VERMISTABILIZATION OF WATER HYACINTH AND SECONDARY SEWAGE SLUDGE: A SUSTAINABLE APPROACH

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ABSTRACT

Water hyacinth, the invasive aquatic macrophyte, can be used as a bulking agent in vermicomposting of secondary sewage sludge. Vermicompost was obtained from different ratios of water hyacinth (WH) and secondary sewage sludge (SS). First set was prepared with 25 % WH + 75 % SS (Set 1), and the second set with 50 % WH + 50 % SS (Set 2). Vermicomposting of these two sets was done using the earthworm species *Eisenia fetida*. A seed germination test was performed to compare the efficiency of compost with normal (garden) soil. Four different seeds were taken for the experiment: Moong bean *(Vigna radiata)*, Guar *(Cyamopsis tetragonoloba)*, Fenugreek *(Trigonella foenum-graecum)*, and Mustard seeds *(Brassica nigra)*. After 7 days of growth, the seed vigour index was calculated for each seedling. Seeds grown in vermicompost obtained from sets 1 and 2 showed a higher seed vigour index compared to garden soil. It can be concluded that vermicompost obtained from these two substances is suitable for planting.

Keywords: *sewage sludge, water hyacinth, Eisenia fetida, vermicompost, seed vigour index*

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is one of the most troublesome invasive weeds that has resisted physical, biological and chemical methods of decimation [1]. Under the condition of optimum temperature and moisture, water hyacinth can double itself in just 5 days [2]. The water loss of a surface covered with water hyacinth is eight times more than the uncovered surface [3]. Because of its clogging nature and good absorbance of macronutrients, like potassium, nitrogen, and phosphorus from water, it can be used as a substrate in vermicomposting. One of the properties of water hyacinth is its decaying nature. Because of that, composting is a good alternative for its eradication [4, 5]. Some researchers have carried out vermicomposting of water hyacinth in combination with different materials, like cow dung, poultry litter, grass clippings, and pig manure using different earthworm species, such as *Eisenia fetida, Perionyx excavates*, and *Eudrilus eugeniae*. [1, 3, 5 - 10].

Downstream from Tapi, before it meets the Indian Ocean in the Dumas region of Surat, it passes through the city. Tapi river is also the main source of water supply for the entire city.

Surat is the fastest growing city in India in terms of urbanization and industrialization. Because of this, numerous openings of sewage systems discharge sewage water into the Tapi River. This water is rich in phosphorus and nitrogen, which leads to the development of water hyacinth.

Currently, the Surat Municipal Corporation has established nine sewage treatment plants. These plants are also the origins of secondary sewage sludge, by-product that is dangerous for the environment [11]. The previous studies show successful vermicomposting of sewage sludge with earthworm species, such as *Eisenia fetida, Eisenia Andrei, Eudrilus eugeniae,* and *Perionyx excavates* [11 - 16]. The main objective of this study is the valorisation of both the substrates, water hyacinth, and secondary sewage sludge by vermistabilization.

Seed vigour is one of the properties which determines the growth and development of normal seeds under a variety of environmental conditions [17]. In this study, the seed vigour index was determined to evaluate the quality of the procured vermicompost.

MATERIALS AND METHODS

Sampling site

Tapi river supplies water to the entire Surat city and is heavily affected by water hyacinth [18]. For this study, four sampling sites were selected along the river bank that are strongly affected by water hyacinth: (1) Kurukshetra Smashan Bhumi (21.242853, 72.793925), Jahangir Pura, (2) Amroli Bridge region (21.234395, 72.842248), (3) Patidar Bridge region (21.229252, 72.878412), (4) Khadi Maholla region, Nana Varachha, Surat (21.229155, 72.886777) (Figure 1). The average distance between the two investigated sites is approximately 3900 m.

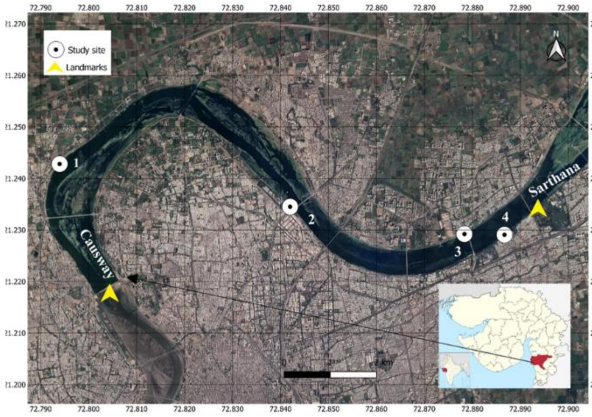

Figure 1. Water hyacinth sampling sites

Water hyacinth was collected from the locations between causeway (check dam) to Sarthana, Surat. In this region, river water flow is very slow and mostly static, except in the monsoon season. Because of that, clogging with water hyacinth is higher in these areas.

Collection of samples

Water hyacinth (WH) was collected from various locations on the Tapi riverbank, Surat (Gujarat, India) during February 2022. After collection WH was washed with tap water to remove dust and other unwanted material and then dried in the sun for 12 to 15 days. Dried WH was ground into powder using a laboratory grinder and stored in an airtight container for further analysis.

Secondary sewage sludge (SS) was collected from Tertiary Sewage Treatment Plant, Bamroli, Surat (Gujarat, India). Collected SS was dried in the sun for 5 to 6 days. Then it was ground into powder using a laboratory grinder for further experiments.

Earthworms (*Eisenia fetida*) used for vermistabilization of both substrates were collected from Ambikaniketan Gaushala, Kosmada, Surat (Gujarat, India). Partially decomposed garden waste with cow dung was placed in a rectangular container (130 cm × 65 cm × 50 cm), and then earthworms were inoculated for cultivation.

Precomposting

Two sets (Set 1: 75 % SS + 25 % WH and Set 2: 50 % SS + 50 % WH) were prepared by mixing powdered WH and SS by weight. The material was added in a rectangular plastic container and moisture content (60 - 70 %) was maintained by spraying water. For 7 days, the mixture was turned for aeration and also for the removal of volatile gases. During the initial 2 - 3 days of precomposting, the increase in temperature was observed. The precomposting process is necessary to overcome this rise in temperature. After that, the temperature was stable and favourable for the earthworms.

Experiment setup

The overnight soaked cardboard was crushed in a laboratory blender to prepare cardboard bedding material for the experiment. For vermicomposting of the pre-composed material, a layer of the cardboard bedding was prepared in a rectangular plastic container (60 cm × 30 cm × 25 cm) [19]. A hundred mature clitellated earthworms were randomly selected from the stock culture. The weight and length of earthworms were measured and then the earthworms were introduced into the bedding material. The next day, a layer of 2 kg pre-composed material was added over the bedding material. Humidity was maintained up to 70 % by spraying with water. pH and temperature were measured every day. Every 15 days, a sample was taken from each set and dried at 60 °C to analyse physicochemical parameters, such as Total organic carbon (TOC) and Total phosphorus (TP). Total Kjeldahl nitrogen (TKN), Total potassium (TK), and C:N ratio were determined before composting and after vermicomposting of the substrate material. TOC was analysed by Walkey and Black titration method [20], TP by spectrophotometer (EPA Method 365.3) [21], TKN by Kjeldahl method [22], and TK by acid digestion method using flame photometer (Elico CL 361 Flame photometer). Initial physicochemical parameters of the substrate material are shown in Table 1. The experiment lasted for 45 days. After 45 days of vermicomposting, earthworms were removed by manual sorting and the number of earthworms was counted. The compost was taken and used for further analysis.

Table 1. Initial physicochemical parameters of substrate material

Parameters	Set 1	Set 2
pH	7.3 ± 0.40	7.8 ± 0.64
TOC (%)	18.68 ± 0.85	20.45 ± 0.87
TP (mg/kg)	133.33 ± 4.50	106 ± 6.24
TK (%)	0.090 ± 0.003	0.069 ± 0.004
TKN (%)	1.64 ± 0.05	1.34 ± 0.07
C : N ratio (%)	11.38 ± 0.89	14.86 ± 0.84

values are in form of mean ± S.D.; p value < 0.05

Effect of vermicompost on seedlings

Four seeds, i.e., *Vigna radiata* (Moong bean), *Cyamopsis tetragonoloba* (Gaur), *Trigonella foenum-graecum* (Fenugreek), and *Brassica nigra* (Mustard seeds) were grown in the obtained vermicompost from Sets 1 and 2. Garden soil was taken as control sample for comparison. Seeds were grown at the depth of 2.5 cm. Water was sprayed every day. After 7 days, the root length and shoot length of each seedling were measured. The seed vigour index was calculated from the root and shoot length [23]:

$$\text{Seedling vigour index} = (\text{Mean root length} + \text{Mean shoot length}) \times \%\ \text{seed germination}$$

Statistical Analysis

All data from three replicates for TOC and TP were analysed statistically by two-sample t-tests and the other parameters were analysed by two-way ANOVA using R software.

RESULTS AND DISCUSSION

Earthworm survival rate

The earthworm survival rate was 100 % during the experiment in sets 1 and 2. The physical parameters, pH, temperature, and moisture content were within desirable limits and favourable for the survival of the earthworms. Initially, 100 earthworms were taken for the experiment, and at the end of experiment, 112 ± 1.2 and 108 ± 1.8 earthworms were observed in sets 1 and 2, respectively. An increase in the number of individuals in both sets shows that the co-composting of WH and SS is suitable for the growth and reproduction of earthworms in the given proportions, and they can be used for vermicomposting.

Changes in physicochemical parameters

pH

At the initial stage of the experiment, pH of the substrate was 7.3 ± 0.40 and 7.8 ± 0.64 in sets 1 and 2, respectively. During the experiment, a minor variation in pH was observed. After 45 days of vermicomposting, the final pH of compost from sets 1 and 2 was decreased to 6.9 ± 0.32 and 7.1 ± 0.18. A decrease in pH during vermicomposting was also observed by other researchers [24 - 26]. The reason for the decrease in pH could be the production of ammonia, organic acid, and CO_2 due to microbial activity [11].

TOC and C : N ratio

During the experiment, TOC decreases with the time (Table 2). Unlike set 1, in set 2 TOC decreased linearly (Figure 2). Lower TOC concentration was the result of enhanced decomposition of the substrates [3, 27 - 28]. Lower TOC also indicates the greater stability of vermicompost [29]. The C : N ratio also decreases during vermicomposting (Table 3). Over time, the carbon is used by the microbes for the decomposition process, while the nitrogen is mineralized and converted into ammonia and nitrates [3]. C : N ratio of less than 20 shows stabilization of the organic waste [30].

Table 2. Changes in TOC (%) during the experiment

	Initial	15 days	30 days	45 days
Set 1	18.68 ± 0.85	15.50 ± 0.26	10.99 ± 0.22	10.14 ± 0.13
Set 2	20.45 ± 0.87	16.27 ± 0.42	11.8 ± 0.59	9.69 ± 0.59

values are in form of mean ± S.D.; p value < 0.05.

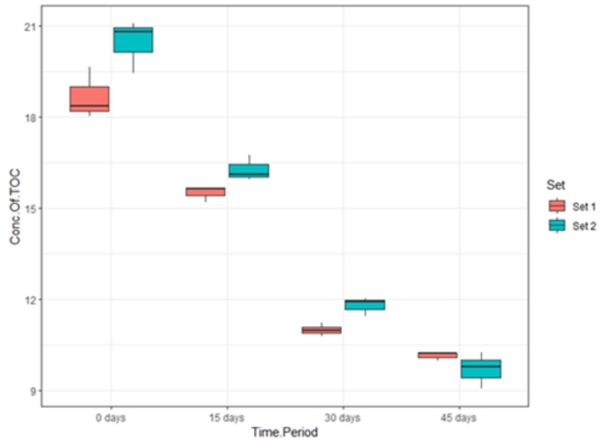

Figure 2. Decrease of TOC during the experiment

Table 3. TKN, TN, and C : N ratio before and after vermicomposting

	Set	TKN (%)	TK (%)	C: N ratio (%)
Before composting	Set 1	1.64 ± 0.05	0.090 ± 0.003	11.38 ± 0.89
	Set 2	1.34 ± 0.07	0.069 ± 0.004	14.86 ± 0.84
After vermicomposting	Set 1	2.83 ± 0.11	0.260 ± 0.04	3.85 ± 0.20
	Set 2	2.00 ± 0.09	0.141 ± 0.004	4.74 ± 0.05

values are in form of mean ± S.D.; p value < 0.05.

Macronutrients (TKN, TP, and TK)

Total nitrogen was increased by 77.35 % in set 1 and by 58.03 % in set 2 (Table 3). Nitrogen-fixing bacteria present in worm cast and nitrogenous waste of earthworms could be the reason for the increase in nitrogen content [6]. Another reason for increase in nitrogen could be the mineralization of organic matter [31 - 34].

The levels of total potassium (Table 3) and total phosphorus (Table 4) also increased in the final compost. In the case of set 1, a continuous increase of TP was observed. In set 2, TP content was initially low, and the highest value was observed after 15 days of the experiment. After an additional 15 days, the TP level decreased, and it increased again after 45 days of the experiment (Figure 3). The probable reason for the increased phosphorus level could be the ability of earthworms' intestines to convert phosphorus into the available form of phosphorus [7].

The enzymatic activity and acid production of earthworm gut microflora convert insoluble potassium into soluble potassium [11, 28]. Due to these activities in the earthworm gut, the level of the macronutrients increased in the final compost.

Table 4. Changes in TP (mg/kg) during the experiment

	Initial	15 days	30 days	45 days
Set 1	133.33 ± 4.50	137.40 ± 3.50	144.37 ± 5.73	147.58 ± 4.12
Set 2	106 ± 6.24	189.10 ± 2.71	141.33 ± 4.72	144.79 ± 5.50

values are in form of mean ± S.D.; p value < 0.05.

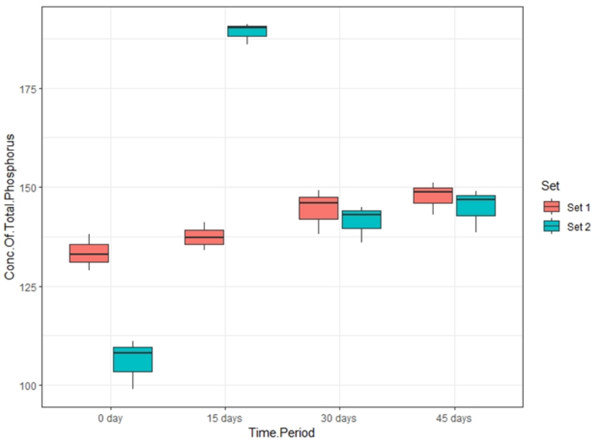

Figure 3. Increase of TP during the experiment

Seed vigour index

Moong seeds *(Vigna radiata)* show a higher vigour index in compost prepared from set 2 compared to the control sample (garden soil) (Table 5). On the other hand, Guar *(Cyamopsis tetragonoloba)* and Fenugreek *(Trigonella foenum-graecum)* seeds show a higher vigour index in compost obtained from set 1. Except for Mustard seeds *(Brassica nigra)*, all other three seeds showed a higher vigour index in compost prepared from the WH and SS than in the garden soil. A higher vigour index of seeds (except for Mustard seeds) indicates better seedling growth in the vermicompost compared to normal garden soil. Therefore, the compost is suitable for the plants from the Fabaceae family (Moong, Guar, and Fenugreek). Some researchers have also used vermicompost obtained from water hyacinth as a growing medium for planting Lilies [35]. From the results, it can be said that the obtained vermicompost can be used as a potting amendment.

Table 5. Seed vigour index

	Vigna radiata	*Cyamopsis tetragonoloba*	*Trigonella foenum-graecum*	*Brassica nigra*
Control (garden soil)	1734.26	836.77	407.52	575.60
Set 1	1917.64	843.22	443.64	321.67
Set 2	1970.72	550.96	424.02	129.70

CONCLUSION

The use of SS and WH as raw materials for vermicomposting can help eliminate the wastes and produce value-added vermicompost. A mixture of WH and SS was favourable for the growth of *Eisenia fetida*. It was found that the final product from the experiment is more homogenous and stabilized than the initial material from sets 1 and 2. The obtained vermicompost was rich in nitrogen and phosphorus. Potassium content was slightly lower in the obtained vermicompost compared to other fertilizers. Both vermicomposts from sets 1 and 2 had almost the same amount of macronutrients. Seed vigour index had higher values in vermicompost from set 1 (75 % SS + 25 % WH) than in set 2 (50 % SS + 50 % WH). Therefore, vermicompost from set 1 may be more beneficial for seedling growth. However, further research is needed to assess the quality of the produced vermicompost. From this study, it can be concluded that both SS and WH can be used to obtain nutrient-rich fertilizer using the vermicomposting method, and the obtained vermicompost can be used as a bio-fertilizer.

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