Chapter

Vermiconversion of Textile Industrial Sludge; Waste Management and Nutrients Recycling

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Abstract

The present study aimed for the conversion of textile industrial sludge (TIS) amended with the cow dung into vermicompost operated by the epigenic earthworm *Eudrilus eugeniae.* To accomplish the intent of the experiment, the substrate was allowed to decompose for 30 days, under monitored environmental conditions. Three different combinations were prepared ($V_{25\%}$, $V_{50\%}$, and $V_{75\%}$) from TIS, and compared with V_{agro} (vermicompost prepared from agricultural waste) and V_{soil}. Among the entire three treatments, $V_{75\%}$ was shown by physicochemical parameters for *Trigonella foenum* (Fenugreek/Methi) plant growth, seed germination, and leave production in the tested pot. The maximum amount of available nitrogen, phosphorus, potassium (NPK) was recorded at $V_{75\%}$. On the other side, toxic metal (Cr, Mn, Cu, Pb Cd, and Zn) concentrations were diluted to minimum levels. The result advised that vermicomposting consider one of the alternative methods for waste management and energy recovery from industrial waste.

Keywords: textile industrial sludge, agricultural waste, toxic heavy metal, vermicomposting, energy recovery, waste management

1. Introduction

The increase in solid waste generation in developing countries is more worrisome than in developed countries owing to the shortage of supply and the need for suitable disposal techniques. The research was prepared the vermibed from three different vegetable waste, rice straw and cow dung in a different ratio, and inoculated with two different species of earthworm (*Eisenia fetida and Perionyx excavates*) *E. fetida* showed that the total organic carbon (TOC) decreased, pH was falling to neutral and the NPK ratio, microflora (nitrogen fixing bacteria (NFB), phosphate solubilizing bacteria (PSB), and total bacteria) was raised by vermicomposting [1]. Sludge generation in industries is generally a solid/semi-solid substance, which is contaminated with toxic elements and other contaminants. Generated waste management and recovery of energy is a difficult procedure. It is directly related to technological progress, economic growth, and industrialization. Various industries, such as pulp, paper, sugar, cement, tanneries produce sludge and disposal. To manage industrial waste, safe, eco-friendly, cost-effective, and socially acceptable techniques are needed [2]. Industrial sludge, irrespective of scale or location, presents a major challenge for all Indian industries as a result of strict national disposal requirements. Industrial growth has led to the higher production of goods, and enhanced urban livelihoods, but has degraded cities' environmental quality. The major issues faced due to toxic industrial wastes include: (a) groundwater and surface water pollution by the toxins in the sludge by leaching, (b) contamination caused by the heavy metals and chemicals present in the sludge, (c) color imparted on water or soil, (d) odor issue, and (e) risk to human health that calls for public concern. There have been several strategies for the disposal of solid waste worldwide. Open dumping, land-filling, composting, thermal drying, and incineration are some of the major techniques used for disposal of solid waste. Each approach has both benefits and disadvantages. There is no single approach with absolute applicability [3]. Industrial waste disposal methods are expensive and hard to handle, integrating the biosolid waste composting with vermistabilization provides a sustainable development value [4]. Industrial sludge disposal practicing on open roadsides/railway track beside and in agricultural fields in addition to poorly designed and maintained landfill sites by various Indian industries owing to high capital needs, operational costs for sludge treatment, and stricter waste disposal regulations, where there is a huge risk of soil or water contamination and health hazards eventually damage to the ecological balance. Also, open dumping is impractical as after a certain period there will be a limitation in open spaces. Because of the costs of installing sludge stabilization and dehydration systems, sludge management remains a challenging task [5].

Textile industrial sludge (TIS) comprises a mixture of organic and inorganic heavy metal complexes, such as Fe, Cu, Cd, Zn, and Cr. Textile industrial use various dyes and chemicals are employed in various steps and the emissions polluted with different inorganic and organic chemicals [6]. As compared to conventional methods of disposal methods, such as land-filling and incineration, vermicomposting is a better option ecologically and economically [7]. The industrial sludge stabilized by vermicomposting will reduce the toxic elements in the compost, moreover, it may apply in agricultural practices [8]. Agricultural solid residue can be converted and used for plant growth, it can provide nutrients and enhance the quality of the soil [9].

2. Methodology

2.1 Sample collection

Samples were collected from the textile industry where completely organic dyes are being used for coloring the bed materials. Therefore, the wastewater and sludge were containing organic waste. That helps to easily degrade the mechanism for earthworms.

2.2 Textile industrial sludge

It was collected from the textile industry, in Gujarat, India. It was allowed to air dry and converted to a fine powder. The main chemical characteristics were analyzed pH (8.12), TOC (15.7%), available nitrogen (890.6 kg/ha), available phosphorus (167.9 kg/ha), available potassium (3160.6 kg/ha), and C:N ratio as 394.8.

2.3 Cow dung

Raw cow dung was brought from a cow farm. Major properties of the cow dung were pH (8.12), TOC (16.6%), available nitrogen (752.6 kg/ha), available phosphorus (46.1 kg/ha), available potassium (2383.2 kg/ha), and the C:N ratio 494.

2.4 *Eudrilus eugeniae*

Healthy earthworms (*E. eugeniae)* were collected randomly from the vermiculture.

2.5 Stoichiometry

Sampled waste materials were dried under sunlight, dehydrated waste crushed into powder, and then poured into four different ports for decomposition.

2.6 Experimental design

Three feed mixtures had distinct ratios of TIS and cow dung, together one filled with only cow dung (CD). One-and-a-half-liter cylindrical mud vessels were lined with a layer of rice straw and packed with 600 g of crushed and air-dried CD in pot-1 (V_C), 450 g of crushed and air-dried CD with the combination of 150 g crushed and air-dried TIS in pot-2 ($V_{25\%}$), 300 g of crushed and air-dried CD and 300 g of crushed and air-dried TIS in pot-3 ($V_{50\%}$), and finally, 150 g of crushed and air-dried CD and 450 g of crushed and air-dried TIS were in the pot-4 ($V_{75\%}$) (**Table 1**). Vessels remained under darkness with room temperature 22–26°C and maintained moisture by 60–80% by sprinkling the required amount of water over the experiment period. To provide additional aeration, and overcome the volatile toxic chemicals the blend was tuned manually after 15 days we introduced 40 healthy earthworms (*E. eugeniae*) to the pods and coved the pods with a green mesh cloth to protect earthworms from rodents and heat. After 30 days decomposed mixture from the pod was taken out, separated the cocoons were allowed to be air-dried, finally, compost was grained and stored in plastic cylindrical pods for further applications.

2.7 Chemical analysis

Homogenized samples were collected from the reactor vessels and recorded the physicochemical parameters with different standard methodologies, pH and EC were recorded by pH conductivity meter, bulk density, porosity, and water holding capacity of vermicompost were taken and estimated in sediment [10]. Total available nitrogen, phosphorous, and potassium were estimated with the Kjeldahl method [11], Estimated the C:N ratio based on the measured quantity of C and N [12], TOC, and organic matter concentration (OMC) of the sample was recorded with the help of the titration method [13], heavy metals, such as Al, Ba, Cd, Co, Cr, Cu, Li, Mn, Mo, Ni, Pb, and Zn were estimated by the adaptation of atomic absorption spectrophotometer [14].

2.8 Seed germination and plant growth observations

Six pods were collected and filled with 250 g of soil and added 25 g of prepared vermicompost to V_C, $V_{25\%}$, $V_{50\%}$, and $V_{75\%}$, another cylinder V_{agro} has filled with prepared vermicompost, finally, the sixth pot V_{soil} was poured soil only it left without

Physico-chemical parameter	Treatment 1 (25% TIS)			Treatment 2 (50% TIS)			Treatment 3 (75% TIS)		
	Control	Inceptive	Eventual	Control	Inceptive	Eventual	Control	Inceptive	Eventual
pH	7.32 ± 043	7.82 ± 0.9	7.12 ± 1.01	6.24 ± 0.26	7.01 ± 0.45	6.97 ± 1.41	7.23 ± 1.11	6.98 ± 1.31	6.55 ± 1.28
EC (dS m^{-1})	690 ± 97	982 ± 91	1435 ± 37	728 ± 30	1107 ± 40	1967 ± 113	942 ± 118	1327 ± 103	2140 ± 73
Available nitrogen (kg/ha)	1354.7 ± 20.3	1402.1 ± 20	1517.8 ± 96.5	1312.6 ± 98.3	1498.7 ± 176.9	1618.1 ± 84	1526.8 ± 114.1	1672.1 ± 117.7	2101.8 ± 77.4
Available phosphorus (kg/ha)	254.1 ± 12	291.0 ± 69.9	362.2 ± 51.1	213.4 ± 193.42	289.7 ± 76.5	357.2 ± 11.1	268.6 ± 13.9	308.9 ± 21.4	383.5 ± 11.1
Available potassium (kg/ha)	4393.4 ± 204.2	4983.2 ± 848.8	6898.4 ± 755.2	4583.9 ± 449.3	5019.7 ± 87	8570.6 ± 136.4	5019.3 ± 996.1	7829.5 ± 108.2	10306.4 ± 178.4
Ca^{2+}%	8.0 ± 1	11.6 ± 1.5	15.2 ± 0.9	8.7 ± 0.8	10.2 ± 1.1	18.4 ± 1.2	8.7 ± 1.3	12.6 ± 1.2	27.2 ± 0.9
Mg^{2+}%	14.2 ± 1.1	15.1 ± 1	18.8 ± 1.3	14.6 ± 1.2	16.3 ± 0.4	20.4 ± 1	14.4 ± 1.3	17.9 ± 1.5	22.8 ± 1.4
Na^{+}%	1.22 ± 0.11	1.41 ± 0.11	2.54 ± 0.33	1.28 ± 0.16	1.41 ± 0.1	2.67 ± 0.68	1.26 ± 0.24	1.32 ± 0.05	2.97 ± 0.79
Bulk Density (g/cm^3)	0.64 ± 0.05	0.61 ± 0.07	0.51 ± 0.09	0.63 ± 0.11	0.62 ± 0.09	0.37 ± 0.08	0.64 ± 0.11	0.60 ± 0.09	0.25 ± 0.132
Porosity (%)	75.34 ± 5.22	77.92 ± 6.47	82.01 ± 2.01	75.26 ± 5.14	76.82 ± 6.7	90.32 ± 1.09	75.82 ± 0.85	77.26 ± 0.99	93.58 ± 1.34
TOC (%)	14.9 ± 1.1	14.2 ± 1.1	12.8 ± 1.2	14.7 ± 1.2	13.1 ± 0.8	10.08 ± 1.04	14.8 ± 1.4	09.2 ± 1.1	06.1 ± 0.9
C:N ratio	246.3 ± 32.1	241.1 ± 39	188.9 ± 14.3	245.8 ± 44.2	2440.5 ± 426.3	138.4 ± 13.2	246.7 ± 15.3	213.8 ± 12.3	65.00 ± 0.79

Note: All of the parameter values were mean values of five times repeated experiments.

Table 1.
Physico-chemical parameters with a standard deviation of TIS in different composition allowed to vermicompost (30 days).

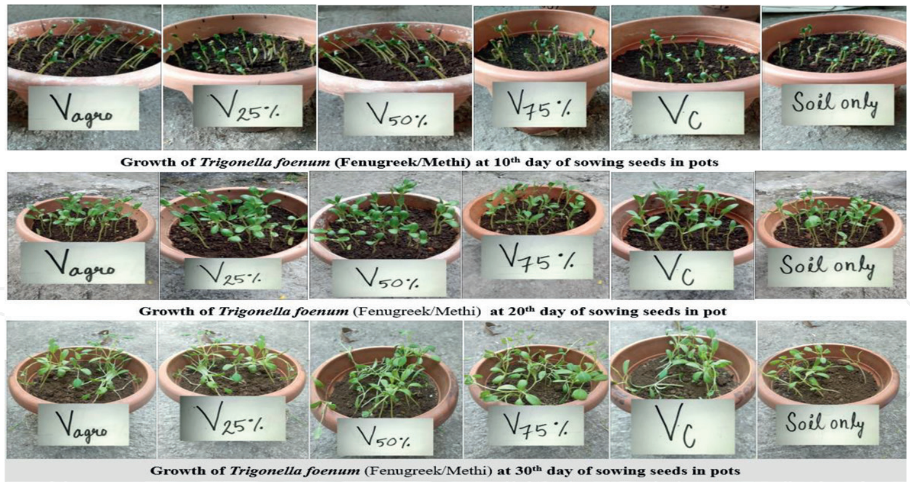

Figure 1.
Effects of prepared vermicompost (textile sludge compost) on T. foenum germination, growth, and leaves production in the pot (Vagro, $V_{25\%}$, $V_{50\%}$, $V_{75\%}$, VC, and V_{soil}).

adding prepared vermicompost. After that in each pot, 30 soaked seeds of *Trigonella foenum* (Fenugreek/Methi) were sown and the six pots were monitored in regular intervals for seed germination, recording the aspects, such as the number of seeds germinated, the number of leaves produced, and measuring the plant height in 10 days frequent intervals of 30 days' time period (**Figure 1**).

3. Result and discussions

3.1 Mineral consignment of prepared vermicompost

Vermicompost prepared by various treatments on the expanse of feedstock after 30 days, the final product was more stable, odour free, appear dark brown, and enriched with nutrients. Newly formed vermicompost physicochemical parameter changes were recorded (**Table 1**). pH vermicompost was prepared with cotton industrial waste with a combination of sheep manure and the decomposition was carried by earthworms, they were observed that the pH was reduced. On the other side, compared with the vermicompost prepared without earthworms' treatment, cation exchange capacity (CEC), total mineralization was raised and total nitrogen was decreased but at the same time nitrates were raised in the prepared vermicompost [15]. pH plays an important role in vermicompost for encouraging plant growth, in this study, we observed the gradual reduction of pH in treatment 1–3 after 30 days of decomposition (T_1–T_3), the pH decreases due to the conversion of N, P, and organic material into nitrates, orthophosphates, and organic acids, it was helpful to identify the alkalinity nature. In this analysis, $V_{25\%}$ were recorded and exhibited maximum pH reduction from 7.82 to 7.12 with a standard deviation value of 0.9–1.01, the lowest reduction was noticed in $V_{50\%}$ 6.97 with a value of the standard deviation of 1.41, and the medium pH reduction was observed in $V_{75\%}$ treatment 6.55 with a standard deviation value of 1.28 (**Table 1**).

3.2 Electrical conductivity

EC measured based on the formation of TDS (total dissolved salts) in the decomposed substrate (vermicompost), it decreases in compost and vermiwash while decomposing time, moisture concentration in vermicomposting increases the electrical conductivity it can be observed in bio-fertilizers [16]. Increased electrical conductivity was observed in the decomposed vermicompost (after 30 days) due to the release of various minerals salts in available form, the highest EC was noticed in $V_{75\%}$ treatment 2140 dSm^{-1} with a standard deviation value of 73 and the lowest EC was recorded in $V_{50\%}$ 1967 dSm^{-1} with a standard deviation value of 113 (**Table 1**). Stabilized, textile sludge is a good source of nutrients, it contains various organic molecules and inorganic plant nutrients, which are essential for growth like NPK and many trace elements and can become a good fertilizer after vermistabilization free of chemicals and pathogens. It is an undesirable toxic bi-product from wastewater treatment plants and other industries; it can trigger biohazards in the environment [5].

3.3 Available nitrogen

Herbal and pharmaceutical effluents were exposed to vermitechnology, as the result, the wastewater and the herbal waste were converted to enriched nutrients [17, 18]. Yadav and Garg [2] demonstrated in their experiment, that bakery industrial sludge combined with cow dung generates valuable vermicompost, they set up the six plastic bins containing 100% CD + 0% bakery industry sludge (BIS) to 50% CD + 50% BIS and observed that all the bins showed a reduction in TOC, pH, and C:N ratio up to 65.4–83.5% but at same time increment was noticed in all bins. Maximum reduction in TOC and C:N ratio were observed in bin 1 in which the combination was 100% CD + 0% BIS and the highest increment in TKN (total Kjeldahl nitrogen) was in the bin in which the combination was 90% CD + 10% BIS and the highest increment in TAP (total available phosphorous) and TK (total potassium) content in bin 1 in which combination was 100% CD + 0% BIS and maximum biomass of worms were found in bin 6, which contain 50% CD + 50% BIS (**Table 1**). Utilization of sludge from recirculating aquaculture system (RAS) in vermicomposting and produced-mineral rich compost. They prepared the setup with 5%, 10%, 15%, and 20% RAS, respectively along with 200 g of shredded wheat straw with initial 70% moisture content and observed the percentage of RAS increased and an increased number of juvenile and cocoons were noticed. Moreover, the end product of this sludge holed a higher amount of available nitrogen, available phosphorous, and other minerals [19]. Available nitrogen was increased in decomposed vermicompost, it was observed that $V_{75\%}$ treatment raised from 1672.1 to 2101.8 kg/ha with a standard deviation value of 117–77, and the lowest available nitrogen concentrations were recorded in $V_{25\%}$ 1517.8 kg/ha with a standard deviation value of 96.5 (**Table 1**). Vermicompost from the sewage sludge along with cow dung, they set up the 4-treatment contained sewage sludge and cow dung in ratios 70:30, 80:20, 90:10, and 95:5. Treatment ratio contained 70:30 (SS:CD) and 80:20 (SS:CD) observed the highest survival and reproduction rate and in ratio 95:05 any earthworm did not survive and in ratio 90:10 observed the highest available nitrogen, available phosphorous and other minerals [20].

3.4 Available phosphorus

Biofertilizer was prepared from municipal sewage sludge (MSS) through the vermicomposting process using tiger worms (*E. fetida*) after 21 days of vermicomposting process available nitrogen was increased up to 19.6–35.7 mg/l, total phosphorous from 9.45 to 10.87 mg/l and TP from 3.44 to 4.80 mg/l, and conversion of MSS to vermicompost found to be 93% by weight and worm biomass showed 30% increment from its initial weight [21]. Mineralization and mobilization of phosphorus by bacterial and phosphatase activity of earthworms could be the main reason for phosphorus improvement in vermicompost. Maximum available phosphorus was recorded in $V_{75\%}$ 383.5 kg/ha with a standard deviation value of 11.1, and the lowest amount of available phosphorus was noticed in $V_{50\%}$ 357.2 kg/ha with a standard deviation value of 1.11 (**Table 1**). Textile mill sludge (TMS) along with cow dung (CD) can be utilized as the raw material for vermicompost, they inoculated three microbial species in their experiment and found out that as the cow dung concentration decreased the growth of microbes was also decreased but as the inoculation of microbes in vermibed increased, available nitrogen and available phosphate were increased comparison to which did not have any microbes inoculated in them, they also noticed that vermicompost which only contains CD was more productive for the growth and multiplication of all the three bacteria than CD + TMS vermicompost, *Azotobacter chroococcum* treated vermicomposts showed the maximum available nitrogen, *Pseudomonas maltophila* inoculated CD vermicompost showed the maximum available phosphorous and finalized that as the number of microbes increased during vermicomposting the available N, P also increased and C:N ratio also decreased [22].

3.5 Available potassium

Vermicomposting was carried out by utilizing a different variety of waste, such as textile sludge, agricultural residue, and vegetable waste, final compost was shown an increase in phosphorous (1.4–6.5 folds) and potassium (4.4–5.8 folds) concentrations in the feed mixture [23]. Available potassium was observed to be increased in prepared vermicompost (after 30 decomposition) due to liberation of different soluble mineral salts in organic matter decomposition, and the potassium mineral salts were present in the form of available. An increased amount of available potassium was noticed in all of the treatments among all of them $V_{50\%}$ was raised at a high concentration of 8570.6 kg/ha with a standard deviation value of 136.4 and the lowest increase was noticed in $V_{25\%}$ 6898.4 kg/ha with a standard deviation value of 755.2 (**Table 1**). Vermicompost was prepared from pig manure with dissolved organic matter and observed the effects on heavy metal behavior. Pig manure mixed with rice straw in different combinations. Concentrations of Cu and Zn in earthworms increased from 8.24 and 17.63 to 40.75 and 362.78 mg/kg separately after vermicomposting, and also increased their availability, the C:N ratio also decreased after vermicomposting from 10.37 to 8.60. The available NPK was observed to be increased after vermiconversion of pig manure with rice straws [24].

3.6 Calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+})

Vermiconversion of paper mill sludge by the earthworms drives the sludge into mineralization effectively and converts the bound form into free minerals forms, Ca, Mg, and Na concentrations were found to be more (12.9%) in treatment 2 [25]. Ca^{2+}, Mg^{2+}, and Na^{+} concentrations were increased in prepared textile vermicompost, among all the three treatments $V_{75\%}$ reactor recorded as highest concentrations of 27.2%, 22.8%, and 2.97% with standard deviation values of 0.9, 1.4, and 0.79, respectively, lowest concentrations were found in $V_{25\%}$ as 15.2%, 18.8%, and 2.54 with standard deviation values of 0.9, 1.3, and 0.33, respectively. Calcium concentration was more than the other elements in the prepared vermicompost, and earthworms (*E. eugeniae)* operated the mineralization effectively and converted a huge amount of Ca^{2+}, Mg^{2+}, and Na^{+} in the organic matter (**Table 1**). Vermicomposting of bakery waste and cow dung by employing the earthworms *E. fetida*, thus the resulting nutrient-rich vermicompost produced, it was highly stabilized and mineralized than the initial food sludge waste more over heavy metal concentration were raise was observed in the newly developed vermicompost [2].

3.7 Bulk density and porosity

It has been found that concentrations of the minerals were more in aquatic weeds than in prepared vermicompost, according to the Fertilizer Control Order [26] decrease in bulk density was due to the gut action performed inside the earthworm and it caused the particle size changes. The bulk density and porosity of the newly prepared vermicompost were analyzed and recorded, it was observed that the $V_{75\%}$ treatment contain less bulk density of 0.25 g/cm^3 with a standard deviation value of 0.132, and the highest porosity of 93.58% with a standard deviation value of 1.34, then the resulting water holding capacity of the prepared compost was more. $V_{50\%}$ treatment noticed a medium bulk density of 0.37 g/cm^3 with a standard deviation value of 0.08 and a medium porosity of 90.32% with a standard deviation value of 1.09, a higher bulk density (0.51 g/cm^3) with a standard deviation value of 0.09, and lowest porosity of 82.01% with a standard deviation value of 2.01 was recorded in the $V_{25\%}$ treatment (**Table 1**).

3.8 Total organic carbon

A study was conducted on food industrial sludge combined with various organic waste and allowed for decomposition and the final results were an increase in total nitrogen, phosphorous, sodium, and potassium at the same time decrease in pH, TOC, and C:N ratio was noticed [27]. TOC was observed in prepared vermicompost, the result suggested that a useful biodegradable pool of organic carbon was slowly used during the reduction of TOCs. In $V_{75\%}$, the maximum reduction was noticed at 06.1% with a standard deviation value of 0.9, and the lowest amount of TOC was noticed in $V_{25\%}$ treatment at 12.8% with a standard deviation value of 1.2, the loss was due to the utilization of carbon by earthworms and microbial consumption and the microbial respiration leads to loss of carbon in the form of CO_2 during the decomposition. Further, the rise in earthworms' population, due to the conversion of some part of the organic fraction of the substrate, can also cause the stabilization of organic matter by earthworms. The lowest TOC content indicates the richness of humic substances, stability, and maturity of compost (**Table 1**). The key concerns related to conventional thermophilic composting are the process takes a long period, the pace of turning of the waste, the size and volume of the materials are often needed to be decreased to provide the necessary surface area, and the loss of nutrients during the lengthy process and the final product is heterogeneous nature. In this composting process, to maintain aerobic conditions, the waste must be turned regularly or aerated in some other way. Mostly, this requires powerful and costly machinery to handle the residuals as efficiently as necessary on a massive scale [4].

3.9 C:N ratio

Vermicompost prepared from milk processing industrial sludge combined with sugarcane trash and cow dung. They prepared nine various combinations of vermibeds with MPIS, ST, and CD. MPIS (60%) + CD (10%) + ST (30%) and MPIS (60%) + CD (10%) + WS (30%) containing mixture show highest reduction, organic carbon and C:N ratio and it exhibited highest raised concentrations in available nitrogen, available phosphorous, and exchangeable potassium [28]. C:N ratios minimized with time in all the vermicomposting treatments, the decline in the C:N ratio may be due to the loss of carbon through microbial respiration in the form of CO_2. In the $V_{75\%}$ treatment, the maximum reduction of C:N ratio (65.0) with a standard deviation value of 0.79 was recorded and the lowest C:N ratio was noticed in $V_{25\%}$188.9 with a standard deviation value of 14.3 (**Table 1**). The research observed the N and P content after inoculation of *A. chroococcum* strains, *Azospirillum lipoferum*, and the phosphate solubilizing *Pseudomonas striata.* Total six treatments were prepared, such as T1-(V + *A. chroococcum*. Mac 27), T2-(V + *A. chroococcum* .54 – 1), T3-(V + *A. chroococcum* .35-47), T4-(V + *A. lipoferum*), T5-(V + *P. striata*), and T6-(V + *P. striata* + Mussoorie rock phosphate 1%). On day 0, the vermicompost initially contained only 1.40 (g/100 g) of N. On the 60th day following inoculation with *A. chrooccocum* (Mac 27), it was increased to 2.72 (g/100 g) Chrooccal (Mac 27). Similarly, N content increased to 2.53 and 2.50 (g/100 g) with inoculation of other Azotobacter strains. *P. striata* also increase the phosphorous content after inoculation in vermicompost [29].

3.10 Heavy metal concentration in vermicompost

Aquatic weeds accumulated with most of the essential elements can be used in the food chain, the paper deals with bioconversion of textile sludge decomposition with the help of earthworm feeding. Heavy metal concentrations of the textile sludge were decreased by the action of earthworm digitations. Significant toxic element (Cd, Cr, Ni, Cu, Pb, and Zn) reduction was observed in the co-vermistabilization experiment [30]. Heavy metal degradation in any substance is not possible but it can be reduced by implementing the recommended methodologies, which are immobilization and toxic reduction/removal. The critical reciprocity of the earth warms and lowers the concentrations of heavy metals in developed vermicompost. Maximum heavy metal concentrations in the developed vermicompost were aluminum (Al), barium (Ba), lead (Pb), and zinc (Zn) (**Table 2**). Significant reduction of Al had been observed in $V_{75\%}$ treatment, it was from 5.01 to 2.61 ppm with the values of standard deviation 0.02–0.36 by the earthworms (*E. eugeniae*), and less reduction of Al had been noticed in $V_{25\%}$ treatment, it was from 3.56 to 2.24 ppm with the values of standard deviation 0.08–0.1. The highest barium content reduction was recorded in the $V_{75\%}$ treatment, which was from 30.56 to 3.55 ppm with the values of standard deviation 1.11–0.56 and the lowest reduction capacity was sported in the $V_{25\%}$ reactor, which was from 11.79 to 1.57 ppm with the values of standard deviation 0.8–0.1. Cd, Co, Cr, Cu, Fe, Li, and Ni concentrations were less in all of the treatment reactors (**Table 2**). Manganese (Mn) reduction was more in the $V_{75\%}$ reactor, it was minimized from 1.47 to 0.05 ppm, with the values of standard deviation 0.06–0.01. Lead (Pb) content was less in the $V_{75\%}$ reactor and the zinc minimization and presence were good in the $V_{75\%}$ reactor, it was from 0.02 to 0.01 ppm with the values of standard deviation 0.001–0.079 (**Table 2**). An experiment was carried out to immobilize the heavy metals in fresh industrial sludge and composite industrial sludge and added the prepared compost to degraded agricultural soils, a surprisingly significant decrease in the heavy metals in the agricultural subsoils was noticed [31].

Heavy metals	Treatment 1 (25% TIS)			Treatment 2 (50% TIS)			Treatment 3 (75% TIS)		
	Control	**Inceptive**	**Eventual**	**Control**	**Inceptive**	**Eventual**	**Control**	**Inceptive**	**Eventual**
Al	5.55 ± 0.88	3.56 ± 0.08	2.24 ± 0.1	5.55 ± 0.88	4.95 ± 0.51	2.48 ± 0.24	5.55 ± 0.88	5.01 ± 0.02	2.61 ± 0.36
Ba	37.35 ± 2.12	11.79 ± 0.8	1.57 ± 0.1	37.35 ± 2.12	21.15 ± 1.04	2.36 ± 0.15	37.35 ± 2.12	30.56 ± 1.11	3.55 ± 0.56
Cd	0.0004 ± 0.0001	0.0002 ± 0.0003	0.0002 ± 0.0003	0.0004 ± 0.0001	0.0009 ± 0.0001	0.0002 ± 0.0003	0.0004 ± 0.0001	0.0003 ± 0.0001	0.0003 ± 0.0001
Co	0.021 ± 0.001	0.02 ± 0.01	0.011 ± 0.079	0.021 ± 0.001	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.001	0.02 ± 0.001	0.01 ± 0.001
Cr	0.009 ± 0.001	0.004 ± 0.001	0.003 ± 0.005	0.009 ± 0.001	0.007 ± 0.001	0.003 ± 0.005	0.009 ± 0.001	0.008 ± 0.001	0.004 ± 0.001
Cu	0.083 ± 0.003	0.06 ± 0.01	0.045 ± 0.004	0.08 ± 0.003	0.06 ± 0.01	0.06 ± 0.01	0.08 ± 0.003	0.07 ± 0.01	0.10 ± 0.001
Fe	0.103 ± 0.001	0.1 ± 0.8	0.008 ± 0.001	0.10 ± 0.001	0.1 ± 0.8	0.04 ± 0.01	0.10 ± 0.001	0.1 ± 0.8	0.06 ± 0.01
Li	0.009 ± 0.001	0.003 ± 0.005	0.001 ± 0.001	0.009 ± 0.001	0.007 ± 0.001	0.002 ± 0.001	0.009 ± 0.001	0.007 ± 0.001	0.003 ± 0.005
Mn	1.55 ± 0.04	0.95 ± 0.04	0.02 ± 0.01	1.55 ± 0.04	1.1 ± 0.2	0.04 ± 0.01	1.55 ± 0.04	1.47 ± 0.06	0.05 ± 0.01
Ni	0.04 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.034 ± 0.005	0.016 ± 0.001
Pb	0.11 ± 0.79	0.10 ± 0.8	0.007 ± 0.001	0.11 ± 0.79	0.1 ± 0.8	0.007 ± 0.001	0.11 ± 0.79	0.09 ± 0.01	0.008 ± 0.001
Zn	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.02 ± 0.001	0.011 ± 0.079

Note: All of the parameter values were mean values of five times repeated experiments.

Table 2.
Concentration of heavy metals with standard deviation of TLS after vermitreatment (30 days).

3.11 Growth rate estimation of *T. foenum* (Fenugreek/Methi) seeds in soil mixed with V_C, $V_{25\%}$, $V_{50\%}$, $V_{75\%}$ prepared vermicompost

An experiment carried out on the combination of vermicompost and NPK fertilizers, enhances the yield of *Allium sativum*, six experimental plots were prepared: T1 (recommended NPK), T2 (vermicompost 15 t/ha), T3 (20 t/ha vermicompost), T4 (15 t/ha vermicompost + 50% NPK), T5 (15 t/ha farmyard manure), and T6 (farmyard manure 15 t/ha + 100% recommended NPK) to observed the effect on garlic, it was exhibited the highest growth in root length, shoot length leaf length in T4 treatment plot [32]. A total of six cylindrical plastic pots were collected and filled with different portions of prepared compost, cow dung, and soil, one reactor total portion was filled with soil and labeled as V_{soil}, second one was filled with cow dung, labeled as V_C reactor and the same three cylinders were ($V_{25\%}$, $V_{50\%}$, and $V_{75\%}$) filled with approximately 250 g of soil in each of them 25 g of prepared 25%, 50%, and 75% vermicompost was poured in different reactors and labeled as V_C, $V_{25\%}$, $V_{50\%}$, and $V_{75\%}$. Every reactor was sown with 30 seeds of *T. foenum* (Fenugreek/Methi) plant, and all of the five reactors were monitored for seed germination, the number of leaves production, and the growth of plants in 10 days frequent intervals of a total of 30 days (**Figure 1**). An experiment was conducted on the chemical nutritional variations in vermicompost, and pit compost, it was tested on the growth of *Pisum sativum* and observed the pot composed of vermicompost. It was exhibited that the maximum growth in every parameter of *P. sativum* plant as compared to pit compost, and garden soil (control). They noticed significant growth of root length, more number of leaves production, and healthy growth of plant height in the vermicompost, the above parameters were less when compared to the control and pit compost [33]. In V_{agro} pot 28 seeds were geminated out of 30 sown seeds, $V_C$cow dung pot was observed with 26 seeds germination out of 30 sown seeds, and $V_{25\%}$, $V_{50\%}$, and $V_{75\%}$ pots were observed with 26, 27, and 29 germinated seeds out of 30 sown seeds, V_{soil} was observed with 25 seed germination. Maximum seed germination was noticed in the $V_{75\%}$ reactor due presence of 75% of the prepared vermicompost in the sampled pot soil and the minimum seed germination was observed in V_C and $V_{25\%}$ pot due to the low nutritional value (**Figure 2**). Pig manure-based vermicompost when used for the growth

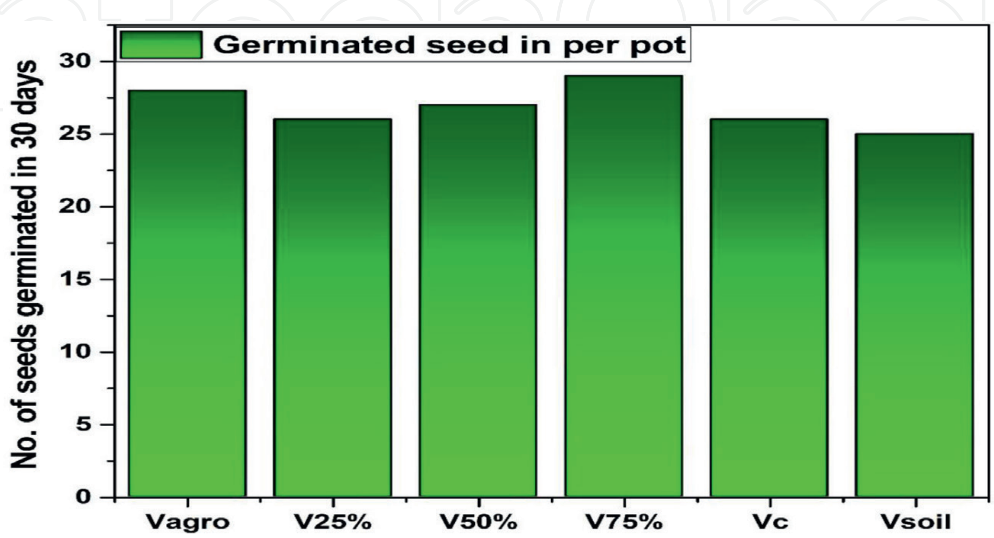

Figure 2.
Number of T. foenum plant seeds germinated on prepared textile sludge vermicompost.

of tomato (*Lycopersicon esculentum* Mill.). It was observed that tomato seedlings had been decreased in the potting mixture containing 100% pig manure vermicompost, likely due to high soluble salt concentrations in vermicompost and lower porosity and aeration. The growth of tomato seedlings was maximum after metro-mix 360 was replaced with between 25% and 50% pig manure vermicompost, with better growth occurring in combinations of pig manure vermicompost and regularly treated with a liquid fertilizer solution than in those without fertilizer [34].

3.12 Plant growth in relation with height

The relative rates of growth (RGR), based on the primary data, net assimilation rate (NAR), leaf area ratio (LAR), and components, thereof, specific leaf area (SLA) and leaf weight fraction (LWF) was calculated for the nursery stage and the transplant date, respectively. The growth response coefficients are based on the assumption RGR = NAR × SLA × LWF (GRC), the relative contribution of each parameter to an RGR change was calculated for NAR, SLA, and LWF. Vermin compost was discovered an effective growth medium for the propagation of vegetable seedlings, used individually or in the mixture [35]. The mean plant growth (height) was significant in $V_{75\%}$ pot, grown was observed up to 15.7 cm in 30 days, it was due to the availability of nutrients in prepared vermicompost from textile sludge. On the other hand, lesser plant height was observed in V_{soil} which was grown up to 11.3 cm. V_{soil} pot was filled with soil only, and no additional vermicompost/nutrients were available in the pot, the resulting in the lesser plant growth (**Figure 3**).

3.13 Mature plant leaves production and leaf growth

The highest growth was observed in plants treated with humic acid-rich vermicompost, which was prepared using fungal pretreatment. The highest root and shoot weight were also observed in plants treated with HARV, as compared to normal vermicompost and control (without compost), HARV treated plants observed 109.17%

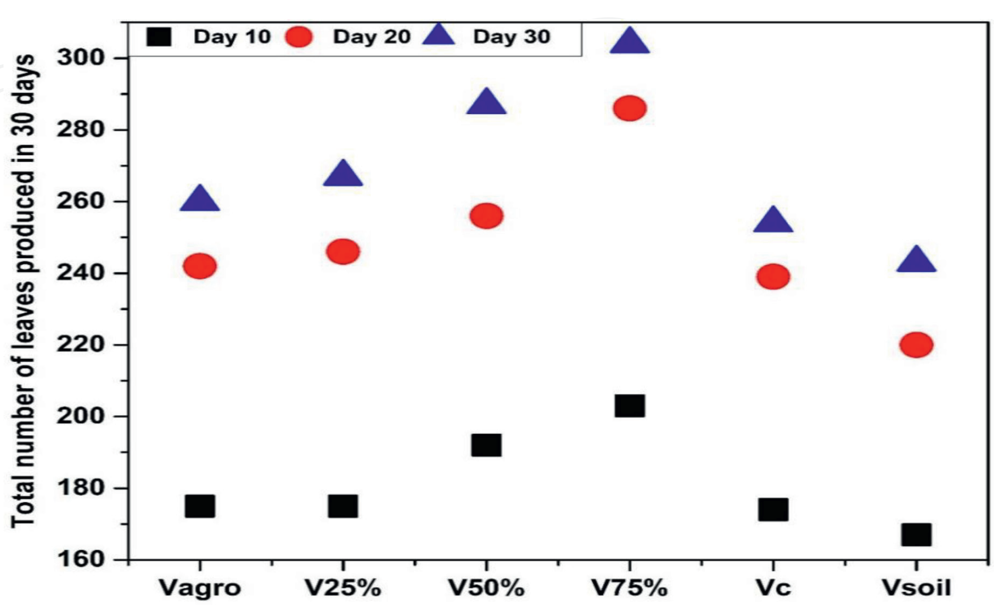

Figure 3.
T. foenum plant growth (height cm) by textile sludge vermicompost.

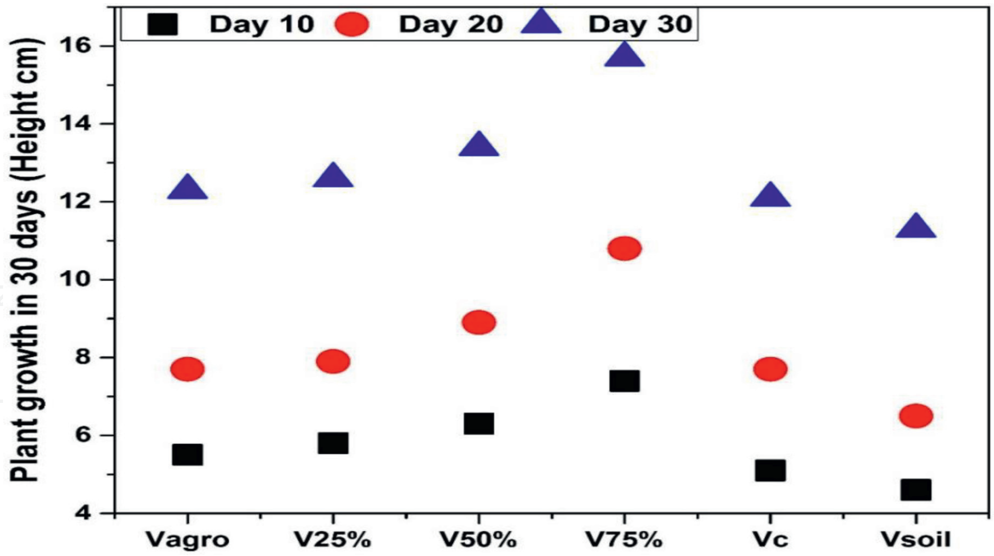

Figure 4.
T. foenum plant leaves production by textile sludge vermicompost.

plant yield, 82.97% in root biomass, and 51.61% in total height as compared to control in which any kind of vermicompost was not used [36]. Matured leaves were counted per pot in all of the five sown pots, the vermicompost use was not significantly different but in the absence of vermicompost noticed the difference in the formation of leaf number count. It was significantly more in all the vermicompost used media as compared to the control soil media. Height mature leaf count was found in $V_{75\%}$ pot (304 leaves) and the lowest count was found in V_{soil} pot (243 leaves) (**Figure 4**). A research team conducted two experiments in the greenhouse to observe the effect of peat compost and vermicompost on the growth of *Sorghum bicolor.* Two types of compost were used, pig manure vermicompost and pet compost, the sterile seed of *Sorghum bicolor* was grown in one experiment containing pet compost and experiment 2 contain vermicompost. After 21 days of germination, they were observed that pod compost experiment 1 induced root colonization in the plant after inoculation of AMF, and the dry weight was more in plant treated with vermicompost but did not induce any root colonization in plants [37].

4. Conclusion

TIS had significant organic and inorganic nutritional value with very low handling costs the disposal management problems can be overcome. The TIS waste can also be used in energy and nutrient recovery rather than used for landfill. Management and energy recovery from the TIS mixed with cow dung in different compositions was attempted to vermicompost by employing the earthworms. The final compost matter found was nutrient-rich, free from odor, it was stable, and highly mature, among all of the treatments $V_{75\%}$ reported the highest NPK values and micronutrients (Ca^{+2}, Mg^{+2}, and Na^{+2}) for plant growth.

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