International Journal of Environmental Protection and Policy
2015; 3(2-1): 27-34
Published online February 26, 2015 (http://www.sciencepublishinggroup.com/j/ijepp)
doi: 10.11648/j.ijepp.s.2015030201.15
ISSN: 2330-7528 (Print); ISSN: 2330-7536 (Online)

Feasibility study of vermicomposting of textile sludge mixed with cow dung and seed germination bioassay for toxicity evaluation of the produced compost

Nusrat Jakarin Easha, Md. Shiblur Rahaman, Taslima Zaman, Md. Khabir Uddin*

Department of Environmental Sciences, Jahangirnagar University, Dhaka-1342, Bangladesh

Email address:
easha_ju@yahoo.com (N. J. Easha), shiblu.ju@gmail.com (M. S. Rahaman), khabir88@yahoo.com (M. K. Uddin)

To cite this article:
Nusrat Jakarin Easha, Md. Shiblur Rahaman, Taslima Zaman, Md. Khabir Uddin. Feasibility Study of Vermicomposting of Textile Sludge Mixed with Cow Dung and Seed Germination Bioassay for Toxicity Evaluation of the Produced Compost. *International Journal of Environmental Protection and Policy*. Special Issue: Advances in Environmental Researches. Vol. 3, No. 2-1, 2015, pp. 27-34.
doi: 10.11648/j.ijepp.s.2015030201.15

Abstract: Transformation of textile sludges into vermicomposts can convert these wastes into good quality manure. The present study investigate the feasibility of vermicomposting process to transform the textile sludge amended with cow dung in different ratio into value added products by using an epigeic earthworm *Eisenia foetida.* Seed germination bioassay also investigated using mustard seeds (*Brassica nigra*) in order to evaluate the toxicity and maturity tests of those different mixtures and their produced composts. The result revealed that the *E. foetida* did not survive in fresh textile sludge. But worms grew and reproduced in textile sludge spiked with cow dung feed mixtures. Presence of more than 20% of textile sludge in feed mixture affected biomass gain and cocoon production largely by earthworms. The net weight gained by *E. foetida* in 100% cow dung was three fold higher than the feed mixture of 50% cow dung + 50% textile sludge. After 13 weeks, maximum cocoons (56 cocoons) were counted in 100% cow dung and minimum (6 cocoons) in 50% cow dung + 50% textile sludge feed mixture. Vermicomposting resulted in pH shift toward slightly acidic, significant reduction in TOC and C:N ratio, and increase in nitrogen phosphorus and sulphur content. Total potassium content, calcium content and heavy metal's (Cu, Cr, Pb, Zn, Fe, Mn) content were lower in the final product than initial feed material. The results of phytotoxicity test showed that all the vermicompost products had the higher seed germination percentage, root elongation percentage and germination index than their respective initial feed mixtures. The feed mixtures having the textile sludge had various phytotoxic compounds which might inhibit seed germination before vermicomposting. But the vermicomposts of different feed mixtures having the presence of 100% cow dung and 10% - 20% textile sludge were matured compost and had no phytotoxic effects as they had the germination index higher than 60. All the results indicated that vermicomposting (using *E. foetida*) is a suitable technology for the decomposition of textile sludge into value added materials. This textile sludge could be converted into good quality manure by vermicomposting if mixed in appropriate ratio (up to 20% on dry weight basis) with cow dung.

Keywords: Vermicomposting, Textile Sludge, Cow Dung, Earthworm, *Eisenia foetida, Brassica nigra*

1. Introduction

In Bangladesh, over the last few decades, there has been a tremendous increase in textile sludge production due to rapid industrialization and its textile based economy. Generally large volumes of organic toxic waste is generated by the textile industry and released into the environment [1]. It is also reported that textile and dyeing factories in the world pose a major environmental threat because of the large amounts of water and dyes involved in the manufacturing process [2]. Environmental pollution caused by textile wastewater results in adverse effects on flora, fauna and the general health of the residents of surrounding industrial area. Due to this pollution load textile industries has been shifted to developing countries from developed countries. Concerns about environmental quality have led to the introduction of alternative disposal methods such as the use as nutrient source to plants and as soil conditioners. Chemical fertilizers termed as a 'mixed blessing' for mankind. It dramatically increased the 'quantity' of the food produced but decreased its 'nutritional quality' and also the 'soil fertility' over the years. It killed the beneficial soil organisms which help in renewing natural fertility [3]. Vermicomposting results in bioconversion of the waste streams into two useful end products- the earthworm biomass and the vermicompost. The former product can further be processed into high-grade horticultural compost [4]. At present, management of textile sludge is one of the global issues because these bulk amounts of sludge are contribute to deterioration of the country's fertile land and water sources with toxicity. So, research on reusing and recycling of this sludge is needed as a way of solving the problems generated. It is now established that application of sludge into land can increase soil water holding capacity, decrease soil bulk density, increase soil aeration and root penetration and stimulate microbial activity [5]. In addition, land utilization of sludge could represent a step forward to more sustainable farming practice and waste management. Our country is based on agricultural activity and if it is possible to turn the sludge into vermicompost with enough nutrients content, huge amount of sludge can be reused as nutrients source of agricultural lands. Earlier studies have reported that textile sludge alone cannot be used as raw material for vermicomposting and some additive was required in the feed mixture [6]. *E. foeida* could not tolerate the fresh textile sludge. Addition of at least 30% of poultry dropping or biogas plant slurry (on dry weight basis) was essential for the survival of the earthworms in the textile sludge [7].

2. Methodology

Fresh textile sludge (TS) was obtained from the wastewater treatment plant of a textile industry located near Dhaka, Bangladesh (Map 1). It is situated at 23^0 49' 31" N and 90^0 15' 27.72" E. Sludge was collected with a prewashed spatula into a clean airtight polythene bag and cow dung (CD) was collected by following the same procedure from Dairy farm, Savar. Collected samples were air dried for two days. After that Samples were carried to laboratory of Department of Environmental sciences of Jahangirnagar University for initial physico-chemical parameter measurement. pH was 7.83 and 8.22, total organic carbon (TOC) was 10.53 and 20.085, total Kjeldhal nitrogen (TKN) was 6.48% and 1.40%, total available phosphorus (TAP) was 0.55% and 4.40%, and C:N ratio was 2.87:1 and 14.31:1 For TS and CD, respectively. Nonclitellated hatchlings of the earthworm *E. foetida* were picked for use in the experiments from several stock cultures maintained in the laboratory with cow dung as culturing material.

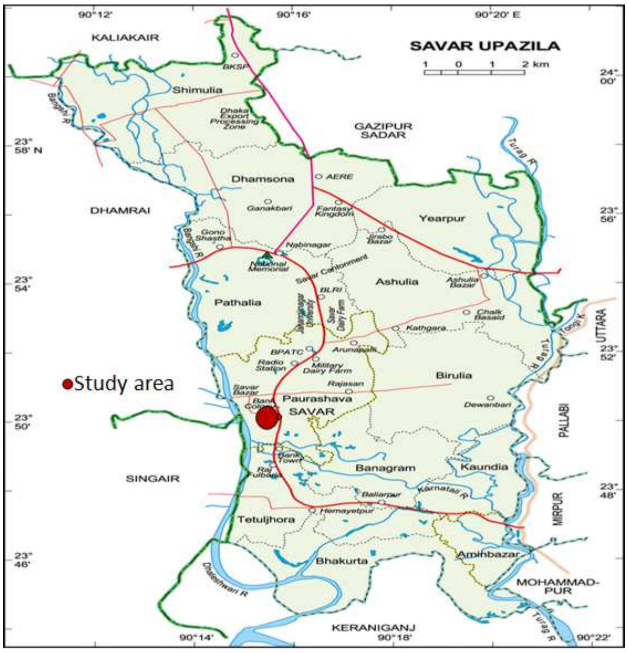
Table 1. *Content (percentage) of different initial feed mixture (textile sludge + cow dung)*

Feed mixture no.	Textile Sludge (%)	Cow dung (%)
1	0(0)[a]	100 (200)[a]
2	10 (20)[a]	90 (180)[a]
3	20 (40)[a]	80 (160)[a]
4	30 (60)[a]	70 (140)[a]
5	40 (80)[a]	60 (120)[a]
6	50 (100)[a]	50 (100)[a]

[a] The figures in parentheses indicate the amount of samples in gram in the initial feed mixture.

Six feed mixtures having different ratios of cow dung and textile sludge were established. One-liter clay containers were filled with 200 g of each feed mixture (on a dry weight basis) (Table 1). The moisture content of the feed in each container was maintained at 60–80% throughout the study period by sprinkling adequate quantities of water. These mixtures were turned over manually every day for 15 days in order to eliminate volatile toxic substances. After 15 days, five nonclitellated hatchlings of *E. foetida* were introduced in each container. There were three replicates for each feed mixture. No additional food was added at any stage during the study period. Another set of feed mixtures without earthworms was established as control to compare the result. All containers were kept in dark at 25± 1°C for 90 days. Homogenized samples of the feed were drawn at 0, and 90 days from each container.

The 0 day refers to the time when feed were filled in the container before pre-composting. At the end of the experimental period (day 90) all earthworms including hatchlings were counted. The cocoons, earthworms and hatchlings were removed manually from each sample. The sludge and cow dung mixed samples were air dried in shade at room temperature, grounded in a ceramic blender and stored in plastic vials for further analysis. After that sample are digested for further analysis.



Map 1. *Study Area*

The pH was determined by using Griffin pH meter (Model no. 40). By flame photometry method (Model no. Jencons, PEP7), potassium was determined at wavelength 766 and 769 nm (Walsh, 1971).). Determination of Nitrogen was carried out by Kjeldahl method (Model No. Model No. : P/N 21284 - 01). For Total Organic Matter (TOM), oxidation with potassium dichromate method was followed. Phosphorus test was performed by the Vanadomolybdophosphoric Yellow Color Method in Nitric Acid System (Walsh, 1971) and the absorbance was taken (Model no: Jenway 6100) at wavelength of 470 nm. For sulfur, digested sample (10 mL) was taken in the measuring flask followed by 10 mL of acid seed solution and 5 ml turbidimetric reagent using pipettes. Then shaking was performed frequently for 20 minutes and measured the absorbance on a spectrophotometer (Model no: Jenway 6100) at 535 nm. Elemental analysis of samples were performed by Atomic Absorption Spectroscopy (AAS) (Model AA-7000) for Cd, Cr, Cu, Fe, Mn, Zn, Ca, Pb and Ca. Biomass gain, clitellum development, and cocoon production by the earthworms (*E. foetida*) in each feed mixture were recorded after 3 months. Earthworms were counted and weighed in full guts before introducing them in the feed.

The seed of mustard (*Brassica nigra*) plant were used for testing the phytotoxicity such as Relative seed germination (%), Relative root elongation (%), Germination Index (GI), of feed mixture and produced composts.

3. Results & Discussion

E. foetida could not tolerate the fresh TS. Experimental study was performed with air dried textile sludge and cow dung. The vermicompost was much darker in color than its origin and had been processed into homogeneous manure after 90 days of earthworm's activity, whereas the material without earthworm remained in compact clumps.

There were slight changes in the pH values in all the feed mixture after vermicomposting (Fig: 1) that there was a shift toward slightly acidic / neutral pH (6.65 to 7.05) from the initial alkaline pH (7.45-8.22) due to vermicomposting.

The pH shift towards acidic condition could be attributed to mineralization of the nitrogen and phosphorus into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of organic acids [8].

A large portion of the TOC was lost as CO_2 (between 27% and 46%) by the end of the vermicomposting feeding except in feed no. 4 (70% cow dung + 30% textile sludge mixture), in which TOC reduction was near 50% where as TOC decreased in control feeds in the range of 11.6% to 26% (Fig.1).The TKN content increased in between 5% to 61% in different feed mixtures after vermicomposting, probably because of mineralization of organic matter (Fig.1). Increase in TKN was less evident in the vermicompost having 40% and 50% textile sludge (12.23% and 4.90%, respectively). Increase in TKN was in the range 0.9% to 12.96%, in the control feeds (Fig.1). The final nitrogen content of the compost would be dependent on the initial nitrogen present in the feed material and the extent of decomposition [9]. Present study revealed loss in organic carbon that might be responsible for nitrogen addition [10]. Earth worms also have a great impact on nitrogen transformation in manure, by enhancing nitrogen mineralization, so that mineral nitrogen was retained in the form of mucus [11]. Addition of nitrogen in the form of mucus, nitrogenous excretory substance, growth stimulating hormones and enzymes from earth worms has also been reported [12]. According to them, these nitrogen rich substances were not originally present in the material and hence might have contributed to the additional nitrogen content. Decrease in pH may be another important factor in nitrogen retention as this element is lost as volatile ammonia at high pH values [13].

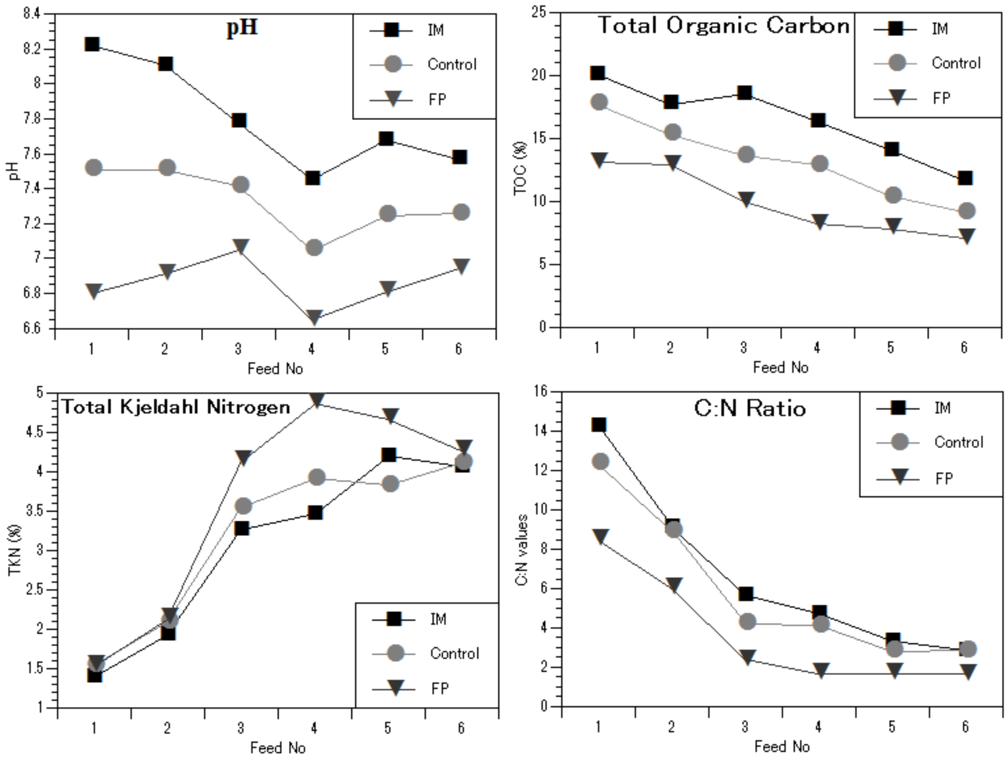


Fig. 1. *Comparison of pH, TOC, TN, C: N Ratio among initial feed mixtures, Control (without earth worm) and produced final products after vermicomposting.*

The C:N ratio, one of the most widely used indices for maturity of organic waste, decrease with time in all the experiments due to decomposition. Initial C:N ratio of different initial feed mixtures were high. The highest C:N ratio remained for 100% cow dung (Fig.1). The declination of C:N ratio less than 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic waste [14]. In this experiments, the C:N ratios were between 8 and 2 for some of the feed mixtures after 90 days of worm activity, where as the final C:N ratio of control feed was higher (in the range 2 to 12) than worm-inoculated feeds (Fig.1).

The amount of TP was higher in the final composts than in the initial feed mixtures (Fig.2). The phosphorus content (TP) in the final products (vermicompost) ranged from 8820 mg/kg (in 100% cow dung) to 12,440 mg/kg (in 80% cow dung + 20% textile sludge mixture) (Fig. 2). The figure shows higher increasing trend in feed mixture 2 and 3 after vermicomposting. On the other hand, feed no. 4, 5 and specially feed no. 6 had very less changes. The TP content in control feed mixtures ranged from 5592 mg/kg to 9045 mg/kg. The feed mixtures under earthworm treatment exhibited faster and greater increase in TP content than did the feed mixture without earthworms, which showed the efficiency of earthworms in mineralization of TP in the feed mixture. Earthworm's role in mineralizing wide ranges of organic materials with the help of various bacteria and enzyme in the intestine was described in detail by [15].

Sulphur content (S) was also higher in the final feed mixtures after vermicomposting than in the initial feed mixtures. The content in vermicompost ranged from 8.31 g/kg (in fresh cow dung) to 26.38 g/kg (in 50% cow dung + 50% textile sludge feed mixture) whereas the initial content was from 1.16 g/kg to 17.62 (Fig. 2). It was also clear from the Fig. 2 that, the source of S was mainly the textile sludge and the feed mixtures under earth worm treatment exhibited greater increase in S content than did the feed mixtures without earth worms that ranged in S content from 2.01 g/kg to 17.98 g/kg. On the other hand, TK and TCa concentration in the final cast were slightly lower than in the initial feed mixtures (Fig. 2). This reduction might have been due to leaching of these cations by the excess water that drained through the feed mixtures or they may be used by *E. foetida* as growth nutrient.

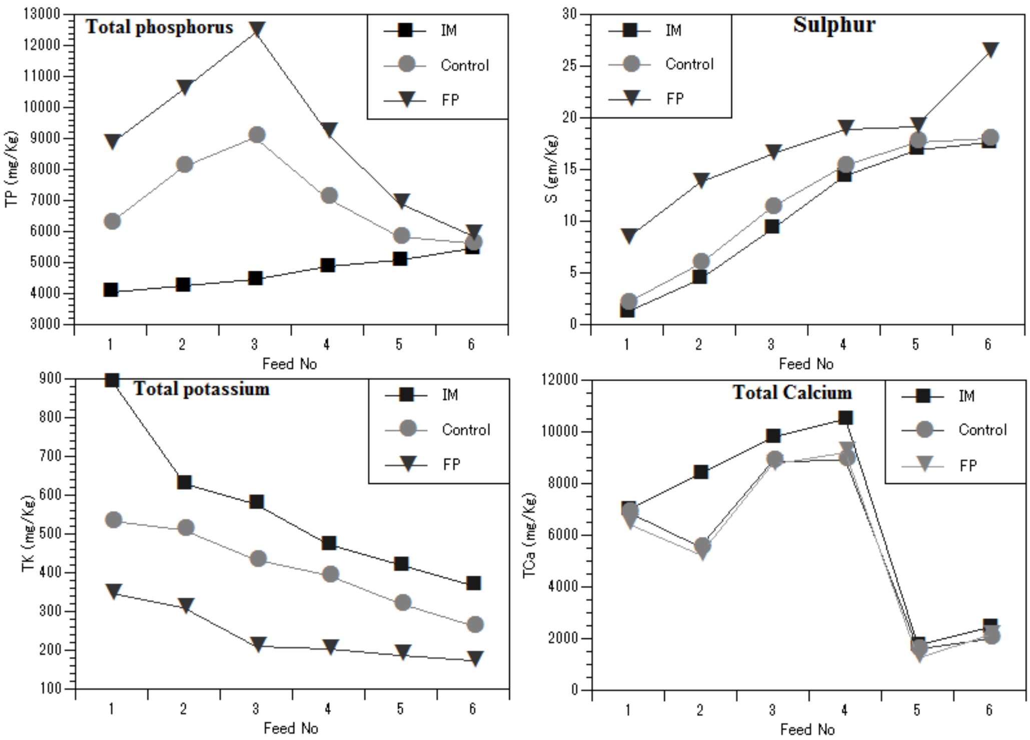


Fig. 2. *Comparison of Total phosphorus (TP), Sulphur , Total potassium, Total Calcium among initial feed mixtures, Control (without earth worm) and produced final products after vermicomposting.*

As the feed no. 4,5 and 6 had decreased proportion of cow dung, the TCa concentration gave a reduced reading compared to the feed no. 1, 2, and 3. There are contradictory reports regarding the nutrient quality of vermicompost.

A reported showed a higher content of TK in the sewage sludge vermicompost where another report showed increase in TCa and decrease in TK after ingestion of coffee pulp waste by earthworms [16, 17]. However, one more study has reported a decrease in TK and TCa in vermicompost after bioconversion of paper pulp mill sludge by *Eisenia andrei*[18]. Another research also found a decreasing trend in TK and TCa in vermicompost of textile sludge and poultry dropping mixture by *E. foetida* [19].

In the experiment it was observed that the Cr and Pb content in initial product (vermicompost) were obtained BDL (below detection level) after vermicomposting although noticeable amount of Cr and Pb were found in different initial feed mixtures. Data showed that the 100% cow dung feed was free from Cr and the textile sludge was the source of Cr found in other feed mixture and the total heavy metal concentrations in the final products (vermicompost) were lower than in the initial feed mixture (Fig.3).

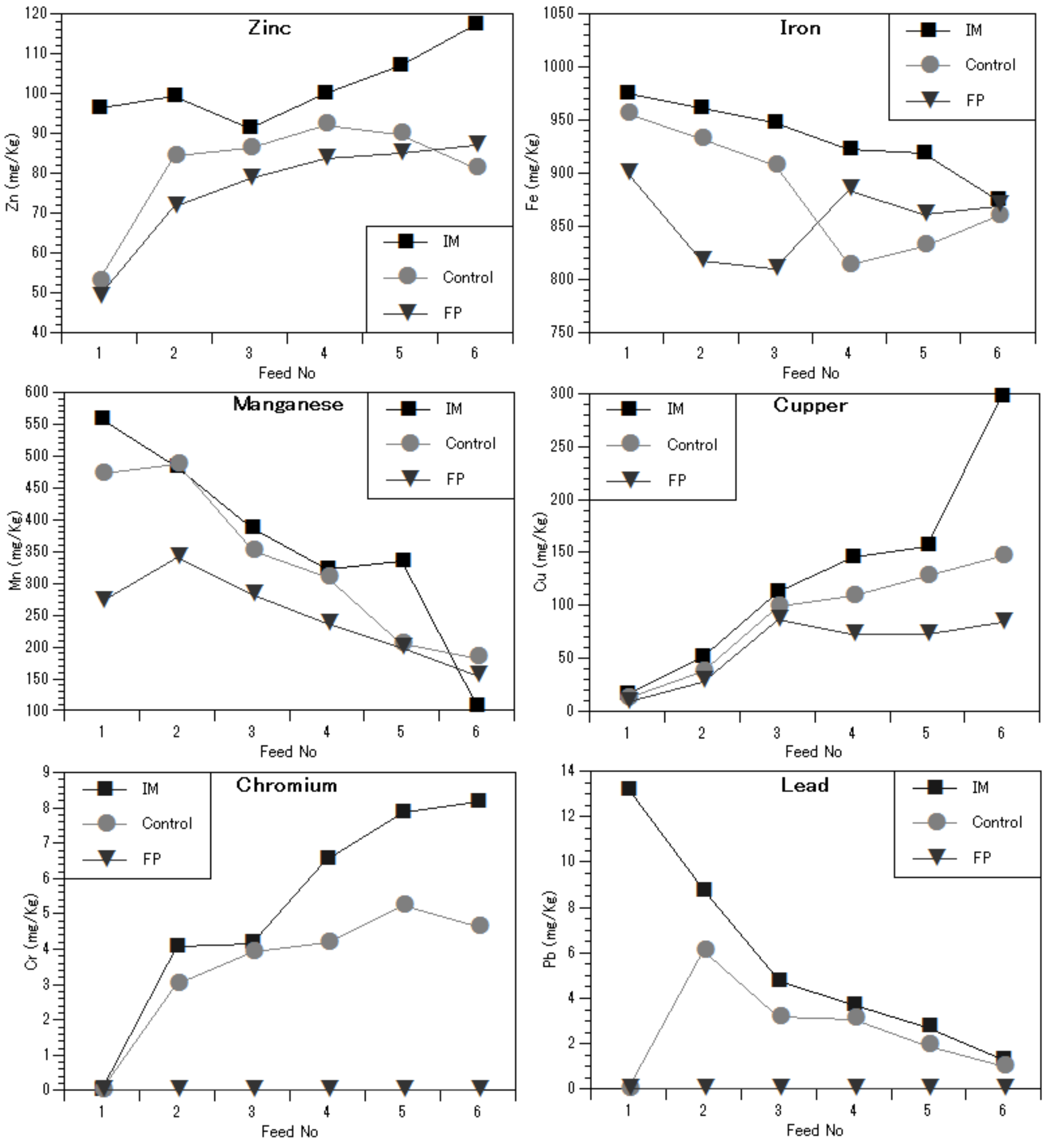


Fig. 3. *Comparison of Zn, Fe, Mn, Cu, Cr, Pb among initial feed mixtures, Control (without earth worm) and produced final products after vermicomposting.*

This metal might be accumulated into *E. foetida* biomass. That shows a great possibility of removing harmful heavy metal from sludge by vermicomposting if these metals entrap into biomass than this sludge can be used as potential nutrient source. Differences in the results could be attributed to the differences in the chemicals nature of the initial raw Zn, Fe, Cu and Mn concentration in the final products (vermicompost) were slightly lower than in the initial feed mixture. The highest amount of Zn, Fe and Mn in the final product were about 86.85 mg/kg (in 50% cow dung + 50% textile sludge feed mixture), 899.34 mg/kg (in 100% cow dung) and 341.04 mg/kg (in 80% cow dung + 20% textile sludge mixture), respectively. The lowest amount of Zn, Fe and Mn in final products were about 48.9 mg/kg (in 100% cow dung), 809.51 mg/kg (in 80% cow dung + 20% textile sludge mixture) and 155.35 mg/kg (in 50% cow dung + 50% textile sludge feed mixture), respectively.

A study reported the decrease in heavy metal concentration in the final product of textile sludge and poultry dropping feed mixture which is as same as the result of present research [19]. The decrease in heavy metal concentration in the final products could be related to leaching of these cations by excess water drainage or consumption and metabolism activities of earth worm body. Contradiction with this result was also reported. Another study reported an increase in heavy metal concentration in the final product of his research [18].

The growth of *E. foetida* in the studied feed mixtures over the observation period are given in (fig. 4) The highest worm biomass was obtained in the 100% cow dung (1260 mg earth worm^{-1}) and the lowest in the 50% cow dung + 50% textile sludge feed mixture (512 mg earth worm^{-1}). Increasing percentage of TS in the feed mixture promoted a decrease in biomass *E. foetida*. The maximum worm biomass was attained in the 12th week in all the feed mixture. The net wet gained by *E. foetida* in 100% cow dung was threefold higher than that in 50% textile sludge containing feed mixture.Cocoon production was started during the seventh week in the 100% cow dung feed (feed no. 1), the eighth week in the feed mixture having 10% textile sludge (feed no. 2), and the ninth week in the remaining feed mixtures. After 12 week maximum cocoons (56 cocoons) were counted in 100% cow dung feed and minimum (6 cocoons) in 50% cow dung + 50% textile sludge feed mixture.

This indicated that a greater percentage of textile sludge in the feed mixture significantly delays the sexual maturity and reproduction of *E. foetida*. A study reported that worms fed with untreated pig manure died within a few hours [20]. Worms were unable to survive in paper-pulp mills sludge and earth worms showed the inability for living in fresh textile sludge [19, 21].

They also attributed this mortality to degradation processes which result in changes of the environmental characteristics. There are a variety of compost phytotoxicity tests which have been proposed and published [22]. The Germination Index, GI is a factor of relative seed germination and relative root elongation. Additionally this germination bioassay was included since it is used to determine the maturity and phytotoxicity of compost and other biowaste materials [23].

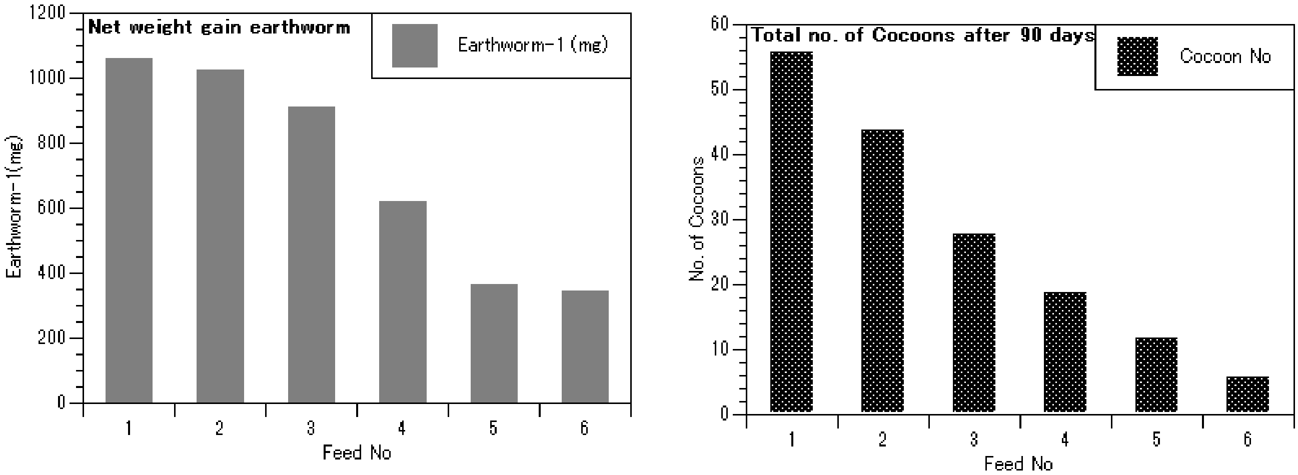


Fig. 4. *Growth of Eisenia foetida and total no of Cocoons in different feed mixtures after 90 days of vermicomposting process.*

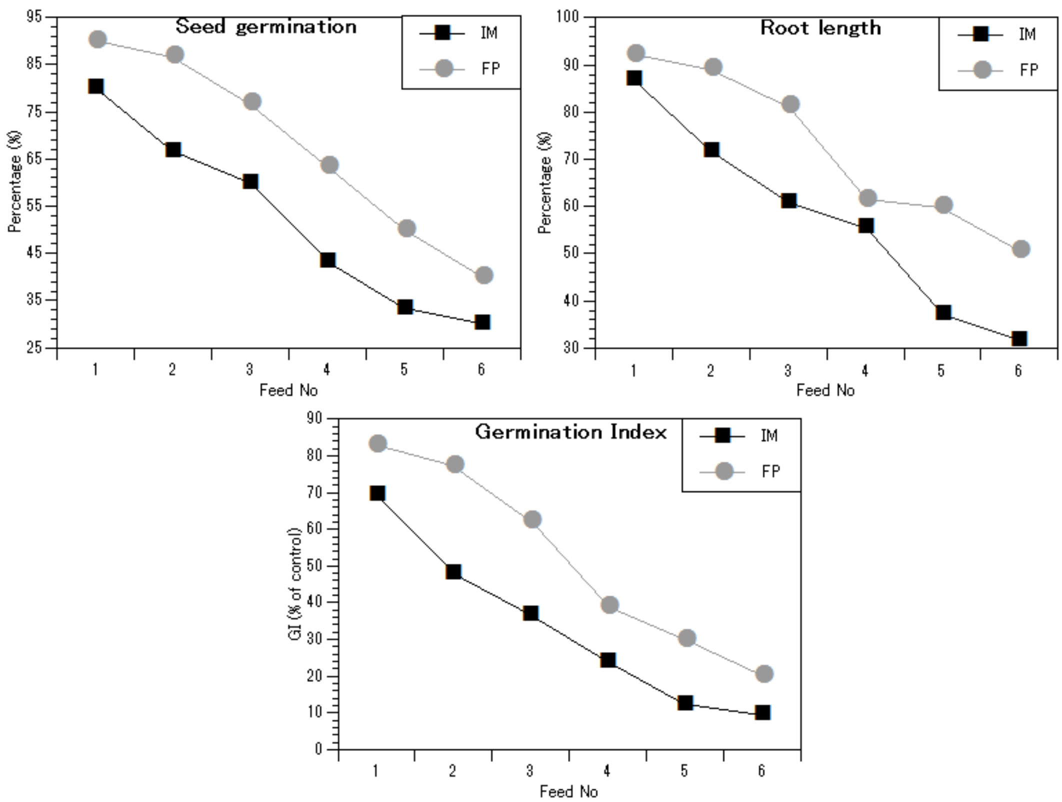


Fig. 5. *Seed germination (%), Root length(%) and Germination Index of mustard seeds in different initial feed mixtures and in produced vermicompost.*

The germination test was also done after vermicomposting of those feed mixture of textile sludge and cow dung. The vermicompost of those respective feed showed different result than the result obtained before vermiposting. The six different vermicompost feeds had the seed germination (%) ranged from 40% to 90% and root elongation (%) ranged from 50.67 % to 92.2%. The germination index of these vermicompost ranged from 20.268 to 82.98 (Fig.5). The cow dung vermicompost had the highest germination index (82.98) and the vermicompost of 50% textile sludge + 50% cow dung feed mixture had the lowest one (20.268).

It was highly noticeable that, all the vermicompost samples had the higher seed germination percentage, root elongation percentage and germination index than their respective feed mixture before vermicomposting. Three vermicompost samples (feed N0. 1, 2, 3) had germination index greater than 50 (Fig.5).

Generally germination index values below 50 indicate the phytotoxic compounds might have not been metabolised inhibiting germination [24]. Among the initial feed mixture all showed the germination index lower than 50 except feed mixture N0.1 (having no textile sludge content). So, it is clear that the feed mixture having 10% to 50% textile sludge contain phytotoxic compounds which inhibit germination. but vermicompost of feed no. 2 & 3 (having 10% & 20% textile sludge) had not phytotoxic compounds as both vermicompost had germination index higher than 50. From the Fig.5 it is observed that, the germination index increase for each feed mixture when it turned into vermicompost. The increases in GI values corresponded with decreases in concentrations of heavy metals in the matured composts (the vermicompost had the heavy metal concentration lower than their initial feed mixture showed in Fig.3).

Moreover, the increase of the germination index up to 50 in the produced products (vermicompost) suggested that the composts did not pose any toxicity on the plant growth and the maturity and this vermicomposting is an important process that has to eliminate toxic compounds present in textile sludge [25, 26].

Therefore, the matured vermicomposts can benefit plant growth and suitable for agricultural application [27]. However, compared with the control seeds with 100% germination index, the composts appeared to contain some phytotoxicity inhibitors although it can decline with time and seed can adjust to the adverse condition [28, 29].

4. Conclusion

Vermicomposting resulted in pH shift toward slightly acidic. Significant reduction in TOC and C:N ratio, and increase in nitrogen, phosphorus and sulphur content were observed after vermicomposting of initial feed mixtures. Total potassium, calcium and heavy metals (Cu, Cr, Pb, Zn, Fe, Mn) content were lower in the final product than initial feed material. The *E. foetida* did not survive in fresh textile sludge. But worms grew and reproduced in textile sludge spiked with cow dung feed mixtures. Presence of more than 20% of textile sludge in feed mixture affected biomass gain and cocoon production largely by earthworms. All the vermicompost products had the higher seed germination percentage, root elongation percentage and germination index than their respective initial feed mixtures. The vermicomposts of different feed mixtures having the presence of 100% cow dung and 10% - 20% textile sludge were matured compost and had no phytotoxic effects as they had the germination index higher than 60. All the results indicated that vermicomposting (using *E. foetida*) is a suitable technology for the decomposition of textile sludge into value added materials. This textile sludge could be converted into good quality manure by vermicomposting if mixed in appropriate ratio (up to 20% on dry weight basis) with cow dung.

References

[1] Kaushik, P. and Garg, V.K., 2003. 'Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida'. Biores. Technol.,* 90 (3), pp. 311–316

[2] Abd El-Rahim, W.M., Khalil, W.K.B. and Mariam, G.E., 2008. 'Genotoxicity studies on the removal of a direct textile dye by a fungal strain, in vivo, using micronucleus and RAPD-PCR techniques on male rats'. *J. Applied Toxicol*., 28, pp. 484-490.

[3] Ministry of Agriculture & Food, British Columbia, Canada, 1996. 'The composting process'. Composting Factsheet, Order No. 382.500-2, Agdex: 537/727.

[4] Sabine, J.R., 1978. 'The nutritive value of earthworm meals', In Hartenstein, R., (ed.), Utilization of soil organisms in sludge management, Syracuse, State University of New York, pp. 122–130.

[5] Dudka, S. and Miller, W.P., 1999. 'Accumulation of potentially toxic elements in plants and their transfer to human food chain'. *J. Environ. Sci. Health B.,* 34, pp.681–708.

[6] Kaushik, P. and Garg, V.K., 2003. 'Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida'. Biores. Technol.,* 90 (3), pp. 311–316

[7] Kaushik, P. and Garg, V.K., 2004. 'Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with w dung and agricultural residues'. *Biores. Technol.,* 94, pp. 203 – 209.

[8] Ndegwa, P.M., Thompson, S.A. and Das, K.C., 2000. 'Effects of stocking density and feeding rate on vermicomposting of biosolids'. *Biores. Technol*., 71, pp. 5–12.

[9] Crawford, J.H., 1983. 'Review of composting' *Process Biochem*., 18, pp.14-15.

[10] Viel, M., Sayag, D., Andre, L., 1987. 'Optimization of agricultural, industrial waste management through in-vessel composting'. *Elseiver Appl. Sci.,* Essex, pp. 230-237.

[11] Atiyeh, R.M., Dominguez, J., Subler, S., Edwards, C.A., 2000a. 'Changes in biochemical properties of cow manure during processing by earthworms (*Eisenia Andrei* Bouche) and the effects on seedling growth'. *Pedobiologia.*, 44, pp. 709-724.

[12] Tripathi, G. and Bhardwaj, P., 2004. 'Comparative studies on biomass production, life cycles and composting efficiency of *Eisenia foetida* (Savigny) and *Lampito mauritii* (Kinberg)'. *Biores Technol.,* 92, pp. 275-278.

[13] Hartenstein, R. and Hartenstein, F., 1981. 'Physico-chemical changes affected in activated sludge by the earthworm Eisenia foetida'. *J. of Environ. Qual*., 10, pp. 377–382.

[14] Senesi, N., 1989. 'Composted materials as organic fertilizers'. *Total Environ. Sci.,* 81, pp. 521-524.

[15] Edwards, C.A. and Lofty, J.R., 1972. 'Biology of earthworms'. Chapman & Hall, London.

[16] Delgado, M., Bigeriego, M., Walter, I. and Calbo, R., 1995. 'Use of California red worm in sewage sludge transformation'. *Turrialba.*, 45, pp. 33-41.

[17] Orozco, F.H., Cegarra, J., Trujillo, L.M. and Roig, A., 1996. 'Vermicomposting of coffee pulp using the earthworm *Eisenia foetida*: effects on C and N contents and the availability of nutrients'. *Biol. Fertil. Soil.,* 22, pp.162-166.

[18] Elvira, C., Sampedro, L., Benitez, E., Nogales, R., 1998. 'Vermicomposting of sludges from paper mill and dairy industries with *Eisenia andrei*: a pilot scale study'. *Biores. Technol.,* 63, pp. 205-211.

[19] Kaushik, P. and Garg, V.K., 2004. 'Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with w dung and agricultural residues'. *Biores. Technol.,* 94, pp. 203 – 209.

[20] Chan, L.P.S. and Griffiths, D.A., 1988. 'The vermicomposting of pre-treated pig manure'. *Biol. Wastes.*, 24, pp. 57-69.

[21] Elvira, C., Sampedro, L., Dominguez, J. and Mato, S., 1997. 'Vermicomposting of wastewater sludge from paper-pulp industry with nitrogen rich materials'. *Soil Biol. Biochem.,* 29, pp. 759-762.

[22] Mathur, S.P., Dowen, G., Dinel and Shnitzer, H., 1993. 'Determination of compost biomaturity: A literature review'. *Biol. Agric. Hortic.*, 10, pp. 65-85.

[23] Roe, N., Stoffella, P. and Graetz, D., 1997. 'Compost from various municipal solid waste feedstock- Emergenc and seedling growth'. *J. Am. Soc. Hortcult. Sci*., 122, pp. 427-432.

[24] Epstein, E., 1997. 'The science of composting'. Technomic Publising Company, Inc., Pennsylvania, USA.

[25] Tiquia, S.M., 1996. 'Assessing toxicity of spent sawdust pig-litter using seed germination technique'. *Environ. Pollut.,* 93, pp. 249-256.

[26] Zocconi, F.M., Pera, A., Forte, M. and De Bertoldi, M., 1981. 'Evaluating toxicity of immature compost'. *Bio Cycle.*, 22, pp. 54-57.

[27] Campbell, A.G., Zhang, X. and Tripepi, R.R., 1995. 'Composting a pulp and paper sludge for use as soil amendment mulch'. *Compost. Sci. util*., 3, pp. 84-95.

[28] Alvarez, M.A., Gangne, S. and Antoun, H., 1995. 'Effect of compost on rhizosphere microflora of the tomato and on the incidence of plant growth-promoting rhizobacteria'. *Applied Environ. Microb*., 61, pp. 194-199.

[29] Wong, M.H., Cheung, Y.H. and Chung, C.L., 1983. 'The effects of ammonia and ethylene oxide in animal manure and sewage sludge on the seed germination and root elongation of *Brassica parachinensis'. Environ. Pollut.,* 30, pp. 109-123.