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Assessment of Applicability of Leather Industry Wastewater Sludge Compost in Sudan

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Abstract

This study was designated to utilize chromium rich leather industry wastewater sludge through composting, so heavy metals can be leached out or collected to the surrounding which is not determined yet in the Sudan. The role of this research work is to find out the suitability of leather industry wastewater sludge compost in terms of pH, organic matter, total Nitrogen, Phosphorous, Potassium and calcium, and the extent of bioavailability of heavy metals. The sludge was blended with chicken manure (organic waste), rice bran, and saw dust at different ratio for composting through preparing composting block shaped piles. Results show that the organic content was dropped from 30 to 25% for the suggested block shaped piles, pH value and NPK content was in satisfactory level for composting. Total heavy metals (Cr, Cd, Cu, Pb, Mn, &Zn) content were all far below the standard value of the upper limits for biosolids classifying them as excellent. No Salmonella sp., Shigella sp. or eggs of helminthes were detected in the compost, however, total coliforms decreased by 10^3 . The compost characteristics indicated that it was mature, and the germination index for cabbage seeds is 85.5%, which may suggest the removal of most of the phototoxic compounds.

Keyword:

Heavy metals, Beneficial organism, leather industry, Compost, Organic matter, Sludge,

1. Introduction

Different types of wastes (organic) are now being explored and used as soil improver for growing of different kinds of plants species (Ornamental, food crops, and forest crops). These include composts of yard wastes, sewage sludge [1]. There is worry, however, about the existence of noxious metallic element like polychlorinated compounds [2,3]. One of the organic fertilizers which used as nitrogen source is leather industry wastewater 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 [4,5]. Owing to the nature of leather industry wastewater sludge there is no certain universal utilization process for sludge management in the world. Different solutions have been planned, verified, practiced, & applied for semi-pilot, pilot, & industrial scale. Effective stabilization of leather industry wastewater sludge in building materials (bricks concrete, tiles, ceramic), and some other engineering purposes had been confirmed by some previous studies [6,7,8], but no one process mentioned previously have been suited and developed at certain level that can meet the industrial need. Furthermore, treatment processes of this hazardous tannery sludge are still need more attention [9].

Composting has been considered as one of the alternative methods to convert organic wastes into products that benefit plant growth and soil amendment. The major goal of composting is to provide a stable compost product that contains sufficient nutrients to be consumed by the plant and also can increase soil fertility. Two of the main components of agro-based biomass, i.e., cellulose and lignin, have been described as main sources of energy and humus formation, respectively, and their characteristics also contribute to air permeability, bulking, and water retention throughout the composting process [10]. Although considerable research on composting has been conducted using various organic wastes [11,12,13,14], there is less information regarding leather industry wastewater sludge composting at the field scale of operation. Therefore, the goals of this study is to investigate the physical and chemical characteristics & microbial succession of prominent microbes during composting process of leather industry wastewater sludge with chicken manure and rice bran with aim of assessing the role of chicken manure in improving the degree of degradation and the quality of the end product.

2. Material and Methods

2.1 Preparation of Raw Materials

The composting of leather industry wastewater sludge was performed at the composting site in the Khartoum tannery- Khartoum-Sudan. Brick blocks with dimension at 2.0 m length, 2.0 m width, and 2.0 m height were used for the composting treatment under the shade and cement base. Fresh leather industry wastewater sludge was collected from closed anaerobic digesting tank system located at Khartoum tannery wastewater treatment plant -Khartoum-Sudan. Then, the dried leather industry wastewater sludge was further ground by conventional mill machine at the same place to obtain small sizes.

2.2 Composting Process

Composting block was used and consisted of approximately 400 kg of composting materials with a ratio of 6:3:2:1 of leather industry wastewater sludge, Rice bran, Chicken manure, and Saw dust respectively. The anaerobic tannery sludge, which consists of beneficial microorganism for composting, was sprayed to the composting pile every four days intervals using a centrifugal pump. After anaerobic tannery sludge was added, then the composting material (The stockpiles) was turned manually to provide sufficient aeration and to ensure good mixing of the added materials. The addition of anaerobic tannery sludge was stopped seven days before maturity stage of the compost and followed by frequent turning. Subsequently, samples were then systematically taken at the end of each week of the composting process, air-dried for 10 days, then ground down into a fine powder. The maturity stage of the compost was determined every four days by C/N ratio analysis using CNHS 2000 analyzer (Leeco, USA).

2.3 Sampling and Analysis Techniques

Temperature was analyzed using a Digital Temperature probe meter, Demista Instrument, (CM2006, USA). pH was analyzed using pH meter, (Mettler Toledo, USA). Electrical conductivity was determined on water sample (10 g/15 ml) using conductivity device (EQ-614-A) [15]. These analyses were performed throughout the composting process. Organic carbon, total nitrogen, and heavy metal elements in the composting material were determined using CNHS 2000 analyzer (Leeco, USA) and Inductively Coupled Plasma (ICP)-OES (Perkin Elmer, USA). Ammonium acetate procedure was used to determine the total content of Calcium, Sodium, Potassium, and Magnesium. Phosphorus, Manganese, and iron were determined after ashing, and measured calorimetrically in the extracts using atomic absorption and flame photometry [16].

2.4. Statistical analysis

ANOVA method of one way have been used to estimate differences among several mixtures. Pearson's correlation coefficient was used to evaluate the relation between different concentrations and chemical parameters. running statistical analysis was done by SPSS program.

3. Results and Discussions

3.1 Properties of Raw Materials

The tannery sludge was alkali in nature (pH 7.450±0.04). 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 (Table 1). The sludge was characterized by being rich in organic matter. However, calcium, sodium, and nitrogen content are twice as high as the typical soil. 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).

Table 1. Physical properties of leather industry wastewater sludge used in this study

Parameters	Sludge (S)	Typical soil
Available water	8.93	5.3
Bulk density (g/cm^3)	0.14	1.3
Total pore space	94	-
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
1500	69.57	15.90

Table 2 showed significant difference ($p < 0.01$) in the physical & chemical properties of the various samples which used in this research study. pH showed noticeable improvement ($p < 0.05$) and well correlation ($r = 0.93$) with cumulative concentration of the tannery sludge. Leather industry wastewater sludge characterization are presented in Table 2. The sludge displayed a low pattern of C/N ratio (38.12) and high nitrogen content (0.80). on other hand, the Leather industry wastewater sludge exhibited high content of heavy metals especially Cr, Cd, & Pb, thus might have a bad influences on growing of plant. The Cr level was very high (1550±2.9 mg/l) and overhead the permissible level which should be available in the soil (100 mg/kg) [17,18]. The Cr low solubility allowed only a small amount of Cr bioavailable [19]. This means that even when crops are grown on soils treated with sludge relatively high in chromium, phytotoxicity is rarely observed. Leather industry wastewater sludge exhibit high pattern of (Pb) content (95.0±3.90 mg/l), when compared with the maximum level of (Pb) in the soil 15 mg/l [17,18]. Cadmium, Copper, Iron, Manganese, and Zinc displayed a mode of pattern such as 3.4±1.03, 39.6±1.05, 750.0±8.90, 40.6±2.03, and 42.4±4.30 ppm respectively (Table 2). This result indicates that the leather industry wastewater sludge is on the satisfactory concentration except for Cr, Cd, & Pb (Table 2).

Table 2. Physico-chemical composition of the raw materials used in this study (mean±SE)

Parameters	**Tannery Sludge**	**Chicken Manure**	**Rice bran**	**Sawdust**
Organic Carbon, %	30.5±0.56	25.5±0.75	40.35	50.46±5.01
Total Nitrogen, %	0.80±0.01	3.0±0.08	1.30	0.9±0.01
Potassium, %	0.48±0.90	1.8±0.05	1.50	0.08±0.03
Phosphorus, %	0.40±0.01	2.55±0.03	0.50	0.25±0.01
Calcium, %	5.50±1.30	1.45±0.04	1.00	0.05±0.01
Magnesium (ppm)	890±10.90	265±5.9	240.20	0.02±0.01
Iron (ppm)	750.0±8.90	950±8.5	200.30	350.46±7.1
Sodium (ppm)	450.0±5.50	85.0±2.9	90.80	65.0±3.9
C/N ratio	38.125±5.35	8.50±1.7	31.04	56.06±0.61
pH	7.450±0.04	7.25±0.07	8.45	8.25±0.07
EC (mS/cm)	3.68±0.05	5.35±0.20	6.45	1.35±0.20
Heavy Metals (ppm)				
Chromium (ppm)	1550±2.9	16.6±2.9	7.5	12.8±1.9
Cadmium (ppm)	3.4±1.03	0.7±0.01	0.3	5.4±0.3
Copper (ppm)	39.6±1.05	125.8±4.9	35.44	4.6±0.5
Manganese (ppm)	40.6±2.03	25.65±1.08	35.40	5.6±1.9
Lead (ppm)	95.0±3.90	1.45±0.06	1.3	16.4±2.3
Zinc (ppm)	42.4±4.30	123.6±4.9	130	8.8±1.3

SE= standard error

During composting process changing of color and texture of the compost were noticed. The final compost (matured) was grayish in color, having a texture and earthy small near to that of normal. The investigation of results shown in Table 2 revealed that saw dust could be used as a carbon source. Chicken manure used in this study had high nitrogen, potassium, and phosphorus content, and the results were almost the same as reported by other researchers [11,12]. According to Hock et al. [12], the addition of Chicken manure (Sources of nitrogen) to leather industry wastewater sludge compost would enrich and accelerate the composting process due to addition of nitrogen source and microbial seeding.

3.2 Assessment of Compost Nutrient Materials

Leather industry wastewater sludge compost analysis was shown in Table 3. The values for N, P, and K were 98.60±8.9, 93.50±7., and 1,520±6.7 ppm respectively, and various amount of these nutrient elements in the compost are not available to flora because it is in the form of organic [20]. Calcium concentration in the compost (69,840±15.7) was high and above the permissible level (30,000). However, acid soils are affected by calcium deficiency, thus the quality of crop is affected if calcium is not enough. Therefore, compost ought to increase calcium availability for crop growth in acid, sandy soils. Compost heavy metals content were all fine underneath the restriction boundary for brilliant biomaterials categorization (Table 3) [21]. Dilution and losses through drainage are considered the main parameters justified the minor content of heavy metals in the compost related with those in the leather industry wastewater sludge as sawdust and chicken manure were added.

Table 3. Concentration of heavy metals in leather industry wastewater sludge, compost, and the maximum allowable limits as described by USEPA [21]

Trace element	Tannery sludge (ppm)	Tannery sludge compost (ppm)	USEPA limits,1995 (ppm)
Total Nitrogen, %	66.58 ±2.9	98.60±8.9	NM
Potassium, %	30.74 ±3.3	80.99 ±5.4	2.0 - 1,600
Phosphorus, %	8.46±1.7	93.50±7.9	2.7 - 400
Calcium, %	77,000 ±10.7	69,840±15.7	30,000
Magnesium (ppm)	1,160±7.7	1,520±6.7	530
Iron (ppm)	1,062±7.4	254±6.7	5,000
Sodium (ppm)	1,006 ±8.7	2,514±11.7	NM
C/N ratio	38.125±50.35	25.234±5.35	15-25
pH	7.450±0.04	8.450±0.06	NM
EC (mS/cm)	3.6	9.5	4.8
Heavy Metals (ppm)			
Chromium (ppm)	1550±2.9	80±2.7	1,200
Cadmium (ppm)	3.4±1.03	1.6±0.03	39
Copper (ppm)	39.6±1.05	54 ±1.7	1,500
Manganese (ppm)	40.6±2.03	20±2.03	NM
Lead (ppm)	95.0±3.90	3.2±0.7	300
Zinc (ppm)	42.4±4.30	148±0.7	2,800

3.2 Characteristics of Final Compost

pH profiles Pattern started with a low pH and increased, fluctuated, and then showed slight drop at the end of the course (Figure 1). The rate of decomposition during composting increases with increasing pH in the range of 6.25 – 8.5. 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 8.4 because of ammonification. At the completion of ammonification, pH will decrease to about 7.5 – 7.8 [22].

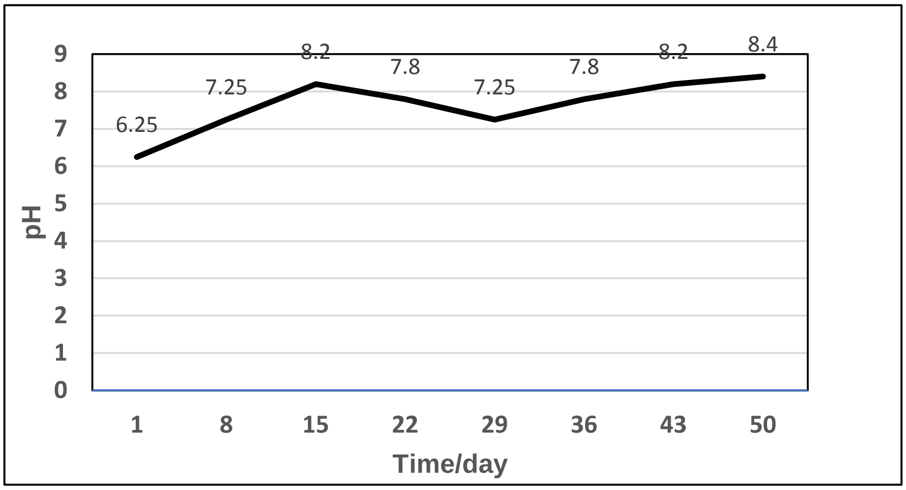

Figure 1. Pattern of pH during the composting process.

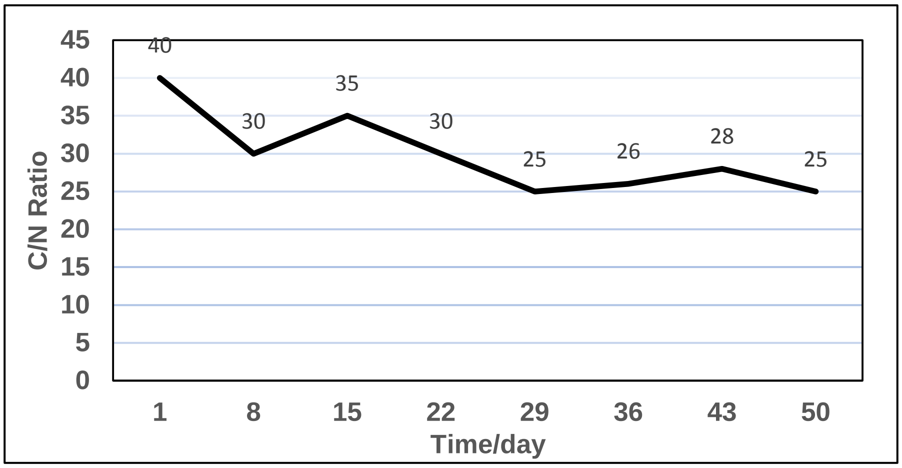

Figure 2. Variation of C/N ratio during composting process

Carbon -nitrogen ratio of the compost was fell from 40 in the day one to around 25 after day fifty of the composting thus showing a reduction pattern from the start of composting until the 50th day (Figure 2); this declining was due to the formation and loss of carbon dioxide. 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 carbon dioxide by the beneficial organisms to meet their physical energy needs. The carbon dioxide diffuses into the surrounding air and thus the carbon content of the composting mass is lowered [23].

Electrical conductivity exhibits obvious rise ($p < 0.05$) and increasingly correlation ($r = 0.97$) with cumulative concentration of the leather industry wastewater sludge. The increasing pattern was in the range of 48.5– 73.3% in different samples. Electrical conductivity (EC) was 9.5 mS/cm and it was higher than the electrical conductivity of 4.8 mS/cm obtained by Van Heerden et al. [24] (Figure 3) in citrus supplement with calcium hydroxide composted for two months. The high electrical conductivity, however, might not to have influenced the activity of the microbes while the process in progress, as observed by the creation of carbon dioxide. High electrolytic conductivity in compost might cause by microbial cells [25]. One research study reported that salt concentration above 8 mS/cm negatively affected the microorganism populations as well as biotransformation of organic matter [26].

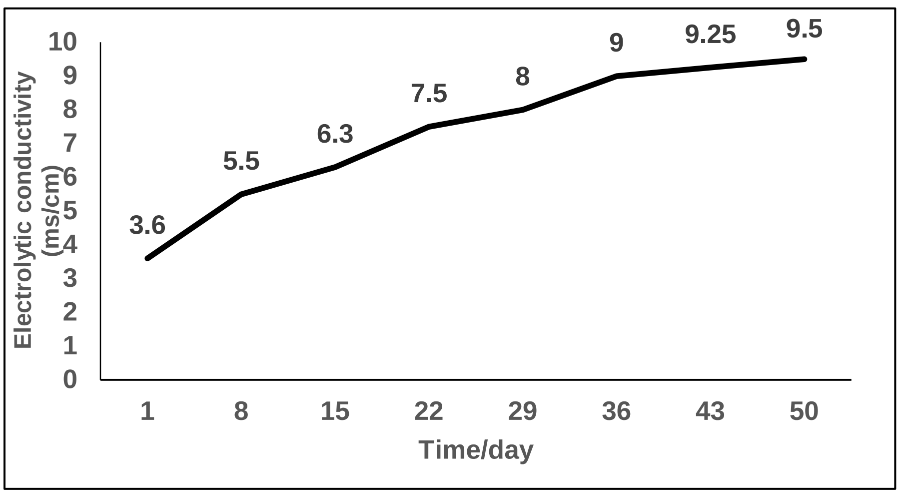

Figure 3. Electrical conductivity (EC) during composting process

Compost temperature profile displayed increasing pattern up to 53.5°C, and then declining to 35°C, which designated the termination of the course of the compost (Figure 4). Previous studies reported that leather industry wastewater sludge compost was able to approach high thermophilic temperature owing to its high content of organic materials. To keep high temperature within the composting block, the compost content should be big enough to allow heat generated by metabolic processes to exceed the heat loss at the exposed surfaces. Composting block width is normally between 5 - 8 meters, whereas the height can be up to 2 – 2.5 meter. The high temperature (55.5°C) reached during the composting process, was enough to reduce the beneficial organisms, as total coliforms reduced hardly, while no Shigella sp., nor Salmonella sp., eggs of helminthes, and facial coliforms were detected (Table 4). Some researcher reports reflect the decontamination of solid waste of sewage industry through the process of compost and discovered that the content of beneficial organism was declined to below the recognition limits before the 27th day of composting [27].

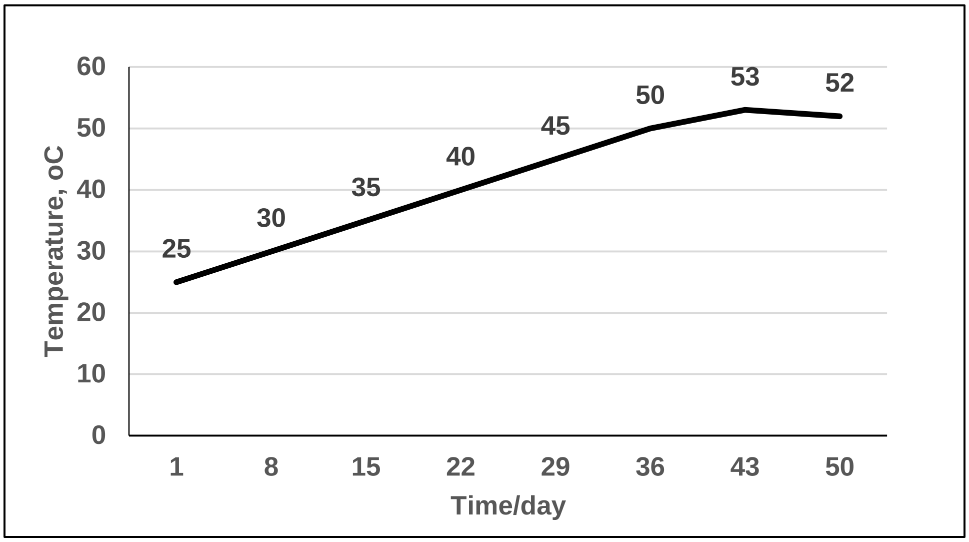

Figure 4. Temperature Variation of throughout composting process

Table 4. Beneficial organism in the tannery sludge, chicken manure, compost, and maximum allowed limits as stipulated by USEPA [28].

Microorganism	Tannery sludge	Chicken manure	Compost	USEPA Limits
Faecal coliforms	< 10	< 10	< 10	$< 10^5$
Total coliforms	2×10^7	2×10^6	2×10^4	NM
Helminthes eggs	ND	ND	ND	$< 10 \times 10^4$
Shigella sp.	ND	ND	ND	< 5
Salmonella sp.	ND	ND	ND	NM

3.4 Assessment of compost toxicity:

The compost toxicity was carried out by using an aqueous compost extract, it was found that the germination index of compost was 85.5%. It is well known that the value higher than 50% of germination index designate satisfactory of maturity stage [29,30,31,32,33] (Zucconi et al., 1981a; Zucconi et al.,b; Mathur et al., 1993a, b; Iglesias-Jimenez and Perez-Garcia, 1989) and phytotoxic compounds such as acetic, propionic, butyric and iosbutyric acid might have not been metabolized inhibiting the germination [34].

4. Conclusion

leather industry wastewater sludge was blended with chicken manure (organic waste), rice bran, and saw dust to improve its content and reduced its phytotoxicity. The composting 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. Total concentration of heavy metals still within the allowable boundary and conformed with the standard of USEPA guide, 1995 making the compost suitable for use as a fertilizer and soil conditioner.

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