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Remediation of leather industry wastewater sludge through eco-friendly technology employing beneficial organisms

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Abstract

This current research work reflects the role of beneficial organism in altering leather industry wastewater sludge into a precious product using chicken manure. leather industry wastewater sludge was lethal to beneficial organism; thus, it was assorted with chicken manure in various ratios viz. (SL0) 0:100, (SL15) 15:85, (SL25) 25:75, (SL50) 50:50, (SL75) 75:25 on dry weight basis. The high stockpile and lower mortality of beneficial organism (earthworm & microorganism) was in (SL0) feed mixture. Carbon nitrogen ratio, EC, and organic carbon were declined in the following pattern 30.87-38.32%, 46.35-73.3%, and 25.85-15.84%, respectively. On the other hand, pH, total Kjeldahl Nitrogen, potassium, Calcium, phosphorus, and sodium were increased from initial in the range of pH (3.45-12.8%), 7.14–64%, 8.1-43.64%, 17.24–76.92%, 10.19–46.87% & 25-68.75%, respectively. Total concentration of heavy metals raised pointedly and within the allowable boundary. Therefore, results designated that remediation of tannery sludge through eco-friendly technology using beneficial organisms is acceptable for altering this leather industry wastewater sludge into valuable manure product.

Keyword: Beneficial organism; Leather industry; Compost; Wastewater; Sludge

1. Introduction

There are many tanneries adopted all over Sudan. Khartoum and Gazira are the regions that have the major tanneries. Almost 85% are cottage and small-scale sectors. Tannery industries generates large quantity of contaminated effluents that usually discharged to surface water bodies and spring water aquifers [1]. The effluent generates approximately 200.000 tons of solids (Raw hide and skin trimmings). Away from respected organic substances which produce precious nutrients on degradation, leather industry waste may contain chrome and noxious organic compounds, which is risky to the environment [2,3]. Therefore, the appropriate discharging of tannery wastes has become significant matter for keeping safe atmosphere. In most of Sudan areas, public authorities lack proper strategies, substructure and economic resources for planned and sustainable for management of solid waste. As consequence, open dumping (96%) represents the principal method of disposal and the other few percentages is sent for composting (4%). Composting using beneficial organisms is well-thought-out as a possible choice in the integration of management of solid waste. However, the quality of the end product and the time of processing differ and depending on the structure of the feeding samples that treated [4]. Below are some examples of industrial wastes which have been composted and converted into valuable product include tannery industry [5], sewage sludge [6], and agro-industrial sludge [7].

In the current research, tannery sludge was mixed with chicken manure in different mixture ratios with aim of assessing the role of chicken manure in improving the degree of degradation and the quality of the end product.

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2. Material and methods

2.1. Preparation of Raw Materials

Beneficial organisms (earthworm & microorganism) were prepared from the stock culture unit, Dept. of Biosciences, Agriculture Research Institute, Khartoum North, Sudan. Chicken manure was brought from chicken farmhouse in the mentioned institute, then was air-dried for two days. The leather industry wastewater sludge used in this study was collected from common effluent treatment plant (ETP) Khartoum Tannery, Khartoum State, Sudan. The collected sludge waste with 75% moisture content, was crushed into fine units to ready for degradation by beneficial organism. Table 1 shows some chemical and physical properties of the raw materials used in this study.

Table 1 Physico-chemical composition of the raw materials used in this study (mean±SE)

Parameters	Tannery Sludge	Chicken Manure
Organic Carbon, %	30.5±0.56	25.5±0.75
Total Nitrogen, %	0.20±0.01	3.0±0.08
Potassium, %	0.48±0.90	1.8±0.05
Phosphorus, %	0.40±0.01	2.55±0.03
Calcium, %	5.50±1.30	1.45±0.04
Magnesium (ppm)	890±10.90	265±5.9
Iron (ppm)	750.0±8.90	950±8.5
Sodium (ppm)	450.0±5.50	85.0±2.9
C/N ratio	152.5±0.35	8.50±1.7
pH	7.450±0.04	7.25±0.07
EC (mS/cm)	3.68±0.05	5.35±0.20
Heavy Metals (ppm)		
Chromium (ppm)	1550±2.9	16.6±2.9
Cadmium (ppm)	3.4±1.03	0.7±0.01
Copper (ppm)	39.6±1.05	125.8±4.9
Manganese (ppm)	40.6±2.03	25.65±1.08
Lead (ppm)	95.0±3.90	1.45±0.06
Zinc (ppm)	42.4±4.30	123.6±4.9

SE= standard error

2.2. Experimental design

A tray (1 kg) made of plastic with dimensions 50 x 30 cm were filled with materials comprising dissimilar ratios of leather industry wastewater sludge and chicken manure as follows: (SL0) 0:100, (SL15) 15:85, (SL25) 25:75, (SL50) 50:50, (SL75) 75:25 on dry weight basis. A fiber substance was used to cover the trays and reserved in a shelter in the experimental plot of Agriculture Research Institute, Khartoum North, Sudan. The samples were turned daily to keep suitable ventilation and to avoid bad smells for four weeks, then augmented with the beneficial organisms (earthworm & microorganism) in each tray. 65–75% moisture content was maintained throughout the study. At the end of the samples was filtered, air dried and kept in laboratory containers for chemical and physical analysis.

2.3. Physico-Chemical analysis

On digested samples the following physicochemical analyses were carried out: ANNE method [8] was used for determination of organic carbon, the pH and Electrical conductivity were determined on water sample (10 g/15 ml) using digital pH meter and conductivity device (EQ-614-A) respectively. Kjeldahl method was used for determine the nitrogen content [9], Olsen method was used for estimation of phosphorus content [10]. The content of Calcium, Sodium, Potassium, and Magnesium were estimated using the ammonium acetate procedure. Phosphorus, Manganese, and iron were determined after ashing, and measured calorimetrically and other heavy metals elements were analyzed in the extracts using atomic absorption and flame photometry [11].

2.4. Statistical analysis

Variances between initial and final values of several chemical parameters was calculated by using Student's t-test. Differences among several mixtures was estimated using ANOVA method of one way. Association between different concentrations and chemical parameters was evaluated by Pearson's correlation coefficient. SPSS program was used for running statistical analysis.

3. Results and discussion

3.1. Beneficial organism progress and prolificacy

Beneficial organisms were incapable to last in completely leather industry wastewater sludge (100%) possibly owing to its deadly condition. Addition of chicken manure as substrate additives (organic materials) to leather industry wastewater sludge was essential for the Beneficial organism persistence. Estimation of these organisms exhibited statistical difference ($p < 0.01$, $F = 3.122$) in diverse sample blends and displayed negative correlation ($r = -0.97$) with percentages of leather industry wastewater sludge. In 50 days SL0 & SL15 samples showed improved pattern in percentage of beneficial organisms, compared to SL25 on 65th day. Thirty-five was the maximum number of beneficial organism (earthworms &microorganism) that noticed in (SL0) on 80th day of experiment followed by 25 in SL15 and 20 in SL25 sample blend. In SL0 &SL15 samples, the beneficial organisms amount began to decline between 80th & 100th day (Fig. 1). Comparable remarks have been stated by other researchers in 90 days of composting of in pulp and paper making sludge and textile industry sludge [12,13]. The total amount of beneficial organism started decline up to the termination of the trial. The reduction in the total amount could be owing to the consumption of nutrients. The persistence, beneficial organism's biomass production is the indication of the composting progression. The findings from Ravindran *et al.* (2008) [1] were compared with our current research study in that beneficial organisms were capable to alter leather wastes (hide and skin) from leather industry wastewater sludge into valuable compost materials. Beneficial organism's biomass starts to reduce in SL50 and SL75 samples from day 15th of experiment. High pattern of mortality was observed in SL50 (70%) and SL75 (50%) feed mixtures from original values at the end of experiment. The justification of this mortality owing to the non-affinity and harmfulness of leather industry wastewater sludge. Previous reports explained that affinity and kind of nutrients in a straight line affected the reproduction potential, survival, and growth rate of beneficial organism [14,15,16]. Thus, chicken manure stand-in as a matching surplus, not only decreased the time of process but, likewise enhanced its value and transformed the leather industry wastewater sludge into valuable product.

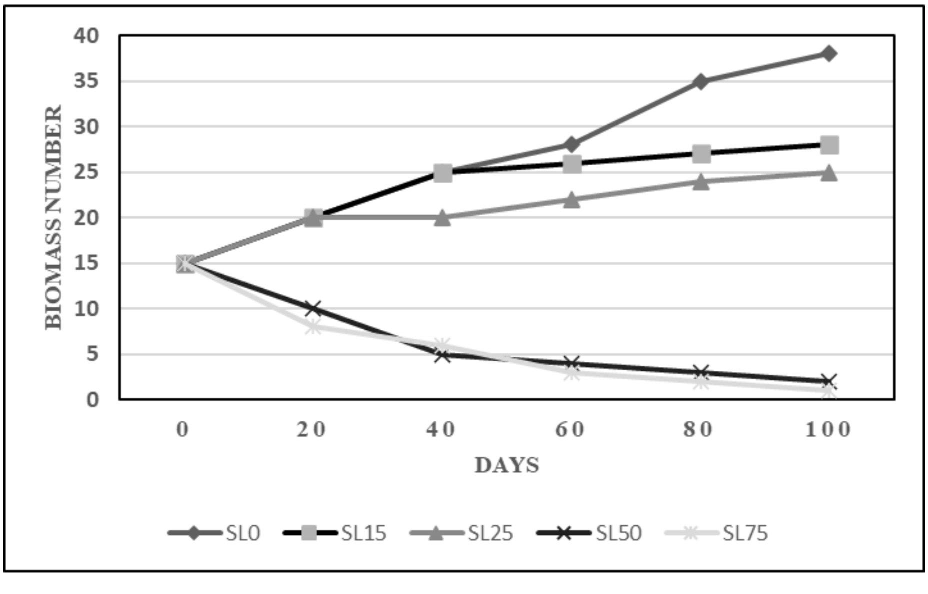

Figure 1 Growth of beneficial organism in various feed mixtures of Tannery sludge and chicken manure

3.2. Physico-chemical properties

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. The highest rise in pH was in SL50 (9.28%) feed mixture and lowest was in SL0 (3.44%). The pattern of increasing pH percent was in the following order SL50 > SL15 > SL25 > SL75 > SL0. Some researcher report showed increasing trend in pH during composting [17]. This increase in pH is attributed to the organic nitrogen compound not consumed by the beneficial organisms which is appear as gas of NH_3 which become liquefied in water and increased the pH of the stockpile [18].

Electrical conductivity (EC) exhibits obvious reduction ($p < 0.05$) and depressingly correlation ($r = -0.97$) with cumulative concentration of the tannery sludge. The decreasing style was in the range of 48.5– 73.3% in different samples. The pattern of decreasing in electrical conductivity was in the following manner SL75 > SL50 > SL25 > SL15 > SL0. EC explained the saltiness of samples. This rise in electrical conductivity was attributed to the production of various minerals salts such as $(NH_4)_3PO_4$ and K_3PO_4 etc. [19].

Organic Carbon total exhibit declined pattern ($p < 0.01$) and negative correlation ($r = -0.98$) from the starting with cumulative concentration of the leather industry wastewater sludge and unusually reduction when the experiment finished. Decrease in Total organic Carbon was highest in SL75 (15.83%) feed mixture. The reduction in Total organic Carbon (TOC) content was in the following order SL75 > SL50 > SL25 > SL15> SL0. The decline in Total organic Carbon subsequent composting designates substrate organic matter stabilization which attributed to shared act of beneficial organism (earthworms &microorganism). In general, beneficial organism changes the environmental condition of substrate, then the reduction of carbon from the substrates was improved in the form of carbon dioxide through the process of microbial respiration [6,15,20,21].

Table 2 Physico-chemical properties of tannery sludge and Chicken Manure in initial feed mixtures and final products (mean ± SE) on dry weight basis

Parameters	Concentration	SL0	SL15	SL25	SL50	SL75
Organic Carbon, %	Initial	20.5±0.04	23.2±0.95	24.2±0.6	27.2±0.7	32.2±0.8
	Final	15.2±0.02	18.1±0.02	20.1±0.3	22.1±0.4	27.1±0.5
Total Nitrogen, %	Initial	2.80±0.01	2.3±0.02	1.70±0.3	1.60±0.4	1.25±0.5
	Final	3.00±0.01	3.70±0.03	2.50±0.2	2.33±0.1	2.05±0.3
Potassium, %	Initial	1.85±0.02	1.90±0.03	2.00±0.1	2.10±0.2	2.20±0.4
	Final	2.00±0.04	2.10±0.01	3.00±0.2	3.14±0.3	3.16±0.2
Phosphorus, %	Initial	2.55±0.03	2.55±0.04	1.80±0.3	1.68±0.2	1.60±0.2
	Final	2.81±0.05	3.15±0.02	2.90±0.1	2.80±0.3	2.35±0.1
Calcium, %	Initial	1.45±0.03	1.95±0.01	1.80±0.1	1.60±0.1	1.30±0.3
	Final	1.70±0.03	2.25±0.02	2.50±0.02	2.4±0.02	2.30±0.05
Magnesium (ppm)	Initial	265±5.90	285.0±3.4	300.0±2.4	385±1.4	250±2.4
	Final	280±7.30	250.0±4.4	220.0±3.5	210±3.5	200±3.5
Iron (ppm)	Initial	950±8.50	1050±8.50	1150±5.50	995±3.5	1110±4.5
	Final	970±1.22	1100±1.22	1200±3.02	980±2.1	1000±2.2
Sodium (ppm)	Initial	60.0±2.90	98.0±1.09	100.0±1.9	115±1.2	80±1.09
	Final	75±3.50	115±2.40	120±2.40	125±2.1	135±2.04
C/N ratio	Initial	7.32±0.04	10.1±0.04	14.2±0.04	17±0.04	21.4±0.6
	Final	5.06±0.01	4.89±0.01	8.04±0.1	9.48±0.1	13.2±0.3
pH	Initial	7.25±0.07	7.20±0.07	7.15±0.07	7.9±0.7	6.25±0.7
	Final	7.5±0.040	7.7±0.040	7.5±0.040	7.3±0.4	7.05±0.40
EC	Initial	5.35±0.20	4.30±0.20	4.10±0.20	2.45±0.2	2.25±0.20
	Final	2.75±0.01	1.90±0.01	1.70±0.01	0.80±0.1	0.60±0.01

Heavy metals						
Chromium (ppm)	Initial	1.66±0.02	1.45±0.09	1.30±0.28	1.25±2.0	1.20±0.28
	Final	1.86±0.96	1.90±0.96	1.93±0.92	1.96±0.9	1.98±0.92
Cadmium (ppm)	Initial	0.7±0.01	0.50±0.01	0.80±0.02	0.9±0.02	0.80±0.02
	Final	0.9±0.01	1.10±0.01	1.15±0.05	1.25±0.5	1.35±0.05
Copper (ppm)	Initial	125.8±4.9	130.5±3.9	135.5±2.9	138±2.09	141.5±2.9
	Final	130±1.02	140±1.02	145±3.02	148±4.02	150±3.02
Manganese (ppm)	Initial	25.6±1.08	20.6±1.08	23.6±1.07	24.6±1.0	25.1±1.07
	Final	26.4±.90	30.4±0.90	34.4±0.95	35.4±0.9	36.4±0.92
Lead (ppm)	Initial	1.45±0.06	1.22±0.06	1.35±0.04	1.55±0.2	1.70±0.06
	Final	1.65±0.04	1.85±0.04	1.95±0.03	2.8±0.3	2.20±0.04
Zinc (ppm)	Initial	123.6±4.9	115.6±2.4	117.3±3.4	118±4.2	121.6±3.2
	Final	125.3±0.8	119.3±0.7	122.5±1.7	121±1.3	125.4±1.5

The ultimate Total Kjeldahl Nitrogen (TKN) content in the designated compost was reliant on the nitrogen concentration in the samples and the breakdown extent. Total Kjeldahl Nitrogen improved intentionally with negative correlation ($r = -0.99$) with growing leather industry wastewater sludge concentration. The highest value in Total Kjeldahl Nitrogen was in SL0 (78.57%) and minimum in SL75 (36.66%). The increasing pattern in Total Kjeldahl Nitrogen (TKN) was in the following order SL0 > SL15 > SL25 > SL50 > SL75. Beneficial organism (earthworms &microorganism) improved the mineralization of nitrogen in the growing media, so nitrogen was reserved in the form of nitrate. In addition to that beneficial organism (earthworms &microorganism) play a vital role in improving the content of nitrogen through the breakdown and assimilation of substances of organic origin [22,23].

Decrease in C: N was high in SL0 feed mixture (58.46%). The pattern of reduction in carbon nitrogen ration was in the following manner SL0 > SL15> SL50 > SL25 > SL75. The carbon nitrogen ratios of tested samples displayed the mineralization of organic waste and steadying during the breakdown process. A reduction in carbon nitrogen ration might be due to the liberation of CO_2 through the respiration of beneficial organisms and concurrent adding of molecular nitrogen by another organism consortium (Atiyeh et al., 2000; Suthar, 2006). Previous reports also showed that C: N, was considered as one of the most parameter which determined the maturation of compost [23,24].

Noticeable rise in total potassium content in various sample ($p < 0.01$) from the beginning of the experiment was negatively correlated ($r = -0.96$) with cumulative concentration of the tannery sludge. The high growth in potassium content was observed in SL0 (66.6%) sample. The rise in potassium content was in the following manner SL0 > SL15 > SL25 > SL50 > SL75.

The Phosphorus content in this study (P) was increase significantly in the final samples than the initial. The increase in phosphorus is due to act of beneficial organism (earthworms &microorganism) enzymes and indirectly to motivation of the microflora [25]. The raise in phosphorus content in the course of composting was possibly owing to phosphorus mobilization and mineralization as a result of enzymes phosphatases of beneficial organism (earthworms &microorganism) and extra production of phosphorus may be to solubilization of Phosphorus by microflora in stockpile [26].

Sodium increased substantially ($p < 0.05$) from initial feed blend sample and with positive correlation ($r = 0.97$) with cumulative concentration of the tannery sludge. There was 6.29-22.35% rise in total sodium in various samples. The pattern of growth in total sodium was in the following manner SL0 > SL25> SL15 > SL50> SL75.The final compost shows increasing of the total Sodium. [27,28] confirmed the above scenario.

Calcium concentration in the final compost was high. However, the calcium shortage can be a problematic for acid soils, and the plant value is usually affected if calcium is not adequate. Therefore, in Acidic sand soils, compost can rise calcium availability for growth of plant.

Heavy metals are abundantly present in soil and groundwater due to extensive usage of heavy metals in industrial and manufacturing activities such as leather manufacturing and tanning, also its important for the health of plants, animals, and humans. On other hands, the excess of heavy metals has lethal influences [29]. The harmfulness of heavy metals is not initiated by the simple existence of metals, but it depends on metal bioavailability, mobility, poisonousness, concentration, the path of uptake mechanism, and accumulation in plants [30]. Consequently, control of metallic element in polluted earths using beneficial organism (earthworms &microorganism) looks to be a best substitute in comparison with luxurious and difficult remediation methods [31]. In this study heavy metals significantly increased ($p < 0.015$) from initial samples blend but the rise was within allowable boundary. The rise in heavy metals concentration was comparative with cumulative concentration of the tannery sludge and it was 10.7-65.3% for Chromium, 22.75-65.34 for Cadmium, 3.23-5.66% for copper, 3.03-31.04% for Manganese, 12.12-22.7% for Lead, and finally 1.35-3.03 % for Zinc. Higher level of concentration of metals in tannery soils and cultivated lands have been reported [32]. In spite of raise in the heavy metals concentration but the contents were within the acceptable concentration level for compost which shows that the compost can be used without any adverse effects on the soil [28].

4. Conclusion

Beneficial organisms were affected by toxicity of leather industry wastewater sludge when high amount of sludge was used. Hence, it was blended with chicken manure (organic waste) to improve the its contents. Outcomes exhibit that beneficial organism produced food contents, minor carbon nitrogen ratio, and lesser EC. Total concentration of heavy metallic elements amplified but still within the allowable boundary. Therefore, it can be used as mature manure. In this research it was demonstrated that beneficial organism might be presented as an operative knowledge to adapt the lethal leather industry wastewater sludge into a precious product.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no conflict of interests exists.

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