COMPOSTING OF TANNERY SLUDGE WITH CHICKEN MANURE AND RICE BRAN

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Abstract

The study was designed to investigate the development of tannery sludge collected from Kenny leather factory in Melaka, Malaysia to compost material. The sludge contained utilizable nutrients and toxic organic compounds which might affect soil processes and plant growth, and pathogens, which might pose a threat to the local environmental communities. Tannery sludge was composted with chicken manure and rice bran for 50 days to reduce pathogens and toxic organic compounds. The compost was characterized by electrolytic conductivity (EC) of 11.6 dS/m, pH 8.11 and C/N ratio of 16.98. The total concentrations of chromium, lead, cadmium, copper, zinc, iron, and sodium as mg/kg dry compost were 30, 3.2, 1.6, 54, 148, 254 and 2,514, respectively. No *Salmonella* sp., *Shigella* sp. or eggs of helminthes were detected in the compost, however, total coliforms decreased by 10^2. The compost characteristics indicated that it was mature, and the germination index for Chinese cabbage is 82.5%, which may suggest the removal of most of the phototoxic compounds.

Keywords: Composting, tannery sludge, pathogens, heavy metals, organic matter changes

Introduction

Many organic waste materials are now being investigated and used as soil amendments in the growth of ornamental and some food crops in many communities. These include composts of yard wastes, sewage sludge, and to lesser extent, municipal solid wastes either singularly or in combination (Goldstein, 1991). There is concern, however, about the presence of toxic metals, polychlorinated biphenyls and asbestos (lisk *et al*., 1992; Manos *et al*., 1992). Another waste material, which is commonly used in organic fertilizers as a source of nitrogen, is tannery sludge, a by-product of leather manufacturing. Basically, three types of by-products are produced: solid wastes from splitting and trimming hides; sludge from liming, dehairing, pickling, and chrome tanning; and liquid wastes from each step in the operation (Hughes, 1988).

Chromium is both a toxic and essential element for humans (Anderson, 1981) and has long been used in the tanning of leather (Riegel, 1949). The resultant fertilizer products may contain extremely high concentrations of the metals. Apart from organic material, which

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releases valuable nutrients on decomposition, tannery sludge may contain pathogens and toxic organic components, which pose a serious threat to the environment.

Aerobic (composting) or anaerobic (fermentation, biogas digestion) treatments can be applied to reduce pathogens and reduce toxic organic compounds. Composting which is a biological aerobic decomposition in which labile organic matter is degraded to carbon dioxide (CO_2), water vapor, ammonia (NH_3), inorganic nutrients and stable organic material containing humic-like substances (Senesi, 1989). This phenomenon has been updated to process organic wastes of different origins, such as sewage sludge, animal manure, agro-industrial wastes (Paredes *et al*., 1996; Bernal *et al*., 1998). Compost, the generated product, can subsequently be applied to soil to increase soil organic matter content, which will release nutrients upon decomposition, and improve soil structure and cation exchange capacity.

The objective of this study was to compost tannery sludge with rice bran, chicken manure and sawdust to reduce pathogens and toxic organic components, so that the disposal of tannery sludge into the landfill can be limited while generating a product that can be used to improve soil fertility.

Materials and Methods

The dried tannery sludge used in this study was collected from Kenny leather Sdn Bhd in Melaka, Malaysia, as it is the most abundant type of tannery waste produced in Malaysia.Tables 1 and 2 show the analysis of sludge for its physical and chemical properties.

Composting

A windrow type of compost was used and consisted of approximately 200 kg of material with ratio of 5:2:2:1 of sludge, sawdust, chicken manure, and rice bran, respectively, and the initial moisture content of the stockpile was 61.6%. The composting cycle lasted for seven weeks. The stockpiles were turned daily to maintain adequate aeration and to prevent odors. Subsequently, samples were then systematically taken at the end of each week of the composting process. Each sample was air-dried for a period of ten days. The dried sample was ground down into a fine powder.

Chemical and Microbial Analyses

A 0.5 g of dried sample was transferred to the digestion flask, and then 5 ml conc. H_2SO_4 acid and 20 ml of 50% H_2O_2 were added to digested flask on a hot plate for 12 min, after cooling, the digested samples were diluted with distilled water to 100 ml (Stilwell and Graetz, 2001). The digested samples were then analyzed for measurement of total Cr, Pb, Cu, Mn, Zn, Fe, and Cd by flame atomic absorption spectrometer (Varian Spectra AA220 Fast Sequential) (USEPA, 1998 method 3051).

Table 1. Physical properties of the tannery sludge used in this study.

Parameters	Sludge (S)	Typical soil*
Bulk density (g/cm^3)	0.14	1.3
Total pore space	94.72	-
Available water	8.93	5.3
Water retention at pressure (kPa) (%w/w, dry basis):		
0	153.41	33.40
1	117.50	32.20
10	89.50	22.80
33	78.50	21.20
1,500	69.57	15.90

*Mokhtaruddin *et al*. (2001)

Table 2. Chemical composition of the tannery sludge used in this study.

Parameter	Sludge	Sawdust	Chicken manure	Rice bran	Typical soil*
Organic-C (%)	20.03	57	30.4	49.33	3.9
Nitrogen (N) (%)	0.99	0.3	4	1.1	0.4
C/N	20.02	190	7.6	45.72	9.75
Potassium (%)	0.42	0.02	1.23	0.99	0.4 - 3
Phosphorus (%)	0.10	1.17	3.02	0.23	0.05 - 0.2
Calcium (%)	7.7	0.02	1.99	0.30	0.7 - 50
Magnesium (ppm)	1,190	0.004	1.05	236.33	0.06 - 6
Iron (ppm)	1,062	402	1,738	142.33	55
Sodium (ppm)	1,006	64	123	98	3
Heavy metals					
Chromium (ppm)	1,404	14.6	16.6	6.3	100
Lead (ppm)	93	16	1.3	1.2	15
Cadmium (ppm)	3.23	6.5	0.5	0.2	0.5
Copper (ppm)	41.4	4.8	329.67	24.33	20
Zinc (ppm)	44.67	8.2	634.67	127	50
Manganese (ppm)	70	4.6	34	24	850

*Mokhtaruddin *et al*. (2001)

The sludge, compost, and chicken manure were analyzed for total and faecal Coliform, *Salmonella* spp., *Shigella* spp. and for eggs of helminthes (USEPA, 1999). A serial dilution technique was used to determine the *Salmonella* spp., and *Shigella* spp. A sub-sample of 10 g biosolid was added to 90 ml sterile buffered peptone solution using an aseptic technique and 10^{-1}, 10^{-2} and 10^{-3} dilutions were made using sterile 0.8% NaCl solutions. A 0.1 ml aliquot was plated on two selective media *Salmonella* and *Shigella* agar and sulfite bismute-agar. The second media is highly specific for *Salmonella*. The colonies were identified by form and color (USEPA, 1999).

Germination Index

The germination index was used to determine the inhibitory potentials of water extract. Seed germination test was carried out with Chinese cabbage using substrate extract. Two g of oven-dried compost was placed in test tube with screw cap and 20 ml of distilled water was added, then the tube was placed on electric rotator at 125 rpm for 1 h. The supernatant was decanted and centrifuged at 10,000 rpm for 10 min and filtered through Whatman paper. Two ml of filtrate was diluted with one ml of distilled water and sprayed over a sheet of filter paper kept inside the Petri dish. Ten seeds of Chinese cabbage were then placed on the filter paper, another filter paper was moisten with 3 ml distilled water and 10 seeds and was used as a control. The percentage of germination was measured after incubating the covered Petri dishes in the dark at 28°C for 4 days (Matheur *et al*., 1993a, b).

Results and Discussions

Characterization of Tannery Sludge

The results of sludge characterization are presented in Table 2. Data for typical soil sample was included for the comparison purposes. The sludge showed low C/N ratio (20.03) and high nitrogen content (0.99). Apart from the plant nutrient, the heavy metal analyses of the sludge showed high amount of trace elements especially chromium, cadmium, sodium and lead, thus might have a negative impact on plant growth. The level of chromium was very high (1,404 mg/l) and above the permissible level which should be available in the soil (100 mg/kg) (Chaney and Ryan, 1993; Chaney, 1990). Alloway (1990) reported that due to the low solubility of chromium, only a little (Cr) is bioavailable. This means that even when crops are grown on soils treated with sludge relatively high in Cr, phytotoxicity is rarely observed. The lead content is high in sludge (93 mg/l), when compared with the maximum level of lead content in the soil 15 mg/l (Chaney and Ryan, 1993; Chaney, 1990).

The concentration level of the cadmium, copper, iron, manganese and zinc in the sludge was 3.23, 41.4, 1,062, 70, and 44.67 mg/l respectively (Table 1). This result indicates that the sludge from tannery is on the acceptable concentration level except for chromium, cadmium and lead.

The tannery sludge was alkali in nature (pH 7.36). More than 83% of the sludge was fraction < 50 μ and its equivalent texture is silty clay. The wet bulk density was close to that of mineral soil but when dry it is relatively light with bulk density equal to 0.14 g/cm.

The sludge was characterized by being rich in organic matter. However the nitrogen content is twice as high as the typical soil. It also has a high content of Sodium and Calcium.

The water holding capacity, bulk density, and pore space of the sludge were high when compared with the typical soils which have low ability to keep water for a long time in spite of their low bulk density and total pore space (Table 1).

Formulation and Production of Compost

Figure 1 shows the temperature variation profile with time for compost development. It was characterized by increasing temperature up to 57.5°C, and then decreasing it to 30°C, which indicated the end of the composting process. It was found that tannery sludge compost was able to reach high thermophilic temperature due to its high content of nutrient from organic materials. To maintain high temperature within the windrow, the compost heap should be large enough to allow heat generated by metabolic processes to exceed the heat loss at the exposed surfaces. Heap or pile width is normally between 3 - 4 meters, whereas the height can be up to 1.2 - 1.5 meter (Eweis *et al*., 1998).

Trends of pH profiles started with a low pH and increased, fluctuated, and then showed slight drop at the end of the process (Figure 2). The rate of decomposition during composting increases with increasing pH in the range of 6 - 9. During composting, pH change is predictable. Fermentation-caused oxygen limitation can slightly drop pH early in the processing. With a rapid early activity, pH can rise up to approximately 8.5 because of ammonification. At the completion of ammonification, pH will decrease to about 7.5 - 8 (Miller, 1993).

The compost C/N ratio dropped from 25 in the first day to around 16.98 after 50 days of the composting thus showing a declining pattern from the start of composting until the 50th day (Figure 3); this declining was due to the formation and loss of CO_2. A portion of the biodegradable carbon in the composting material is assimilated by the microbes and converted to microbial protoplasm, while the remainder is oxidized to CO_2 by the microorganisms to meet their physical energy needs. The CO_2 diffuse into the surrounding air and thus the carbon content of the composting mass is lowered (Golueke, 1973).

The electrolytic conductivity (EC) in the compost was 11.5 dS/m and was higher than the EC of 4.8 dS/m obtained by Van Heerden *et al*. (2002) in citrus supplement with calcium hydroxide composted for two months.

The high EC, however, appeared not to have affected the microbial activity during composting, as witnessed by the production of CO_2. Large EC in compost might lyse microbial cells (Brock *et al*., 1994). Santamaria-Romero and Ferrera-Cerrato (2001) reported that salt concentration above 8 dS/m negatively affected the microorganism populations as well as biotransformation of organic matter.

The high temperature (57.5°C) reached during the composting, was enough to reduce the pathogens, as no facial coliforms, nor

Salmonella sp., *Shigella* sp. and eggs of helminthes were detected while total coliforms decreased sharply (Table 3).

Deportes *et al*. (1998) studied the disinfection of municipal solid waste through composting and found that the concentration of faecal coliforms reduced while *Salmonella* sp. and *Ascaris* eggs were reduced in concentration to below the detection limits before the 27th day of composting.

Aqueous compost extracts had a germination index of 82.5%. The germination index value above 50% indicate that the maturity was sufficient (Zucconi *et al*., 1981a; Zucconi *et al*., b; Iglesias-Jimenez and Perez-Garcia, 1989; Mathur *et al*., 1993a, b) and phytotoxic compounds such as acetic, propionic, butyric and iosbutyric acid might have not been metabolized inhibiting the germination (Epstein, 1997).

Analysis of Composting Material

An analysis of the nutrients in the tannery sludge compost was shown in Table 4. The values for N, P, and K were 1.33, 0.79, and 1.42%

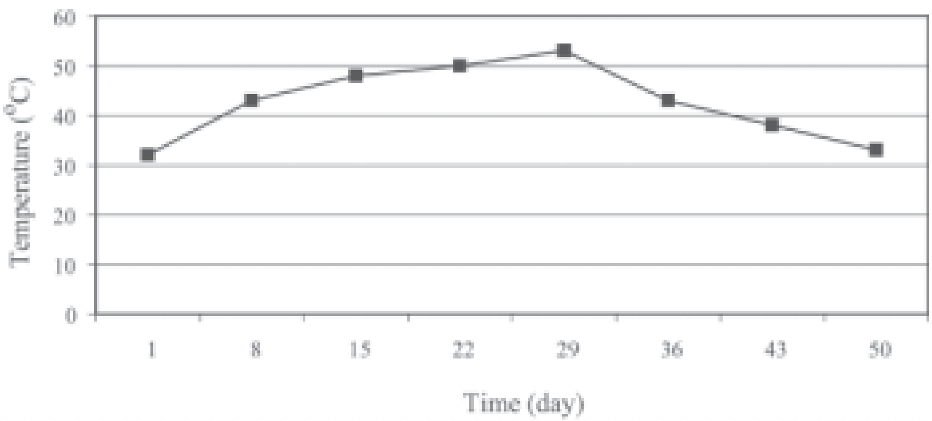

Figure 1. Temperature profile throughout the composting process.

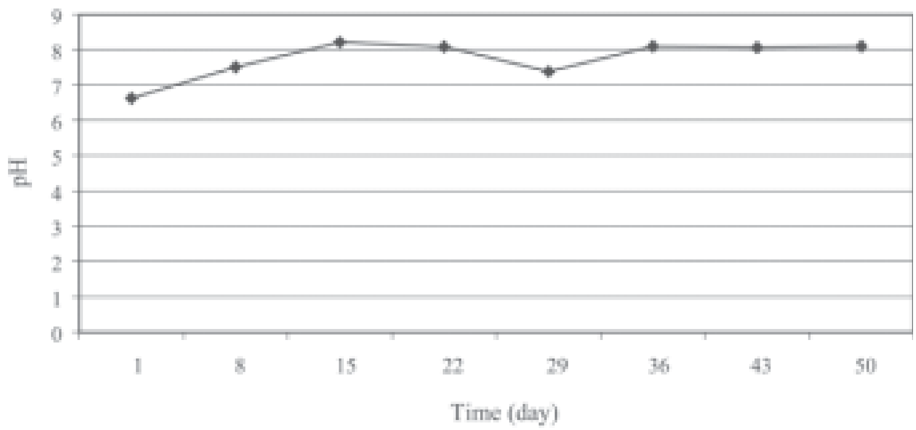

Figure 2. Change in pH during the composting process.

respectively, and varying proportion of these elements in the compost is in the organic forms, which are less available to plants (He *et al*., 2000).

Calcium concentration in the compost was high and above the permissible level. However, the calcium deficiency can be a problem for acid soils, and crop quality is usually affected if calcium is not sufficient. Therefore, for acid soils, especially acid, sandy soils, compost can increase calcium availability for crop growth.

Total concentrations of heavy metals in the compost were all well below the upper limits for biosolids classifying them as excellent (USEPA, 1995) (Table 4). The lower concentrations of heavy metals in the compost compared with those in the tannery sludge was mainly due to dilution as sawdust and chicken manure were added, although losses through drainage cannot be excluded.

Conclusions

The study concluded that the starting concentrations of chromium, cadmium, lead, have decreased significantly as the composting progressed, whilst concentration of copper and zinc were observed to reduce slightly. Total concentrations of heavy metals in the compost complied with the standard of USEPA guide, 1995 making the compost suitable for use as a fertilizer and soil conditioner. The composting

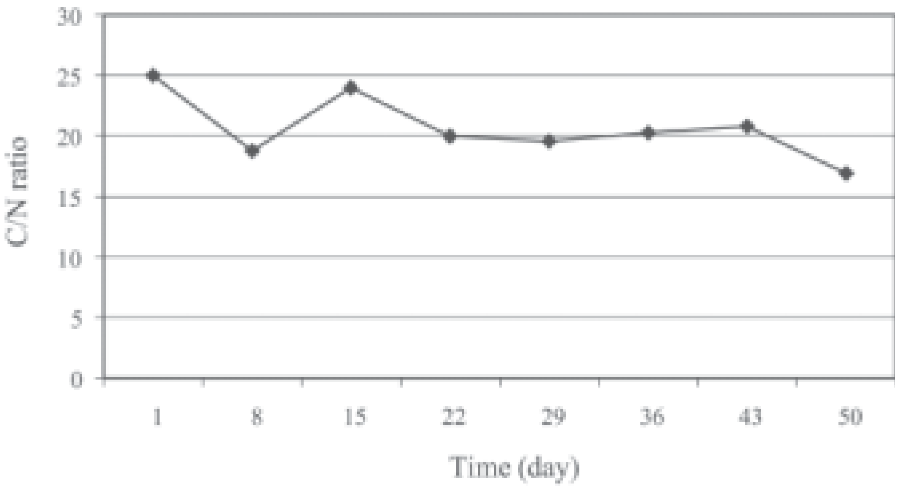

Figure 3. C/N ratio of compost mixture during composting process.

Table 3. Pathogens in the tannery sludge, chicken manure, compost, and maximum allowed limits as stipulated by USEPA (1999).

Microorganism	Tannery sludge	Chicken manure	Compost	USEPA Limits
Total coliforms	2×10^6	2×10^5	2×10^3	NM
Faecal coliforms	< 10	< 10	< 10	$< 10^3$
Salmonella sp.	ND	ND	ND	NM
Shigella sp.	ND	ND	ND	< 3
Helminthes eggs	ND	ND	ND	$< 10 \times 10^3$

NM: not mentioned in USEPA norms (1995) for biosolids
ND: not detectable

Table 4. Heavy metals concentration in tannery sludge and compost, and the maximum allowable limits as described by USEPA (1995).

Trace element	Tannery sludge (ppm)	Tannery sludge compost (ppm)	USEPA limits, 1995 (ppm)
Nitrogen	49.98	66.60	NM
Phosphors	4.86	39.50	2.7 - 400
Potassium	20.74	70.99	2.0 - 1,600
Chromium	1,404	30	1,200
Lead	93	3.2	300
Cadmium	3.23	1.6	39
Copper	41.4	54	1,500
Iron	1,062	254	5,000
Zinc	44.67	148	2,800
Magnesium	1,190	1,820	530
Calcium	77,000	69,840	30,000
Sodium	1,006	2,514	NM

NM: Not mentioned in USEPA (1995) for biosolids

process reduced pathogens and eggs of helminthes thus producing stable and mature compost, and the germination index of Chinese cabbage significantly encouraged the utilization of the compost.

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