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Management of sugar mill industry sludge by vermicomposting employing *Eisenia foetida* and *Perionyx excavatus*

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ABSTRACT

The sugar industry semi-solid sludge, despite repeated recycling, requires treatment prior to disposal. The present study was carried out to dispose the sugar mill sludge biologically using two earthworm species like *Eisenia foetida* (exotic species) and *Perionyx excavatus* (indigenous species). The sugar mill sludge was mixed with bedding material, by the 5%, 10%, 15% and 20% (V/V) proportion. During study, all vermi-beds were analyzed for chemical changes (i.e. pH, Organic Carbon, Total Nitrogen, Phosphorous and Potassium) content of waste before and after treatment. The total number of cocoon was greater in 25% concentration of sludge for *Eisenia foetida* species and 10% concentration for *Perionyx excavatus* species as compared with control. Nitrogen, phosphorous and potassium content of the wastes were significantly increased after the treatment with two species of earthworms. The 25% and 10% mixing of the sludge were recommended for the vermi-culture and vermicompost *Eisenia foetida* and *Perionyx excavatus* species respectively. It could be concluded that sugar industry sludge was toxic to a remarkable extent.

KEYWORDS

Sugar industry sludge;
Eisenia foetida;
Perionyx excavatus;
Reproduction;
Vermicomposting.

INTRODUCTION

Rapid urbanization, industrialization, unplanned growth of human population, misuse and abuse of environment has led to an increased accumulation of solid waste material. Solid waste management in India is emerging and engaging area of study. However, the picture is often confusing and solutions, fuzzy information available in public domain is either scanty or scattered. The use of certain raw wastes of industries is limited to only 1.5%[3]. Any adventures by man to deviate the course of nature are against the creation of nature itself. It has been estimated that 8% of India's lands has become wasteland due to garbage dumps.

India's agro-industrial sector contributes huge potential resource of plant nutrients in the form of wastes, which is either thrown away or buried or burnt causing environmental pollution. Effluent treatment plants (ETP) generally consist of Physical, Chemical and biological process to treat the wastewater discharged from industries or residential complexes. The dissolved organics in wastewater is generated as sludge mainly during the primary and secondary treatment of wastewater.

The solid waste generated from agricultural activities can be directly added to the soil without any proper treatment as they do not posses any toxic pollutants[18], but for the waste like bio-solids from treatment plants much attention is required since they can produce toxicity and have depressive effects on metabolism of micro-organisms[2]. During the recent years the methodology of solid waste management has shifted from conventional disposal strategies such as incineration, landfills etc. to conversion of sludge into value added product[19]. Hartenstein[11] suggested that, *Eisenia foetida* derives a considerable amount of energy from cellulose and that it may selectively remove large proportion of microbes and ambient cellulose matrix. Earthworm fecundity is often expressed in various ways, the rate of cocoon production and the hatchling success of these cocoons and number of offspring emerging from each cocoons is the factor determining the number of new individuals produced per unit time for a specific population of reproductive individuals.

Treatment of sugar mill sludge was brought about by physical, chemical and biological processes. In the present work, sugar mill sludge generated in Kolhapur was subjected to vermicomposting using an exotic (*Eisenia foetida*) and indigenous (*Perionyx excavatus*) species of earthworms. A study was conducted to evaluate the efficiency of *Eisenia foetida* and *Perionyx excavatus* for decomposition of sugar mill sludge into valuable vermicomposting.

MATERIALS AND METHODS

Sugar mill sludge was collected from Kasba Bawda sugar mill, Kolhapur. It was analyzed for pH, Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and Chemical Oxygen Demand (COD) by APHA methods[1]. Breeders of *Eisenia foetida* (Exotic Species) and *Perionyx excavates* (Indigenous Species) were collected from earthworm culture bank of Institute of National Organic Agriculture (INORA) Pune.

Bedding material preparation

The standard bedding material was prepared as follows (Kavian[15]),

1. Kitchen waste (40% by volume)
2. Cow dung (40% by volume)
3. Saw dust (20% by volume)

Vermi-culture tub treatment process

The sugar mill sludge was mixed with bedding material, by the 5%, 10%, 15% and 20% (V/V) proportion and about 2kg of material were add to plastic tub (28cm diameter and 30cm depth). All bedding was kept for 2 week prior to experimentation for thermal stabilization, initiation of microbial degradation and softening of waste. Sexually immature pre-clitellate *Eisenia foetida* and *Perionyx excavatus* (10 number, 15-18 days old) were inoculated separately in each plastic container having the same initial weight 0.152gm and 0.165gm respectively[21]. All the culture tubs were placed in laboratory for 90 days at 28°C to 38°C. Moisture content was maintained throughout the experiment around 70-80% by periodic sparing of adequate quantity of water and pH of bedding material was ranging from 6.5-7.01. The upper surface of the culture tubs was covered with wire mesh to avoid the entrance of predators.

The cocoon productions of earthworms were measured with great care. Counting was done by hand sorting at weekly intervals. Experiments were kept in triplicate for each treatment as well as for control. Vermibed was analyzed for chemical changes (Total Nitrogen, Available Phosphorous, and Exchangeable Potassium) before and after 90^{th} days.

Statistical analysis

Statistical analysis of the data was carried out using Minitab software. Differences were considered significant, where p value ≤ 0.05. The data were tested for greater hatching percentage using proportionality 'Z' test while ANOVA was applied to check for difference between initial and final values of nitrogen and similarly for Phosphorous and Potassium values.

RESULTS AND DISCUSSION

TABLE 1 shows the analysis of the sugar industry sludge. It shows the high moisture content and COD - 92000mg/l. Out of total solids of 34,100 mg/l, TDS 21,200mg/l and 12,880mg/l was TSS. The pH was around 8.0 i.e. alkaline in nature. The tub containing sugar mill sludge incorporated with standard bedding material was inoculated with two earthworm species and incubated at room temperature for a period of 90 days showed interesting results.

TABLE 1 : Physico-chemical characteristics of sugar mill industry sludge.

Sr. No.	Parameters	Results
1.	pH	8.0
2.	Chemical Oxygen Demand (COD)	92000
3.	Total Solids	34100
4.	Total Dissolved Solids	21220
5.	Total Suspended Solids	12880
6.	Nitrogen (%)	0.35
7.	Phosphorous(%)	0.60
8.	Potassium(%)	0.82

The reproductive pattern of the two earthworm species (*E. foetida and P. excavates*) in different concentration of sugar industry sludge amended media is illustrated in TABLE 2. Comparative studies using two earthworm species and waste were carried out to evaluate the potential of earthworm species in composting and survival in different concentration of sludge amended media. Only 100% survival of the earthworms occurred in different sludge amended concentrations, were selected for further study. When comparing the 100% survival of the both species, *E. foetida* survived at higher concentration (i.e. 35% sludge amended media) whereas *P. excavatus* survived at lower concentration of waste (i.e. 25% sludge amended media). At higher concentrations of waste amended media, both species showed behavioral changes i.e. oozing of celomic fluid, shrinking of the body etc. Since these changes were also hampering the biomass of the earthworms, such higher concentrations were not selected for the experiments.

Earthworm in most of the concentrations of the sludge amended media started to produce cocoon only after 1-3 week. This is because it needs some days to acclimatize to high concentration of sugar mill sludge. The higher values recorded in both the experimental sets (with sludge amended media) than the control (without sludge media). This result showed the industrial sludge media support the growth of both the species. In *E. foetida*, maximum number of the cocoons (n= 45) was recorded at 25% concentration of sludge amended media. At 10% sludge amended concentration showed maximum cocoon production (n= 30) for *P. excavatus* species. Chan et al reported increase in number of earthworm up to 39.5 fold in horse manure (without wastes) and 26 fold in cow manure, similarly the greatest number and biomass of hatchling was recorded in horse excreta followed by cow, goat and sheep[5].

TABLE 2 : Reproductive strategy of two different earthworm species over 90 days.

Earthworm species	Concentration	Cocoon	Juveniles	Nonclitellates
Eisenia foetida	Control	29	10	7
	5%	32	10	7
	10%	37	12	8
	15%	40	14	8
	20%	42	16	10
	25%	45	20	11
	30%	43	18	8
	35%	34	15	9
Perionyx excavatus	Control	22	7	4
	5%	26	8	5
	10%	30	8	6
	15%	28	7	5
	20%	25	6	4
	25%	23	5	4

During this experimentation, changes in biomass of the both species were observed (TABLE 3). The mean initial biomass of *E. foetida* species was 0.152 (±0.0026) gm and *P. excavatus* was 0.165 (± 0.0046). After the 90 days of vermicomposting period, biomass of the *E. foetida* species showed higher weight [0.273 (±0.003)gm] at 25% sludge amended concentration and *P. excavatus* showed higher weight [0.280 (±0.002)gm] at 15% of the sludge amended media. Vermicomposting the two earthworm species showed statistical increase ($p<0.05$) in biomass when compared with the initial weight of the species. Comparing both species, biomass was not significantly different ($p>0.05$) that means *E. foetida* and *P. excavatus* species achieved the similar weight after 90 days of composting period and their performance in vermicomposting at 25% and 15% of sludge amended media was comparable respectively. Species *P. excavatus* showed maximum weight (662.05mg) after 120 days in MIXED (mixed crop residues + cow dung in 1:1) substrate[27].

TABLE 4 shows change in the chemical properties of sugar industry sludge after 90 days of vermicomposting period within two earthworm species. Species *E. foetida* and *P. excavatus* were used for vermicomposting to check the efficiency of the two earthworm species in vermicomposting of sugar industry sludge.

Unpalatable aromatic substances produced both by plant material and micro organisms at early stages of

TABLE 3 : Changes in the biomass of the two earthworm species before and after 90th days of vermicomposting period.

	E. foetida (gm)	*P. excavates* (gm)
Initial weight	0.152±0.002	0.165±0.004
Control	**0.255±0.003	**0.270±0.002
5%	***0.260±0.005	***0.274±0.0035
10%	**0.260±0.005	***0.285±0.0026
15%	***0.263±0.002	**0.280±0.002
20%	***0.270±0.004	*0.278±0.0069
25%	***0.273±0.003	*0.274±0.0017
30%	**0.270±0.003	---
35%	**0.270±0.004	--

(* Extremely Significant p <0.001, ** Very Significant p = 0.001 to 0.01, * Significant p value 0.01 to 0.05) All values are the mean of three replicates with + S.D.**

decomposition as recorded earlier[17]. With the advancing progress of decomposition pH of the material decreased slowly, with a lower trend in the both experimental set in comparison with initial concentration. CO_2 and organic acid produced during microbial metabolism probably decrease the pH during composting[12]. It is likely that the comparatively lower pH (nearly neutral) during vermicomposting process is due to the additional contribution made by earthworm. Decreased in the pH within two species of earthworm was not significant. When comparing the initial and species values, it was extremely significant decreased at 25% concentration of sludge amended media than remaining concentrations in case of *E. foetida*, whereas it was at 10% in case of *P. excavatus* species. pH values were decreased significantly in all sludge amended media in case of both the species rather than control (Without Sludge amended media).

Ravindran et al.[23] observed total organic carbon was lower in the vermicompost than that of the control sample. In the experimental set of *E. foetida*, and *P. excavatus* carbon level showed statistically significant decrease trend as compared with initial (before treatment) concentrations ($p<0.05$), while in comparison of both the species organic carbon level was not significantly different ($p>0.05$). Decreasing trend of the carbon content, during composting is indicated degradation of waste material. Carbon level decrease after vermicomposting treatment (with worm) compared with initial values. These results indicated that earthworms accelerated the decomposition process of the organic matter. Similar kind of the results were also reported by Sutar[25], and Gupta and Garg[10].

Total nitrogen content was significantly increased in the experimental sets (Sludge amended) than in control (without industrial sludge).This result showed industrial sludge help in improving the nitrogen content which is essential for the growth of plant. The higher percentage of nitrogen was obtained in the experimental sets of *E. foetida* species 1.80 (±0.200) N% at 25 % amended sludge and in *P. excavatus* 1.6 (±0.346, ±0.036) N% at 10% and 15% amended sludge respectively. The relatively high level of the nitrogen in vermicomposting was contributed by earthworm through excretion of $NH4^+$ and secretion of mucus. Nitrogen content in both earthworm species like *E. foetida* and *P. excavatus* was not significantly different. Total nitrogen content increased significantly with addition of Urea up to 2% in comparison with control but decreased thereafter[24], loss of nitrogen was found more in 4% urea treatment. As like earlier study, trends of increase and decrease of nitrogen was observed in present study. According to Karokin[14], the number of cellulolitic microorganism conserved nitrogen by decreasing the number of denitrifying bacteria.

Although earthworm have great impact on retaining nitrogen in nitrate form the initial nitrogen present in the waste and the extent of decomposition will decide amount of TKN in the Vermicompost. The increase in total phosphorous during vermicomposting is probably due to higher phosphatase activity of earthworm contributing to mineralization and mobilization of phosphorous[6,7]. Total phosphorous content of experimental set (with sludge amended) also showed higher values than control (without industrial sludge). The decreasing trend of phosphorous was in *E. foetida* (2.6±0.200 at 35 % sludge amended) >*P. excavatus* (1.80±0.100 at 10 % sludge amended). While values of the phosphorous compared within two species of experimental sets was also not significantly different. Ghosh et al.[9] reported higher levels of transformation of phosphorous from organic to inorganic state and thereby into available forms during vermicomposting. Same observation was recorded in this experimentation as well.

The values of the potassium compared within two species of experimental sets were significantly different,while experimental sets of the both species shows increased in trend as compared with initial values (Before vermicomposting). Experimental set of the *E. foetida* species showed higher increase in potas-

TABLE 4 : Changes in physico-chemical parameters, during the sugar industry sludge (before and after 90th days (n=2))

Parameters		Control	5%	10%	15%	20%	25%	30%	35%
pH	Initial	7.80±0.050	8.10±0.060	8.25±0.265	8.30±0.173	8.36±0.069	8.40±0.132	8.41±0.021	8.42±0.069
	E. foetida	***7.40±0.020	***7.30±0.044	***7.28±0.020*	***7.26±0.026	***7.19±0.010	***7.15±0.036	7.25±0.010	7.25±0.050
	P.excavatus	***7.42±0.036	***7.32±0.053	***7.20±0.035	***7.22±0.036	***7.23±0.020	***7.25±0.246	-----	-----
Organic Carbon (%)	Initial	35.00± 0.265	37.10± 0.173	38.00± 0.100	38.60± 0.087	39.40± 0.111	39.90± 0.265	40.10± 0.265	40.30±0.100
	E. foetida	***28.1±0.020	***27.8±0.130	***27.20±0.027	***26.90±0.174	***26.40±0.020	***25.2±0.050	26.40±0.050	26.65±0.092
	P.excavatus	***28.3±0.100	***28.0±0.173	***27.80±0.017	***27.80±0.027	***29.00±0.218	***29.6±0.200	-----	-----
Nitrogen (%)	Initial	0.50±0.100	0.60±0.020	0.70±0.265	0.72±0.010	0.76±0.020	0.80±0.173	0.86±0.069	0.90±0.200
	E. foetida	**1.40±0.200	***1.54±0.036	*1.61±0.200*	***1.68±0.035	***1.72±0.035	*1.80±0.200	1.78±0.020	1.70±1.000
	P.excavatus	**1.20±0.200	***1.40±0.020	*1.60±0.346	***1.64±0.036	***1.50±0.027	***1.40±0.346	-----	-----
Phosphorous (%)	Initial	0.70±0.173	0.82±0.040	1.00±0.173	1.08±0.020	1.12±0.040	1.12±0.030	1.19±0.017	1.22±0.173
	E. foetida	**1.30±0.200	***1.57±0.027	**1.80±0.200	***1.88±0.017	***1.95±0.027	**2.00±0.050	1.95±0.100	1.94±0.200
	P.excavatus	*1.10±0.100	***1.40±0.010	**1.80±0.100	***1.78±0.030	***1.70±0.010	1.60±0.200	----	----
Potassium (%)	Initial	1.10±0.200	1.14±0.040	1.14±0.040	1.25±0.087	1.54±0.079	1.70±0.173	1.87±0.044	1.90±0.100
	E. foetida	***2.30±0.200	*2.80±0.010	*3.20±0.200	**3.50±0.020	***3.80±0.020	**4.00±0.347	3.70±0.040	3.50±0.200
	P.excavatus	**2.90±0.020	***3.20±0.265	**3.80±0.346	***3.20±0.173	***3.20±0.100	3.40±0.300	----	----

(* Extremely significant p < 0.001, ** Very significant p = 0.001 to 0.01, * Significant p value 0.01 to 0.05) All values are the mean of three replicates with + S.D.**

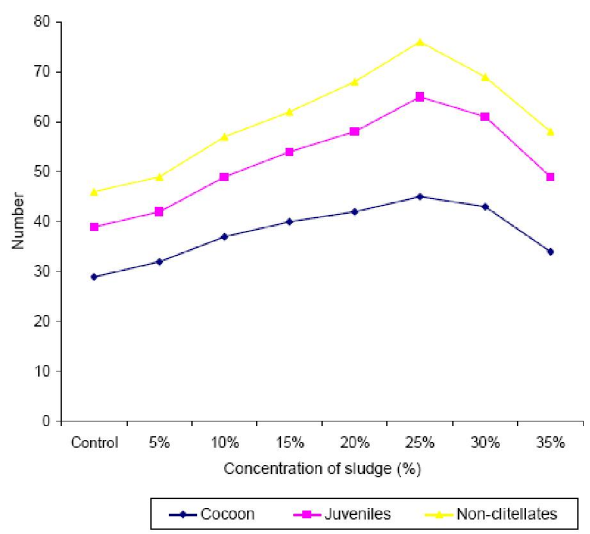

Figure 1: Reproductive strategy of *Eisenia foetida* species at different concentration of sludge amended media

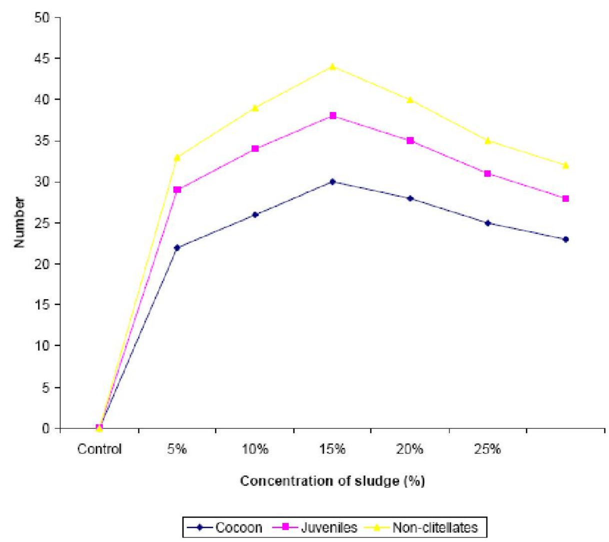

Figure 2: Reproductive strategy of *Perionyx excavatus* species at different concentration of sludge amended media

sium content than *P. excavatus*. The highest value for potassium was observed at 25% sludge amended concentration (4.0 ± 0.347) in case of *E. foetida* whereas 3.8 ± 0.346 at 15% sludge amended concentration in case of *P. excavates*. However during earlier studies the Vermicomposting of livestock excreta using *E. foetida*, total potassium was lowed in the final cast than the initial feed while increased in nitrogen and phosphorous content[7]. This conclusion was supported by the work of [8], where during vermi-stabilization of textile mill sludge spiked with poultry droppings by *E. foetida*. Therefore the difference in the observations can be attributed to the differences in the chemical nature of initial raw material.

Increased NPK content in the compost was observed by Parthasarathi and Ranganathan[22]. Tripathi and Bharadwaj[27] also observed increased in NPK in the composting material taking cow dung using the species *Eisenia foetida*. In this work increased in NPK during the course of composting of sugar industry sludge has also been observed. The present findings are in agreement of Uthaiah[28], Jeyabal and Kuppuswamy[13], Parthasarathi and Ranganathan[22] and Muthukumarasamy et al.[16] as quoted by Kitturmath et al.[20], who observed increased nutrient content of Vermicompost obtained from bagasse and coir waste.

CONCLUSION

Eisenia foetida tolerate to higher concentration of sugar mill sludge than Perionyx excavatus species. Addition of sugar industry sludge to bedding materials is helpful for improving reproduction of both the earthworm species and nutrient contents also increased in vermicompost. The organic carbon content in the waste material was reduced than its initial concentration after 90th days of experimentation, which indicates decomposition of waste material. The efficiency of *Eisenia foetida* and *Perionyx excavatus* was observed to be comparable in 25% and 10% sludge amended media respectively without any statistically significant difference. Bio-management of sugar mill industry sludge has been successfully achieved when this waste material mixed with bedding material with proportion of 25% and 10% for *Eisenia foetida* and *Perionyx excavatus* respectively.

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