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Biomanagement of seafood processing plants sludge

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Research Article

Abstract : Disposing of sludge generated from the effluent treatment of seafood processing plants has always been a problem for seafood processors. Vermicomposting which uses earthworms to stabilize and transform these organic wastes in to valuable products has been proposed as an alternative treatment technology. Physicochemical characteristics and major nutritive elements of the seafood plant sludge were analyzed. The pH, EC and TDS of the sludge were 6.8, 21.65mS, 6.56 ppt respectively. Organic matter, TOC, total nitrogen and total phosphorous content of sludge were 99.32%, 48.66%, 4.82% and 0.03% respectively. Sludge materials collected from the local seafood processing plants were biologically processed for duration of two months using the exotic earthworm *Eudrilus eugeniae*. Vermiculture bed were prepared based on weight using seafood plant sludge, cow dung, sawdust and leaf litter in various configurations viz,10:45:25:20(T_1),15:42.5:25:17.5(T_2),20:40:24:16(T_3),25:37.5:22.5:15 (T_4) respectively. The inclusion of seafood processing plant sludge beyond 25% proved fatal to earthworms. Earthworms of size weighing 1.31 g were introduced in the vermibed at the rate of 2000 worms / m^2.Before introduction of earthworms the vermibed materials were precomposted using microbial inoculum *Trichoderma viride* for ten days. The moisture content (65-70%) of the vermibed was maintained. Composting materials spread in the vermibed were turned once in 5 days. Various physicochemical characteristics such as pH, EC, TDS, organic matter, organic carbon, mineral content, nutrients N, P, K, C:N ratio and microbiological characteristics were analyzed once in 20 days. Results of the analysis of various treatments and suitable configurations evolved for vermicomposting of seafood plants sludge were presented.

Keywords: : Seafood processing plant sludge, *Trichoderma viride, Eudrilus eugeniae*, vermicomposting

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1. Introduction

India has a large network of seafood industry of varying capacity. Totally 401 seafood processing industries are present all along both the east and west coasts of India. India's seafood export is expected to reach 4,500 lakh MT this year. Disposing of sludge generated from the effluent treatment of seafood processing plant has always been problem for seafood processors. Direct use of this sludge for land manuring has been discouraged due to its very high content of organic matter and inorganic elements. Vermicomposting which uses earthworms to stabilize and transform these organic wastes in to valuable products has been proposed as an alternative treatment technology for seafood plant sludge. The transformation of seafood processing plant sludge in to vermicompost is of double interest, in the one hand, a waste is converted in to value added products, and on the other it controls the pollutants. Vermicomposting could be an adequate technology for the transformation of sludge in to valuable products (Elvira *et al*., 1997). Vermicomposting as a principle originates from the fact that earth worms in the process of feeding fragment the substrate there by increasing its surface area for further microbial colonization (Chan and Griffiths, 1988). During this process, the important plant nutrients such as nitrogen, potassium and phosphorous present in the feed materials are converted through microbial action in to forms that are much more soluble and available to plants than those in the parent substrate (Ndegwa and Thomson, 2001) while the worms themselves provide a protein source for animal feeds (Sabine, 1978; Hartenstein, 1981).

Different natural and anthropogenic wastes which have already been converted into useful compost by different species of earthworms include sewage sludge (Delgado *et al* ., 1995; Benitez *et al*.,1999); dairy processing plant sludge (Kavian and Ghatneker, 1991; Gratelly *et al* 1996; Elvira *et al*., 1998); paper mill industry sludge (Elvira *et al*.,1997, 1998; Butt,1993); pig waste (Rech, 1992); water hyacinth (Gajalakashmi *et al*., 2002) paper waste (Gajalakshmi *et al*., 2002) brewery yeast (Butt, 1993); crop residues (Bansal and Kapoor, 2000); cattle manure (Mitchell, 1997); cow dung slurry (Hand *et al*., 1988); vine fruit industry sludge (Atharasopoulous, 1993); rice stubble, mango leaves (Talashilkar *et al.*, 1999). Although numerous experiments have been conducted for stabilization of various industrial sludge through vermicomposting, either to no attempt has been made to stabilize seafood processing plant sludge. Hence the present study was conducted for the vermistabilization of seafood processing plant sludge mixed with cow dung, sawdust and leaf litter in various configurations.

2. Materials and Methods

Settled sludge from seafood processing plants were obtained from the waste water treatment plant of a seafood industry located in Tuticorin in India. The main physico-chemical characteristics and major nutritive elements such as moisture, dry matter, pH, EC, TDS, organic matter, mineral content, total organic carbon (TOC), total nitrogen, total phosphorous, total potassium and C:N ratio of the seafood processing plant sludge were analyzed. Similar to that of seafood processing plant sludge, feed mixtures such as sawdust, leaf litter and cowdung to be included in the vermibed were also analyzed for the same physicochemical characteristics. Vermistabilization experiments were designed on various configurations viz., 10:45:25:20 (T_1), 15:42.5:25:17.5 (T_2), 20:40:24:16 (T_3), 25:37.5:22.5:15 (T_4) using vermibed feed mixtures such as seafood processing plant sludge, cowdung, sawdust and leaf litter respectively. These experiments were conducted in a shady place of 6'x150'x6' size thatched with coconut leaves. Floor of the vermi pit was covered with thick plastic sheet and above the sheet soil without stones and gravel were spread to a height of 15cm. Water was sprinkled over the soil till it becomes wet. Above the soil, shade dried and finely powdered cow dung, leaf litter, sawdust and seafood processing plant sludge were spread as said in the above configurations. They were precomposted for 10 days using microbial inoculum fungi *Trichoderma viride* at the rate of 200g/tone of composting materials. These mixtures were turned over manually every 24hrs for 10 days in order to eliminate volatile substances potentially toxic to worms. Apart from these treatments, a control was also maintained for comparison in which vermibed was prepared without the seafood processing plant sludge. Moisture content of these bed materials were maintained between 40-50% during the precomposting period of 10 days. After 10 days, the exotic earthworms *Eudrilus* *eugeniae* of size 1.31g were introduced in the vermibed at the rate of 2000 worms /m^2. During the vermicomposting period the moisture content was maintained between 65-70% through periodic sprinkling of water. These experiments were replicated twice for each treatment. These experiments were carried out for a period of two months and various physico–chemical characteristics such as moisture content, dry matter, EC, TDS, organic matter, total organic carbon, mineral content, nutrients N, P, K and C:N ratio, and microbiological characteristics were analyzed using homogenized samples of composting materials drawn at the intervals of ten days till the completion of the experiment. The zero day given in the table refers to the day of earthworm introduction after precomposting.

The homogenized samples were air dried in the shade at room temperature, ground in a stainless steel blender and stored at 4ºC for further chemical analysis. All the samples were analyzed in triplicate. The moisture and dry matter content were determined by drying at 80ºC in a hot air oven for 23 hr (APHA, 1995). The pH of the samples were determined in a pH analyzer using a deionised water suspension of samples made at the ratio of 1:10 (w/v) and agitated mechanically for 30min before filtered through Whatman No:1 filter paper. Water extracts were drawn following the method of Ndegwa and Thompson (2001), and analysed for EC, TDS using EC-TDS analyser (Elico CM 183). Organic matter content was obtained by ashing the dried sample at 550ºC for 8.5 hr (APHA, 1995). Total Organic Carbon (TOC) was analyzed using the SHIMADZU TOC analyzer 5000A with SSM. Total nitrogen was determined using the KELPLUS Nitrogen Estimation system (PERKIN – Model KES 12L, (Classic – Dx). Total phosphorus was measured using the calorimetric method with molybdenum in sulfuric acid. Total potassium were determined after digesting the sample in diacid mixture (concentrated HNO_3 concentrated $HClO_4$, 4:1 (v/v) by flame photometer (Systronics, model-Mediflame 127).

3. Results and Discussion

A survey was conducted to assess the quantity of sludge generation in various seafood plants located in and around Tuticorin. Totally 15 numbers of seafood processing plants are operating in Tuticorin district and they generate about 352 metric tons of sludge/year through the wastewater treatment process. Presently these sludge generated are disposed of either landfill or by dumping at sea thus producing environmental pollution. Hence, this vermistabilization of seafood processing plant sludge was attempted for further use as compost. The physico-chemical characteristics of seafood processing plant sludge along with the other vermibed mixtures such as sawdust, leaf litter and cow dung are given in the Table 1. Seafood processing plant sludge recorded a very high nitrogen content of 4.82% with the low C:N ratio of 28.78. Total nitrogen content and C:N ratios of other vermibed feed mixtures utilized for stabilization of this nitrogenous resources such as sawdust, leaf litter and cowdung were 0.15%, 325.75; 2.1%, 23.2; and 0.45%, 98; respectively.

The physico-chemical characteristics of precomposted vermibed materials of treatments for T_1, T_2, T_3 and T_4 are furnished as initial (0' day) in the Table 2, Table 3, Table 4 and Table 5 respectively. Variations in physico -chemical parameters recorded for treatments T_1, T_2, T_3 and T_4 during vermicomposting are shown in the Table 2, Table 3, Table 4, and Table 5 receptively. The physico-chemical characteristics of the final product of control were as follows: moisture 55%; dry matter 45%; pH 7.2; EC 1.24ms; TDS 591.6ppm; mineral content 0.8%; organic matter 99.2%; total organic carbon 33.8%; total nitrogen 1.5%; total phosphorous 0.61%; potassium 0.2; C:N ratio 22.53. Earth worm *Eudrilus eugeniae* could not tolerate the inclusion of sludge beyond 25%. Minimum of 75% of vermibed feed mixtures are essential for 100% survival of earthworms. The vermicompost produced from seafood plant sludge were much darker in color than originally and have been processed in to homogeneous manure after precomposting with fungi *Trichoderma viride* followed by 60 days of earthworm's activity whereas the sludge materials without earthworms remained in compact clumps. During vermistabilization a large fraction of TOC was lost as CO_2 and TOC loss recorded for treatments T_1, T_2, T_3 and T_4 were 4.09%, 5.33%, 5.6% and 4.02% respectively by the end of vermicomposting period. Contrast to TOC, total nitrogen had increased by the end of vermicomposting period between 1.01% and 1.58% in different treatments probably because of mineralization of organic matter (Table 2-5).

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Gaining of total nitrogen content decreases with increase in sludge concentration, The final nitrogen content of the compost would be dependent on the initial nitrogen in the feed material and the extend of decomposition, (Crawford, 1983). The C: N ratio, one of the most widely used indices for maturity of organic waste, always decreased with time in all treatments due to decomposition (Table 2-5). The initial C: N ratio of different treatments were 53.99 (T_1), 45.02 (T_2), 40.08 (T_3), and 33.43 (T_4). A decline of C: N ratio less than 20 indicates an advanced degree of organic matter stabilization and reflects a state of maturity of organic waste (Sensei, 1989). In our experiments C: N ratio of final products 16.83 (T_1), 16.6 (T_2), 17.71 (T_3) and 18.32, (T_4) were reached after 60 days of worm activity. Levi-minzi *et al*., (1986) reported that C:N ratio of final products such as farm yard manure decreased after storing a period of three months. In our experiments earth worms initially accelerated decrease in C:N ratio significantly. The overall decrease in C:N ratio associated with an increase in total nitrogen was documented during 60 days of study. It demonstrates more rapid decomposition and rate of mineralization of organic matter accompanied by increase in total nitrogen during earlier part of study. Similar results have been also reported by Atiyeh *et al*., (2000) and Bansal and Kapoor (2000). Microbiological analysis made during our study also reiterates the above said facts. The dominant microorganisms recorded during the study mainly belong to two genera; they were members of genera, *Acetobacter* (21%), *Pseudomonas* (10%) *Wolinella* (10%), *Bacteriodes* (9%) and their microbial population densities ranged from10^3 -10^{10} cfu/g of compost. The prevalence of genera *Acetobacter* sp might have improved the nitrogen metabolisms during vermicompost.

The amount of total phosphorous in treatments (T_1, T_2, T_3 and T_4) increased gradually with study period. Gaining in total phosphorous content recorded for different treatments were 0.4% (T_1), 0.4 % (T_2), 0.46% (T_3) and 0.58% (T_4). Faster increase in total phosphorus content during vermistabilization showed the efficiency of earth worm in mineralization of phosphorous. Such effects of earthworm in mineralizing wide ranges of organic materials with help of various bacteria and enzyme in the intestine has been described in detail by Edward and Lofty (1972). Mansell *et al*., (1981) showed that plant litter contained more available P after ingestion by earth worms and they attributed this increase to physical breakdown of the plant material by the worms.

Table 1. Physicochemical characteristics of seafood processing plant sludge and vermibed mixture.

Parameters	Sludge	Saw dust	Leaf litter	Cow dung
Moisture %	13	40	5.74	10.3
Dry matter %	87	60	94.2	89.7
pH	6.8	7.6	6.48	7.6
EC	21.65mS	593.5µS	1.47 ms	1.05 ms
TDS	6.56ppt	313.5ppm	802.6ppm	548.2ppm
Mineral content %	0.68	0.29	0.23	0.25
Organic matter %	99.32	99.71	99.77	99.75
TOC %	48.66	48.86	48.89	48.87
Total nitrogen %	4.82	0.15	2.1	0.45
Total phosphorous %	0.03	1.09	0.018	0.18
Total potassium %	0.42	1.09	0.04	0.22
C:N ratio	28.78	325.75	23.2	98.0

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Table - 2. Variation of Physico-chemical parameters in T_1 during composting

Parameters	**0'day**	**10thday**	**20thday**	**30thday**	**40th day**	**50thday**	**60th day**
Moisture %	70.68	68.3	63.24	52.0	53.1	55.0	54
Dry Matter %	29.32	31.7	36.76	48.0	46.9	45.0	46
pH	7.4	7.4	7.3	7.3	7.2	7.2	7.2
EC µS	122.7	165.6	214.3	216.7	319.8	537.9	746.9
TDS ppm	63.7	87.6	103.5	114.1	205.3	316.7	390.7
Mineral content %	0.46	0.42	0.60	0.65	0.67	0.70	0.74
Organic matter %	99.54	99.43	99.40	99.35	99.33	99.30	99.26
TOC %	44.49	43.2	42.60	42.4	42.0	41.5	40.4
Total nitrogen %	0.82	0.92	1.22	1.45	1.89	2.1	2.4
Total phosphorous %	0.46	0.49	0.53	0.61	0.65	0.71	0.86
Total Potassium%	0.7	0.72	0.72	0.75	0.78	0.81	0.82
C:N ratio	53.99	46.96	34.92	29.24	22.22	19.76	16.83

Table-3: Variation of Physico- chemical parameters in T_2 during composting

Parameters	**0' day**	**10th day**	**20th day**	**30th day**	**40th day**	**50th day**	**60th day**
Moisture %	74.28	76.31	68.9	70.0	65.3	57.03	60.5
Dry Matter %	25.72	23.69	31.1	30.0	34.7	42.97	39.5
pH	7.32	7.3	7.3	7.2	7.2	7.1	7.0
EC (µS)	97.24	103.8	143.9	174.5	213.5	273	369.0
TDS (ppm)	51.60	53.03	82.4	90.60	117.3	165.8	190
Mineral content %	0.43	0.48	0.52	0.55	0.55	0.62	0.67
Organic matter %	99.57	99.52	99.48	99.45	99.45	99.38	99.33
TOC%	46.83	45.71	44.8	44.2	43.5	42.8	41.5
Total nitrogen %	1.04	1.14	1.25	1.51	1.78	2.2	2.5
Total phosphorous%	0.50	0.58	0.63	0.72	0.75	0.84	0.9
Total potassium%	0.75	0.76	0.71	0.68	0.55	0.53	0.4
C:N ratio	45.02	40.1	35.84	29.29	24.44	19.45	16.6

Table 4. Variation of Physico-chemical parameters in T_3 during composting

Parameters	0' day	10^{th} day	20^{th}day	30^{th} day	40^{th} day	50^{th} day	60^{th} day
Moisture %	74.31	70.5	68.7	71.0	60.3	58.61	62.97
Dry matter%	25.69	29.5	31.3	29.0	39.7	41.39	37.03
PH	7.15	7.10	7.04	7.0	6.9	6.9	6.85
EC (µS)	135.1	156.3	216.3	228.2	325.7	453.5	569.7
TDS (ppm)	70.30	95.8	130.5	118.9	120.2	285.6	301.9
Mineral content%	0.41	0.57	0.6	0.65	0.67	0.68	0.68
Organic matter %	99.59	99.43	99.4	99.35	99.33	99.32	99.32
TOC %	48.1	47.71	46.55	45.85	44.73	43.7	42.5
Total nitrogen %	1.2	1.4	1.6	1.9	2.1	2.25	2.4
Total phosphorous %	0.56	0.58	0.63	0.72	0.87	0.98	1.02
Total potassium %	0.80	0.81	0.78	0.65	0.54	0.51	0.46
C:N ratio	40.08	34.08	29.1	24.3	21.3	19.42	17.71

Table 5. Variation of Physico- chemical parameters in T_4 during composting

Parameters	0' day	10^{th} day	20^{th} day	30^{th} day	40^{th} day	50^{th} day	60^{th} day
Moisture %	72.56	70.3	69.8	71.5	70.5	63.5	64.97
Dry Matter %	27.77	29.7	30.2	28.5	29.5	36.5	35.03
pH	7.08	7.01	6.95	6.9	6.9	6.9	6.9
EC (µS)	152.9	167.5	195.3	206.2	238.7	351.5	464.2
TDS (ppm)	78.20	81.9	95.17	106.7	156.2	230.3	242.4
Mineral content %	0.44	0.45	0.45	0.47	0.47	0.47	0.58
Organic matter %	99.56	99.55	99.55	99.53	99.51	99.53	99.42
TOC %	49.81	48.51	48.06	47.85	46.71	46.01	45.79
Total nitrogen %	1.49	1.85	1.95	2.1	2.3	2.4	2.5
Total phosphorous %	0.6	0.68	0.97	0.80	0.95	1.03	1.18
Total potassium%	0.82	0.85	0.87	0.76	0.63	0.54	0.51
C:N ratio	33.43	26.22	24.65	22.79	20.31	19.17	18.32

Satchell and Martin (1984) found an increase of 25% in total P of paper-waste sludge, after worm activity. They attributed this increase in total phosphorus to direct action of worm gut enzymes and indirectly by stimulation of the micro flora. Contrast to phosphorus, total potassium concentrations present in the final product of the different treatments were lower than the initial vermibed mixtures and the difference ranged from 0.12% to 0.37%. This might be due to leaching of the total potassium by excess of water that drained through vermibed mixtures. Similar results of decrease in total potassium were also reported by Elvira *et al*.,(1998) in vermicomposting of pulp mill sludge. Growth and reproduction of earthworms were not studied in this experiment. Treatments which ensured 100% of survival were only taken for analysis. Various configuration of seafood processing plant sludge and other vermibed materials required for growth and reproduction need to be studied.

Our experiments demonstrated precomposting with microbial inoculum fungi *Trichoderma viride* followed by vermicomposting using *Eudrilus engeniae* as an alternative technology for the management of seafood processing plant sludge. The results presented here provides the basis for utilization of sludge from seafood processing plant mixed with other vermibed materials cow dung, sawdust and leaf litter. Addition of seafood plant sludge beyond 25% leads to mortality of worms which would be due to the high EC and nitrogen content of sludge.

However the final products obtained for various treatments of the study had lower C:N ratio and rich in nitrogen and phosphorus than initial mixtures. The low pH of final products could be attributed to the accumulation of organic acids. This vermistabilization study provides valuable insight about process and the ranges brought about by earthworm activity. It appears that initial precomposting of vermibed materials using microbial inoculum *Trichoderma viride* becomes essential. This precomposting technique was adopted only after documentation of increased mortality of earthworms even at the 10% concentration of seafood plant sludge. The precomposting was done to eliminate volatile substances potentially toxic to worms. Initial few weeks after introduction of earthworms to the vermibed mixtures are the more critical period because most of the decomposition and stabilization of vermifeed mixtures occurs only during this period. However the final products were more stabilized, as demonstrated by a significant decrease in C: N ratio. Finally the use of seafood processing plant sludge as raw material can potentially help to convert the waste in to value added product, thus avoiding the disposal in land fill and coastal waters.

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