5 : 18	5 : 3	5 : 8	5 : 3	5 : 8	1 : 2	1 : 2
Dry matter input, tonne				1.15	0.8	0.64	0.8	0.64	1.04	1.04

** As produced by Mr. Bowden in his template*
*** Wood is not taken into account in calculation of sludge / admixture ratio as > 90% of wood is recyclable.*

P.S.: Price of material

Sludge	Nil
Fleshing	Nil
Coir pith	INR 350/ tonne (transport cost only)
Green waste	INR 800/ tonne
Paddy straw	INR 1500/ tonne

Annex 6: Details of temperature measured and harvesting details of the piles set up under Mr. Bowden's guidance for the period 10 July – 28 October 2001

Date		Temperature, ^{0}C measured at 0800 hrs each day							
	SSC, Ambur						MAKH & Sons, Ranipet		
	Ambient	Pile 1 on gravel	Pile 2 On gravel	Pile 3 on gravel	Pile 1 on floor	Pile 2 on floor	Ambient	On gravel	On floor
		set on 10/07/01	set on 11/07/01	set on 11/07/01	set on 12/07/01	set on 12/07/01		set on 13/07/01	set on 14/07/01
11/07/01	31	37							
12/07/01	30	44	-	-					
13/07/01	31	52	48	51	33	40			
14/07/01	31	60	54	63	53	52	28	46	
15/07/01	30	63	63	54	62	46	31	69	41
16/07/01	29	53	62	50	59	53	30	68	70
17/07/01	30	60	58	58	50	57	32	73	73
18/07/01	29	58	67	60	59	58	32	74	74
19/07/01	29	65	62	57	56	55	33	65	74
20/07/01	29	64	64	58	57	55	34	65	73
21/07/01	30	61	64	58	58	53	32	67	71
22/07/01	30	62	61	61	59	51	32	47	59
23/07/01	32	59	60	57	52	48	32	62	70
24/07/01	31	56	59	58	53	51	30	60	72
25/07/01	31	57	62	63	52	47	30	50	59
26/07/01	29	57	59	57	52	45	31	55	62
27/07/01	29	56	60	54	51	47	28	52	61
28/07/01	30	52	60	54	51	47	30	49	59
29/07/01	29	51	56	52	46	44	30	54	57
30/07/01	29	53	51	54	45	47	31	55	57
31/07/01	30	54	51	53	51	45	35	53	59
01/08/01	28	52	53	53	45	44	28	47	61
02/08/01	29	53	52	51	46	47	28	48	63
03/08/01	28	51	54	53	46	43	28	49	64 Φ
04/08/01	28	53	54	52	45	43	31	48	62
05/08/01	29	53	54	52	48	47	32	40	51
06/08/01	28	54	56	50	44	42	31	41	49
07/08/01	29	52	55	49	42	42	33	38	52
08/08/01	29	51	55	49	43	42	32	38	54
09/08/01	29	47	55	48	42	42	31	38	53
10/08/01	29	51	53	50	44	43	31	37	44
11/08/01	30	50	54	49	42	40	31	43	45

12/08/01	30	52	53	52	40	40	34	44	46
13/08/01	30	51	60	49	41	39	32	44	46
14/08/01	30	53	55	51	40	39	30	35	41
15/08/01	30	51	55	49	38	38	32	31	36
16/08/01	29	50	53	49	39	39	31	33	39
17/08/01	30	51	53	47	37	37	33	34	38 Φ
18/08/01	29	51	53	48	37 Φ	37 Φ	33	35	37
19/08/01	30	50	53	49	39	39	34	35	34
20/08/01	28	50	53	51	50	50	31	33	37 Φ
21/08/01	29	50	52	53	53	55	31	31	35
22/08/01	30	53	53	50	54	52	32	31	34
23/08/01	30	47	52	53	56	55	31	32	37 Φ
24/08/01	30	50	52	52	55	58	33	32	36
25/08/01	31	50	50	54	55	57	32	32	40
26/08/01	30	50	53	54	54	53	31	30	41 Φ
27/08/01	30	48	53	53	52	54	28	30	41
28/08/01	29	48	52	52	53	55	32	31	40
29/08/01	30	48	53	53	55	56	30	31	36 Φ
30/08/01	29	49	50	53	55	54	30	31	32
31/08/01	30	49	48	52	55	51	32	30	32
01/09/01	30	50	48	51	53	49	32	29	32 Φ
02/09/01	30	50	49	53	55	50	33	29	33
03/09/01	30	47	49	49	53	52	31	31	31
04/09/01	30	51	51	48	46	48	31	31	36 Φ
05/09/01	31	48	53	49	50	48	32	31	36
06/09/01	31	48	51	47	47	47	32	30	36
07/09/01	30	47	51	48	48	48	32	32	37
08/09/01	30	46	51	48	48	50	31	34	38
09/09/01	31	46	47	47	47	53	31	32	37
10/09/01	29	47	47	47	46	53	29	33	38
11/09/01	29	44	45	46	43	51	28	33	39
12/09/01	28	45	46	45	44	51	28	30	37
13/09/01	29	48	48	45	46	44 Φ	33	31	36
14/09/01	29	47	47	46	44	41	23	30	32 Φ
15/09/01	29	47	47	46	45	40	28	30	32
16/09/01	29	45	52	46	45	44	30	32	34
17/09/01	29	44	51	46	48	44	31	33	35
18/09/01	29	45	49	47	53	45	31	31	34
19/09/01	29	42	45	47	45	42	31	31	34
20/09/01	28	42	45	46	44	42	32	31	35
21/09/01	29	42	46	45	44	42	32	32	34

22/09/01	29	39	46	44	44	39	32	33	34
23/09/01	28	43	45	42	44	43	31	34	35
24/09/01	28	42	46	45	40	42	31	32	34
25/09/01	28	39	44	43	38	39	32	34	33
26/09/01	29	39	41	40	38	39	29	34	33
27/09/01	28	40	43	39	39	40	29	37	34
28/09/01	28	39	42	38	38	39	27	30	31
29/09/01	28	40	43	37	39	40	29	29	31
30/09/01	28	39	41	36	38	39	33	29	31
01/10/01	28	41	39	37	43	41	29	30	32
02/10/01	29	41	37	37	41	41	30	31	32
03/10/01	29	39	35	36	35	39	31	30	32
04/10/01	29	38	41	39	42	38	32	30	32
05/10/01	29	38	40	38	42	36	27	30	32
06/10/01	28	38	39	37	41	36	28	30	31
07/10/01	29	39	41	39	42	35	35	29	32
08/10/01	29	40	41	40	43	36	31	29	33
09/10/01	29	41	41	41	43	37	34	30	34
10/10/01	29	38	37	40	37	36	32	31	33
11/10/01	29	37	38	39	37	36	31	31, Heap opened for harvesting	32
12/10/01	29	36	40	39	36	36	30		32, Heap opened for harvesting
13/10/01	29	36	40	39	40	37			
14/10/01	29	37	40	37	37	36			
15/10/01	30	38	39	35	35	36			
16/10/01	28	36	40	38	33	52			
17/10/01	29	35	39	38	31	52			
18/10/01	29	35	40	38		49			
19/10/01	29	35	38	37		47			
20/10/01	29	35	38	37		47			
21/10/01	29	36	39	37		46			
22/10/01	29	37	37	37		45			
23/10/01	28	34	35			43			
24/10/01	28	33	33			40			
25/10/01	28	34				39			
26/10/01	29	34				37			
27/10/01	28	32				36			
28/10/01	28	31				33			

Φ: Turnover

Peak temperature details

#	Pile	Peak temperature	
		^0C	Day
	Shafeeq Shameel & Co., Ambur		
1	Pile 1 on gravel	65	9th day
2	Pile 2 on gravel	67	7th day
3	Pile 3 on gravel	63	3rd day
4	Pile 1 on floor	62	3rd day
5	Pile 2 on floor	58	6th day
	MAKH & Sons, Ranipet		
6	On gravel	74	5th day
7	On floor	74	4th day

Dewar flask temperature details during July - August 2001

Heap type	Date		N^{th} day of setting	Temperature, ^0C		
	Start	Final		Min.	Max.	Difference
1. Shafeeq Shameel & Co., Ambur						
Pile 1 on gravel	4-Aug	7-Aug	25	27.2	34.4	7.2
	21-Aug	25-Aug	42	26.8	33.8	7
	8-Sep	11-Sep	60	30.2	33.8	3.6
Pile-2 On gravel	17-Jul	22-Jul	6	26.3	43.4	17.1
	7-Aug	10-Aug	27	28.2	35.5	7.3
	25-Aug	27-Aug	45	28.4	32.7	4.3
	12-Sep	15-Sep	63	26.8	31.6	4.8
Pile-3 On gravel	26-Jul	29-Jul	15	27.5	39.2	11.7
	11-Aug	14-Aug	31	28.7	33.9	5.2
	28-Aug	1-Sep	48	27	33	6
	16-Sep	19-Sep	63	27.8	31.7	3.9
Pile-1 On floor	1-Aug	4-Aug	20	28.3	34.1	5.8
	18-Aug	21-Aug	38	28.4	37.4	9
	4-Sep	7-Sep	55	27.9	35.1	7.2
	22-Sep	25-Sep	73	29.1	31.3	2.2
Pile-2 On floor	29-Jul	1-Aug	17	27.1	34.1	7
	14-Aug	18-Aug	33	28.3	32.2	3.9
	1-Sep	4-Sep	51	29.8	33.2	3.4
	19-Sep	22-Sep	69	29	34.3	5.3

2. MAKH & Sons, Ranipet						
On gravel	23-Aug	26-Aug	41	32.5	36.7	4.2
	27-Aug	30-Aug	45	26.8	33.9	7.1
	31-Aug	4-Sep	49	26	35.5	9.5
	5-Sep	9-Sep	54	26	36.2	10.2
	10-Sep	14-Sep	59	28.3	34.3	6
	15-Sep	18-Sep	64	28.1	33.6	5.5
	19-Sep	23-Sep	68	28.1	32.8	4.7
On floor	25-Sep	29-Sep	73	28.1	35.6	7.5
	1-Oct	6-Oct	79	27.9	32.7	4.8
	9-Oct	13-Oct	87	26	33.3	7.3

Shafeeq Shameel & Co., Ambur

Pile 1 on gravel		
	Compost (after drying, breaking and sieving)	1150 kg
	Coarse material	90 kg
Pile 2 on gravel		
	Compost (after drying, breaking and sieving)	800 kg
	Coarse material	40 kg
	Wood	260 kg
Pile 3 on gravel		
	Compost (after drying, breaking and sieving)	870 kg
	Coarse material	50 kg
Pile 1 on floor		
	Compost (after drying, breaking and sieving)	820 kg
	Coarse material	35 kg
	Wood	260 kg
Pile 2 on floor		
	Compost (after drying, breaking and sieving)	880 kg
	Coarse material	60 kg
		940 kg