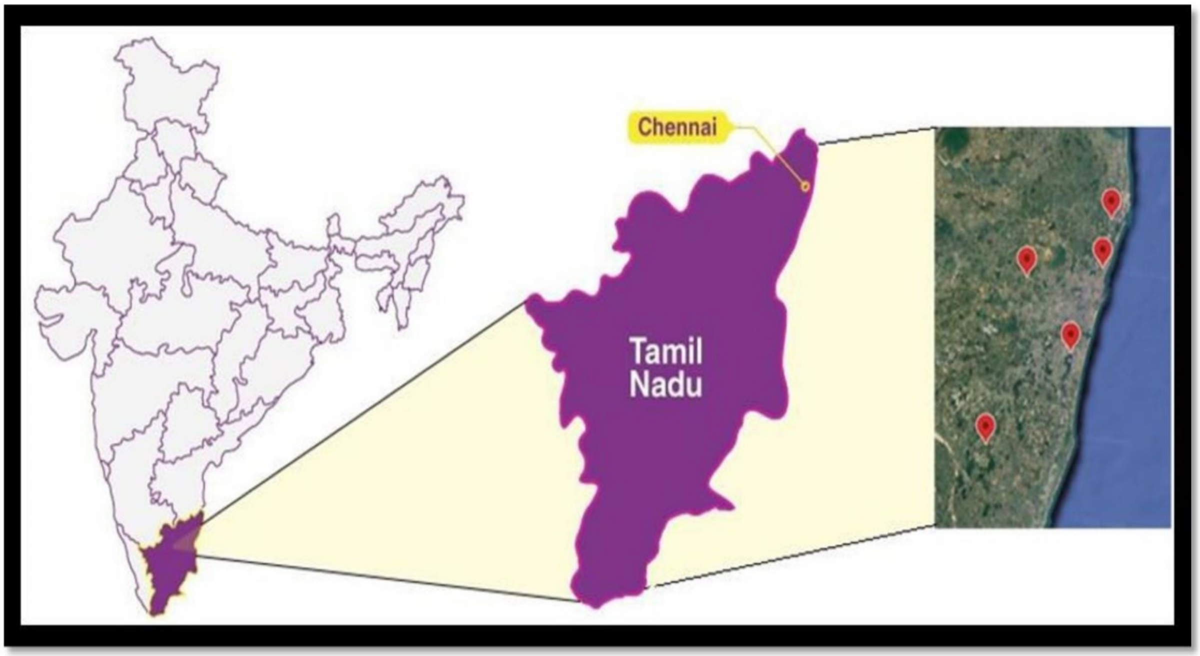
Vermicomposting Bio Earth: A Sustainable Approach for Enhanced Nutrient Content and Heavy Metal Remediation in Soil Management

S. Banupriya, and S. Kanmani*

Centre for Environmental Studies, College of Engineering Gunidy, Anna University, Chennai,
600 025, Tamil Nadu, India. banupriya6@gmail.com

Corresponding author email: skanmani683@gmail.com

GRAPHICAL ABSTRACT



Abstract

The study aims to enhance soil quality, nutrient level and reduce metal concentration by evaluating the efficacy of vermicomposting by utilizing earthworms. The present study obtained the Bio Earth sample from six locations, represented as LS-(1-6). The collected bio earth sample was blended with an adult earthworm (*Eisenia fetida*). The experimental investigation was conducted for 108 days, and earthworms showed maximum biomass and population ephemerality in Bio Earth samples (Bio Earth + cow dung). However, the pre-treated and post-treated samples were monitored through physicochemical analysis like pH, electrical conductivity (EC), bulk density (ρ), total organic content (TOC), total nitrogen (TN), total phosphorous (TP), total potassium (TK), C:N ratio, and heavy metals. Among the six Bio Earth samples, the most significant LS-3 reveals the reduction of operating parameters and finds the below detection limit of heavy metals. At the initial level of LS-3, samples were found to be pH-7.2, EC-1.4 ms/cm, ρ-0.8 g/cm^3, TOC-8.6%, TN-0.6%, TP- 0.3%, TK-0.4%, C:N ratio-16.3%, heavy metals (Zn-448.8 mg/kg; Cu-132.5 mg/kg; Ni-61.4 mg/kg; Pb-91.2 mg/kg; Cr-116.3 mg/kg), whereas the post-treated vermicomposting sample results were exhibited at pH-6.8, EC-2.167 ms/cm, ρ-0.85 g/cm^3, TOC-9.54%, TN-0.67%, TP-0.48%, TK-0.13%, C:N ratio-14.23%, heavy metals (Zn-64.13 mg/kg; Cu-5.5 mg/kg; Ni-7.26 mg/kg; Pb-101 mg/kg; Cr-51 mg/kg). The data displays that vermicomposting (using *E. fetida*) is an applicable technology for decomposing organic matter into prosperous nutrient soil enlargement.

Keywords: BioEarth, Eisenia fetida, vermicomposting, heavy metals, C:N ratio

1. Introduction

As per the survey of United National Population Fund, India is the second highest country in the world's population with 142.86 crores in the year 2023. Forty-two million tons municipal solid waste (msw) generated in India annually (1.15 million metric tons per day). The 30-35% of solid waste is biodegradable, 40-55% is inert, and 5-15% is recyclable. Ministry of House and Urban Affairs (MoHUA) has released the waste composition based on the size of the city, season, and income group. According to the recent report of Tamil Nadu Pollution Control Board (TNPCB, 2023) the whole number of solid waste collected in Tamil Nadu, India is dumped in the 271 dumpsites which are located in various places in the state. Overall, sixteen thousand tons of solid waste were generated, of which 15 thousand tons per day were collected, nine thousand solid wastes were handled, and approximately six thousand tons per annum were landfilled. This type of landfilling poses a massive threat to land, air, and water. Landfill mining is one of the techniques used for recycling and sustainable waste management; efficient and environmentally benign methods, otherwise known as landfilling or biomining, which include stabilizing aging legacy waste in landfills by recovering valuable materials.

Bio Earth explores the advantage beneath growth outlined to discover the combined manifold stand-alone models within the earth system model structure to engender functional evidence for natural and agricultural resource executives at the provincial scale (Byun and

Schere, 2006; Guenther et al., 2012; Tague and Band, 2004). The overview of earth is to enhance the empathy of the interfaces among combined Carbon: Nitrogen: Dynamics of water and human like activities at zonal and decadal balances beneath worldwide modification to recover the understanding of the vital part that the resource controlling activities have affecting universal system crescendos, and to enlighten sources exclusively regarding the significances of their resolutions on global system with a specific effort on enumerating unreliabilities, ecological advice, cost-effective, and environmental interchanges (Adam et al., 2014; Allen et al., 2013; Liu et al., 2013; Liu et al., 2014). BioEarth facilitates the quantification of the effects of human decisions on greenhouse gases (GHGs), additional atmospheric contaminants, global environmental health, water quality and quantity, and possessions via simulating handling of entire cropping system (e.g., irrigation, crop selection, residue management, and fertilization) (Rajagopalan et al., 2011; Stöckle et al., 2014), rangeland ecosystem (e.g., grazing and restoration) (Allen et al., 2017; Kooch et al., 2022), forested environments (e.g., renovation and thinning) (Yang et al., 2020), air quality (power plants, industrialized facilities, contaminant precursors from automobiles, and parameter of pollutant emissions) (Saravanan and Ramesh, 2023), and water supply management (WSM) (e.g., water transfers, reservoirs, water rights limitation) (Hamlet and Lettenmaier, 1999; Mullis et al., 2014).

Vermicomposting is a biological progression that includes connections among microorganisms and earthworms, which proficiently convert various categories of biodegradation carbon containing wastes into rich nutritional compost (Amouei et al., 2017; Pigatin et al., 2016). Vermicomposting is a thoughtful composting method used everywhere through which earthworms are recycled to renovate organic matter into a quality end product (Wang et al., 2021). In this method, earthworms ingest most of the organic matter, which rushes the decomposition rate and ultimately leads to the maintenance of the substrate and the final product yielded in a rich nutrient vermicompost, which enables plant development by providing enormous nutrients (Garg and Kaushik, 2005). This method has been broadly used for conversion of debris like waste of agro-industry, agriculture residue, household waste, fly ash, sludge of papermill, etc.to valued final yields known as vermicompost. However, small stages of macronutrients are still a foremost difficulty for the broader application of vermicompost on a commercial scale (Ndegwa and Thompson, 2001). Many research havebeen before taken to makeready vermicompost and reported on physicochemical studies like pH, bulk density, electrical conductivity, organic carbon, volatile solids, and nutritional contents in the final compost. (Parthasarathi et al., 2016; Kavitha et al., 2010; Achsah and Prabha, 2013). The significant key causes for influencing the adequate consumption of compost in farming fabrication depend on maturity and stability, which is the decomposition of toxic substances created throughout the technique of composting (Wang et al., 2004). Henceforth, the improvement of intensities of nutrimentals in the vermicompost a significant advantage, and to overwhelm problem, the combination of numerous rubbish has been recommended as an unconventional preference (Barthod et al., 2018).

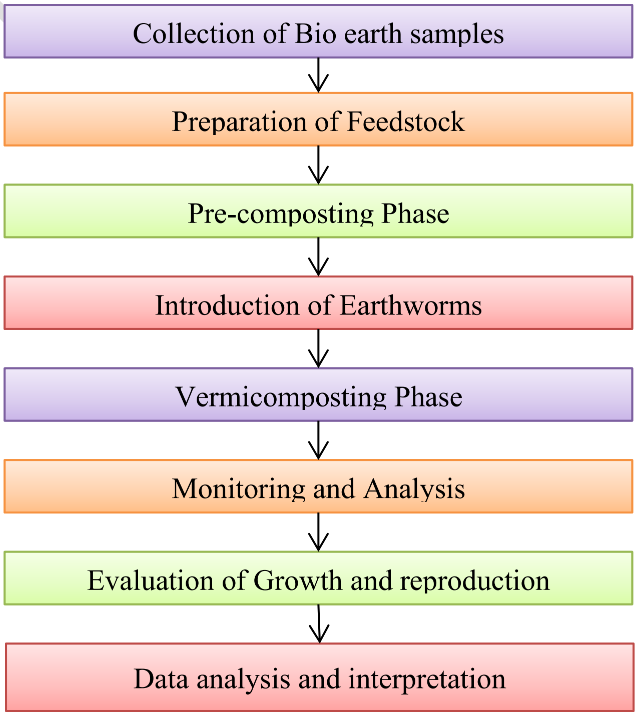
E.fetida is an earthworm determined to be the most extensive all around the globe in several inhabitats, and its vermicomposting promise has been before established. For instance, E.fetida has been chiefly used for waste of agro industry waste like paper and its mill sludge (Negi and Suthar, 2018; Suthar et al., 2014), fruits and vegetable waste (Sharma and Garg, 2017), bakery industrial sludge (Yadav and Garg, 2019; Yadav et al., 2015), slurry of biogas plant (Hanc and Dreslova, 2016), leaf waste (Singh et al., 2021), odor plant industries (Singh et al., 2013; Boruah et al., 2019), and duckweed (Guasin and Suthar, 2020). In the epigeic earthworms, Eisenia fetida was the extreme favored for vermicomposting owing to its broad range of forbearance towards numerous ecological variables (Suthar, 2009). Therefore, the present study reveals the six different bio earth samples collected from Chennai, the southern region of India is used as soil amendment, although some of heavy metals of sample prevents it from attaining compost criteria and lowers soil productivity. E. fetida has a noteworthy effect on soil fertility, vermicomposting, and the bioconversion of soil into agricultural productivity. The bioconversion efficiency of bio earth employing E. fetida and bulky agent as cow dung during vermi conversion of bio earth was studied. Moreover, the end product of vermicomposting was evaluated as per the changes occurred in physico-chemical analysis, earthworm population, and biomass. The vermicomposting samples were assessed regarding alterations in operating parameters, C/N ratio, and changes in atomic absorption spectroscopy (AAS).

Inconsistent nutrient content and the possibility of heavy metal buildup, which might exceed safe thresholds and compromise soil quality, are major problems for the vermicomposting models currently in use. The inability of these models to handle fluctuations in compost content may make them unsuitable for extensive agricultural application. To maximize compost stability and nutrient balance, on the other hand, the suggested model combines cow dung and Eisenia fetida earthworms. The model guarantees the creation of high-quality vermicompost that satisfies agricultural standards by closely monitoring physicochemical factors, such as heavy metal concentrations, throughout the process. This strategy is a potential development in sustainable agriculture since it improves soil fertility while reducing the environmental dangers connected to conventional vermicomposting techniques.

However, this study aims to improve the soil quality, nutrient level and reduce the heavy metal concentration by assessing the vermin composite effectiveness using Eisenia fetida earthworms in bio earth samples gathered from six different locations dumpsites in Chennai, India. The study is to evaluate changes in pH, bulk density, electrical conductivity, organic content, nitrogen, phosphorus, potassium, C ratio, and heavy metal levels before and after vermicomposting using physicochemical analysis. The research aims to provide insights into vermicomposting technology-based soil remediation techniques and sustainable waste management practices.

2. Materials and methods

Bio earth sample collection from Chennai's LS-1 to LS-6 biomining dumpsites is the first step in figure 1 of the proposed system's flowchart. Earthworms (Eisenia fetida) are added to glass aquariums after these samples are pre-composted with cow manure. When the proper moisture and temperature are maintained, vermicomposting takes place over a period of 108 days. Earthworm biomass and physicochemical characteristics are tracked continuously, resulting in



data analysis and evaluations of the efficacy of soil amendments. Vermicomposting is a systematic way to improve soil quality and assure thorough assessment.

Figure1. Flowchart of proposed system

2.1 Collection of bio earth samples, earthworms, and cow dung

The bio earth sample was collected from six different biomining dumpsites in Chennai, India. The locations are represented as LS-1, LS-2, LS-3, LS-4, LS-5, and LS-6 shown in Fig. 2. It guarantees a thorough evaluation of vermicomposting's effectiveness in the various soil types and local environmental circumstances. These kind of collected samples are air-dried, sieved, correctly labeled, after stored in air tightly covered, and then sent to the laboratory for physicochemical evaluation. The epigeic earthworm *Eisenia fetida* was procured at Chennai, India, and maintained in a glass tank using partially decomposed cow dung. In the present study, only clitellated earthworms were used. Cow dung (urine-free) was procured from an intensively in Chennai, India.

Fig. 2 Geographical location of collected Bioearth samples from different dumpsites in Chennai region.

2.2 Experimental design

The six glass tanks dimensions 30x15x15 cm with capacity is 6750 cm^3 were used in the real-time vermicomposting process. For the experimental design, 1.5 kg of feedstock was used in each treatment and mingled with cow dung in a 3:1 ratio (75% of bio earth + 25% of cow dung) and two weeks for pre-composted. To remove the foul gases, waste was turned manually. Following pre-composting, 10 healthy adult earthworms of average size 3.9-4.6 g were introduced in each glass tank. The vermicomposting preparation is done for 108 days and during this period 70-80% is maintained at 25 °C by sprinkling manually so that it gets decomposed and keeping the glass tank with a water bath. While this timeframe allows thorough evaluation, the extended duration may pose a disadvantage for practical applications requiring faster result.

2.3 Growth and reproduction studies on earthworms

The biotic parameters such as weight of earthworm, its mortality rate, and fecundity of the earthworms were observed in this treatment. Earthworms are physically removed from the feed mixtures on days 30, 60, and 108 and cleaned with water. After, it is add together and weighed then shifted to its corresponding glass tank. After completion of 108 days, all earthworms (adults + hatching) were splited from the glass tank and washed with water. Then counted, weighed and earthworm biomass also taken separately to calculate the growth parameters.

Firstly, environmental factors are important. Temperature and moisture content are two examples. Temperatures between 15 to 25°C are ideal for earthworms, and they need between 70 and 80 percent of moisture to stay active and properly break down organic materials. Second, the type and quality of the feedstock are crucial. Since partially degraded organic materials are easier for earthworms to consume and continue to break down, they are preferred. Due to their high organic content and readily available nutrients, materials such as kitchen scraps, garden trash, and livestock manure are appropriate. Thirdly, the decomposition of organic materials and the behavior of earthworms are influenced by pH levels. The ideal pH range for earthworms is 6.5–7.5, which is neutral to slightly acidic. High pH levels can slow down the rate of decomposition and discourage earthworm activity. Ultimately, the health and activity of earthworms may be negatively impacted by the presence of harmful materials like pesticides or heavy metals in the feedstock. During vermicomposting, these materials may build up in the tissues of earthworms, which may have an impact on the worms' ability to reproduce and function normally.

2.4 Physio–chemical and heavy metal analysis

The bio earth substrates were tested for pH, EC, Total Organic Carbon (TOC), Total Nitrogen (TN), Total Phosphorus (TP), Total Potassium (TK), C:N ratio, and the presence of heavy metals (Cu, Fe, Mn, Zn, Cd, Pb, and Cr). Dry weight was used as the foundation for the physicochemical analysis. pH was determined utilizing a portable digital pH meter (Eco Test pH 2 with Automatic Temperature Compensation). The EC was carried out using an EC meter (Model 1056 digital conductivity Meter; temperature compensation 5 to 45 °C). The electrical conductivity was determined by a portable conductivity meter in a 1:10 (w/ v) aqueous solution prepared in deionized water. The organic content of the soil, carbon (%), and nitrogen (%) were assessed using a Walkley-Black method (Walkley and Black, 1934). Likewise, TOC (%) is determined using the FAO Method 2007 (Walkley black wet combustion method). Nitrogen (%) using Kjeldahl's technique, Phosphorus (%) was found by using Colorimetric technique, and potassium (%) was found by utilizing a Flame-Photometer-FP910. Heavy metals were recorded on an Atomic Absorption Spectrophotometer (AAS vario 6).

3. Results and discussion

3.1 pH

The pH were increased in Bioearth samples LS-1 (6.9-7.1), LS-5 (6.7-6.9), and LS-6 (6.9-7.4). The intense microbial activity and organic matter decomposition formed ammonia and raised pH level of the compost in the primary days (Suthat et al., 2015, Omrani and Asgharnia, 2005). Conversely, there was decrease in the samples LS-2 (7.2-6.8), LS-3 (7.2-6.8), and LS-4 (7-6.9), as represented in Fig. 2a. The pH goes down, which could be attained by CO_2 production according earthworm microbial activities and microorganisms (Amouei et al., 2017). Due to the conversion of the nitrogen and phosphorus into nitrates and orthophosphates decreased the pH. The rising pH could be more consistent in compost vermicomposting samples in results.

3.2 Electrical conductivity

The most negligible conductivity value was 1.3 (mS/cm) noted from the two sites, LS-1 and LS-6, and the most significant value was 2.4 (mS/cm) in LS-5 in the beginning stage. Conductivity in the LS-6 dumpsite was 1.102 (mS/cm) and 2.388 (mS/cm) in LS-4 and LS-6, which are the lowest and the highest conductivity values at the end of the investigation. As illustrated in Fig. 3b, the graph established the conductivity changes in all the dumping sites. The findings established that the EC was reduced due to earthworms and the decomposition of organic matter. The accumulation of few minerals in the earthworm bodies was caused reduction of EC. The activity of earthworms, organic matter decomposition, compounds mineralization, and their solvability and mobility were raised, which leads to raised EC.

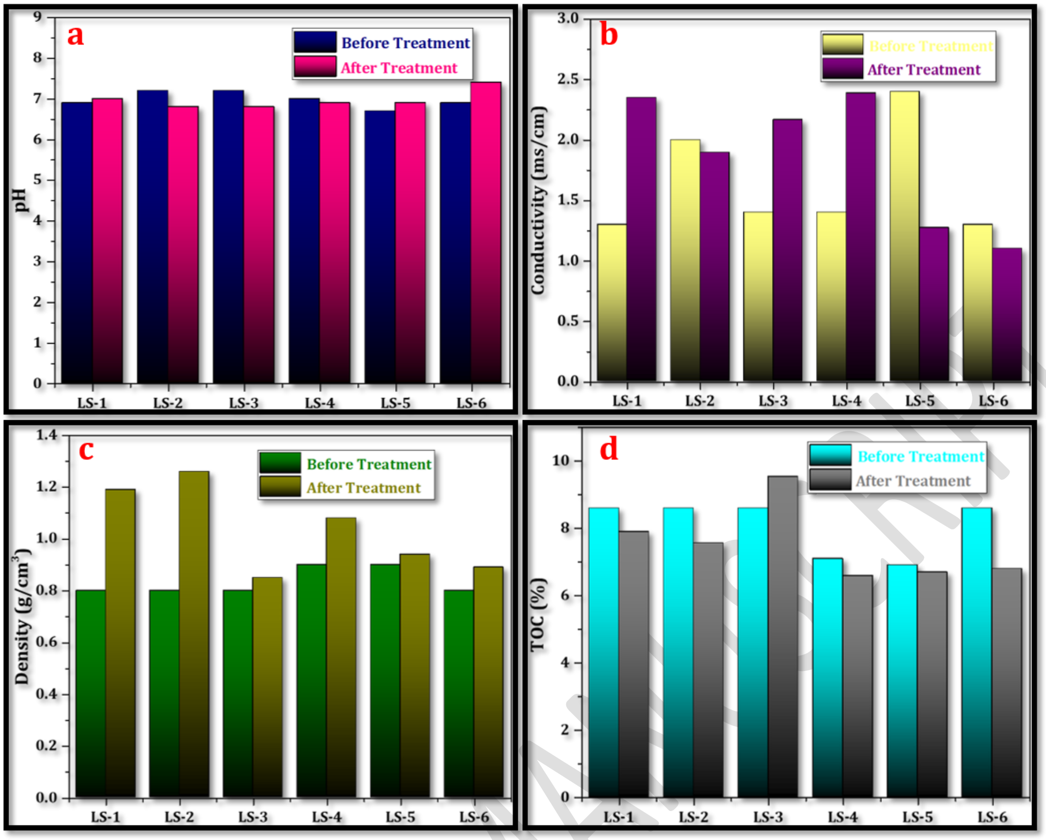


Fig. 3 (a) pH, (b) electrical conductivity, (c) bulk density, and (d) TOC of vermicomposting samples at different locations (LS 1-6)

3.3 Bulk density

The bulk density initially varied from 0.8 (g/cm^3) to 0.9 (g/cm^3) and finally ranged from 0.85 (g/cm^3) in LS-3 and 1.26 (g/cm^3) in LS-2 respectively. The bulk density in the LS-2 boomed, and other dumping sites increased with different levels. Overall, the values were presented in Fig. 2c.

3.4 Total organic carbon

In primary stage, TOC was determined slightly at 6.9% from LS-3 and 8.6% in the remaining four dump sites except LS-4. The minimum TOC at the end of the day was 6.59% in LS-4, and the maximum was 9.45% in LS-3. More nitrogen content in vermicompost than feedstock was probably due to accumulation of nitrogen by the earthworms and reduced organic carbon in the form of eliminated nitrogenous substances, mucus, growth-encouraging hormones, rhizobium, and enzymes. In the present study, except for the LS-3 dumping site, the total organic content has reduced with a marginal difference from the initial weeks, as represented in Fig. 2d.

3.5 Nitrogen

Further, the total nitrogen was obtained from 0.4% in LS-4 and LS-5 to 0.6% in the preliminary stage at all dumping sites. Likewise, LS-5 had 0.38%, which is the lowest nitrogen content, and 0.67%, the highest in LS-3 at the ending level as shown in Fig. 3a. In vermicomposting, earthworms play an important role in increasing the nitrogen content. The graph shows that the dumping sites LS-2 and LS-3 had an increased nitrogen content.

3.6 Phosphorus

The total phosphorous content is 0.3% at all dumping sites except the LS-4 at the starting stage. The same absolute phosphorous content minimum of 0.19% was obtained from LS-4 and a maximum of 0.39% in LS-2 at the end, primarily due to the phosphatases in earthworm cast enzymes, which may be a reason for the increased total phosphorus content. Upon seeing the investigation's final results, dumping sites LS-2, LS-3, and LS-6 complete phosphorus content had improved, as presented in Fig. 3b.

3.7 Potassium

The total potassium collected was 0.2% in LS-4 and 0.5% in LS-2 at the elementary level. On the contrary, 0.13% at LS-3 and LS-4 while the other dumping sites, had a marginal difference. Maximized potassium level during vermicomposting is probably due to the microbes in the earthworm’s gut, which might have played an essential role in the vermicomposting process. According to the current study, the total potassium content increased in site LS-2 as presented in Fig. 4c.

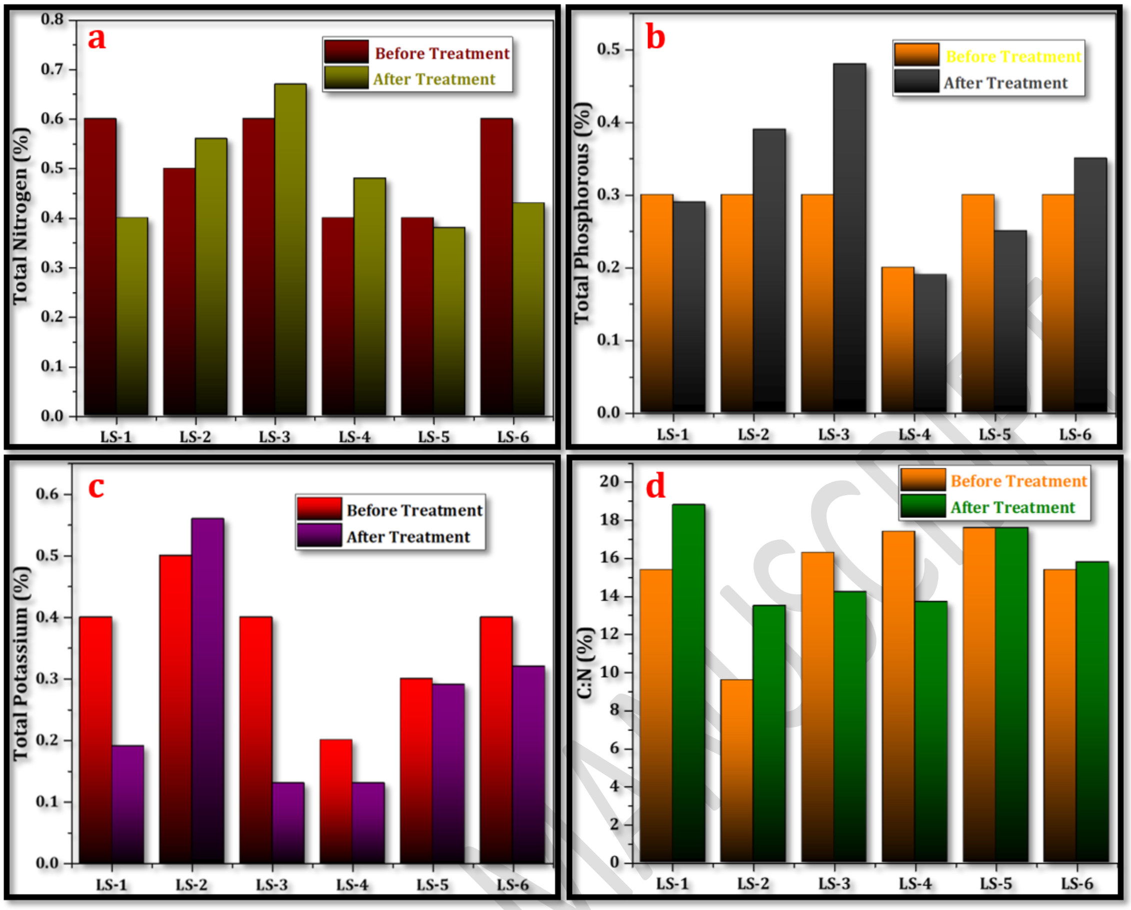


Fig. 4 (a) nitrogen, (b) phosphorous, (c) potassium, and (d) Carbon: Nitrogen ratio of vermicomposting samples at different locations (LS 1-6).

3.8 C:N Ratio

The Carbon: Nitrogen ratio lies between 9.6 and 17.6 at the LS-2 and LS-3 primary stages of the vermicomposting. At the same time, 13.5 in LS-2 and 18.8 in LS-5 were the maximum and minimum ratios in the terminating level. The carbon-nitrogen ratio presents the decay of organic materials and stability determined in initial stage of composting. The Carbon - Nitrogen ratio of substrate was reduced in all samples over time. The production of part of organic carbon as co2, and the mineralization of n owing to the microbial decay process and the production of enzymes, mucous, and nitrogen compounds attains by the decomposition of organic matter. Afterwards the experiment period, the carbon-Nitrogen ratio has reduced. In this investigation, LS-3 and LS-4 dump sites had a minimum C/N ratio at the end of the study as presented in Fig. 3d.

3.9 Heavy metals

The Fig. 5 shows the heavy metals (Zn, Cu, Ni Pb, and Cr) in the vermicompost produced by bio earth. Findings explained that heavy metal concentration reduced over time, indicating that earthworms could biotically gather heavy metals in its tissues. (Asgharzadeh et al., 2014). In addition, it differed in each good earth sample like LS-1 (422.7-465.27 mg/kg), LS-2 (618.8-496.35 mg/kg), LS-3 (448.8-64.3 mg/kg), LS-4 (645.3-13 mg/kg), LS-5 (448.8-545.03 mg/kg), and LS-6 (422.7-458.11 mg/kg). Soil pH plays a major factor in controlling the availability of the Zn. In the present study, pH is directly proportional to zinc and copper. Previously it was described that zinc concentration were 20-110% higher in vermicomposts of food industry sludge. After the treatment, the copper ranged in each bio earth sample such as LS-1 (132.5-209.14 mg/kg), LS-2 (465.3-349.98 mg/kg), LS-3 (132.5-5.5 mg/kg), LS-4 (210.1-78.67 mg/kg), LS-5 (112.2-72.48 mg/kg), LS-6 (132.5-52.93 mg/kg). The lead in bio earth/good earth samples LS-1 (91.2-88.24 mg/kg), LS-2 (121.6-126.4 mg/kg), LS-3 (91.2-101 mg/kg), LS-4 (108.4-27.87 mg/kg), LS-5 (67.6-64.12 mg/kg), LS- 6 (116.3-48.8 mg/kg). At the end of this investigation, the chromium in bio earth/good earth samples LS-1 (116.3-116.9 mg/kg), LS-2 (142.6-131.8 mg/kg), LS-3 (116.3-51 mg/kg), LS-4 (132.7-55.74 mg/kg), LS-5 (128.9-53.11 mg/kg), LS-6 (116.3-48.8 mg/kg). After the treatment, the lead in bio earth/good earth samples LS-1 (61.4-47.43 mg/kg), LS-2 (88.4-78.24 mg/kg), LS-3 (61.4-7.26 mg/kg), LS-4 (71.3-24.01 mg/kg), LS-5 (76.1-46.72 mg/kg), LS-6 (61.4-52.07 mg/kg).

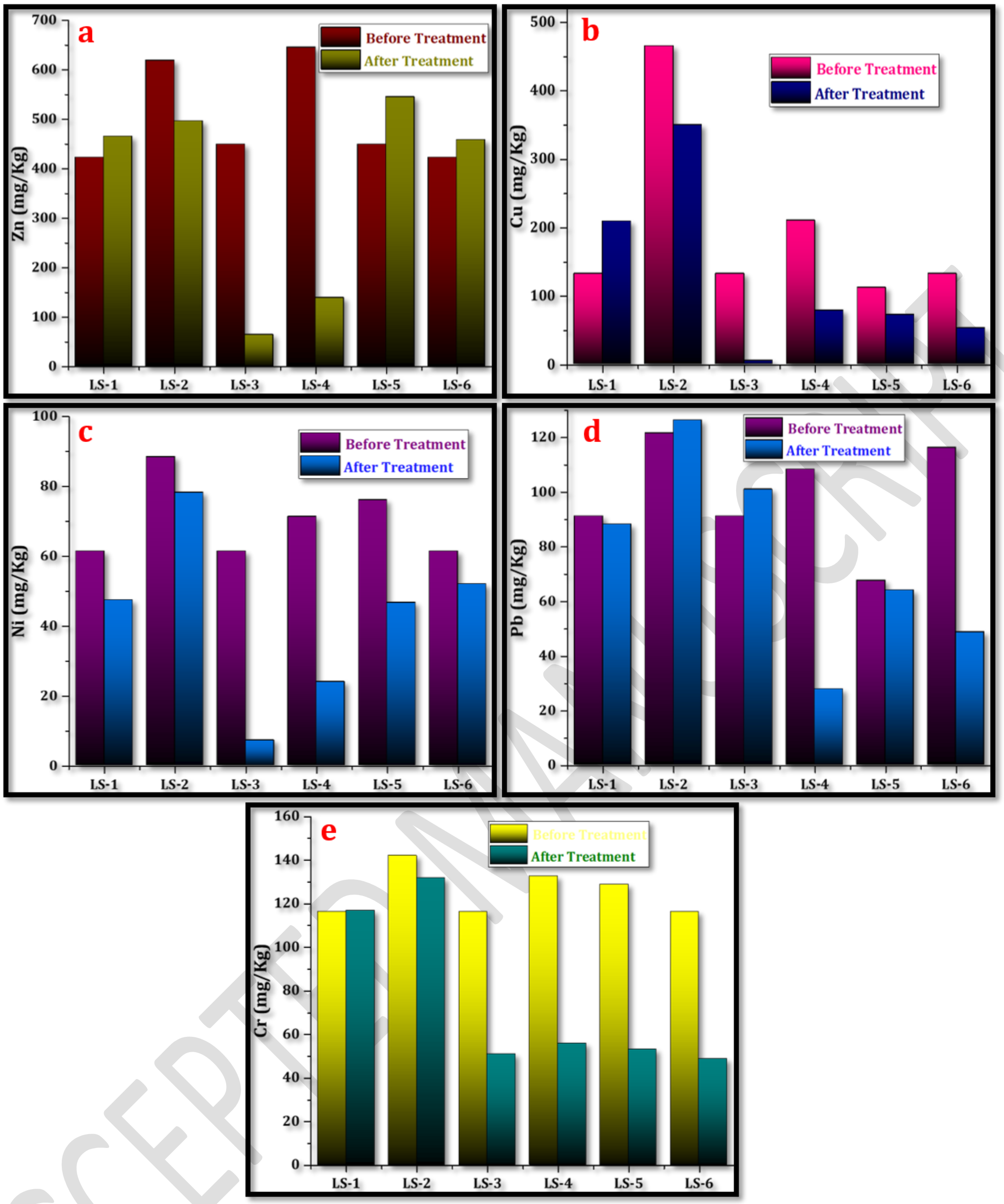


Fig. 5 (a) Zinc, (b) Copper, (c) Nickel, (d) Lead, and (e) Chromium of vermicomposting samples at different locations (LS 1-6)

3.10 Growth and reproduction on earthworms

The results of the growth and reproduction of earthworms are represented in Table 1. In the existing research, the evaluation of E.fedita was complete on the changes in biomass, its reproduction and overall earthworms calculated in all six treatments at the final stage of the study. It is evident that the earthworm biomass has increased significantly in all the locations. No mortality was observed in this study. Among different locations, the optimal biomass gain and earthworm reproduction were determined in LS-5. The maximal biomass gains (83.1 g) was in LS-5, and the minimal biomass gain (40.0 g) was in LS-2.

Table 1. Biological parameter of *E. fetida*

Bioearth sample	**Earthworm reproduction (Nos)**				**Earthworm Biomass (g)**			
	0th day	**30th day**	**60th day**	**108th day**	**0th day**	**30th day**	**60th day**	**108th day**
LS-1	10	21	84	102	4.6	11.1	31.6	49.3
LS-2	10	61	82	93	4.4	27.2	33.5	40.0
LS-3	10	33	59	97	3.9	15.2	24.5	47.1
LS-4	10	48	107	118	4.6	20.6	45.0	57.0
LS-5	10	54	120	189	4.1	26.9	53.6	83.1
LS-6	10	96	105	161	4.3	44.2	46.8	62.9

The results of the growth and reproduction of earthworms are represented in Table 1. In the existing research, the evaluation of E.fedita was complete on the changes in biomass Earthworms are hermaphrodite with separate testes and ovaries. Most of the earthworm species reproduce by cross-fertilization, although some species produce cocoons parthenogenetically or by self-fertilization.

Table 2 provides a comparative analysis

Species of earthworm	**Growth rate (mg worm^{-1}day^{-1})**
Perionyx excavates [41]	22.91
Perionyx ceylanensis [42]	1.34
Lumbricus rubellus [42]	8.02
Dendrobaena rubida [42]	3.84
(Proposed system) E.fedita	73.15

A comparison of the development rates of different earthworm species when given cow dung as their substrate is shown in table 2.

The species with the fastest growth rate, Eisenia fetida, also referred to as the red wiggler or red worm, is listed. Its rate is 73.15 mg worm-1day-1. This demonstrates E. fetida's remarkable capacity to break down organic materials quickly and turn it into biomass. Because of this, it is a recommended option for vermicomposting because of its effective nutrient cycling. Perionyx excavates has a moderate buildup of biomass, growing at a rate of 22.91 mg worm-1day-1. With a growth rate of 8.02 mg worm-1day-1, Lumbricus rubellus exhibits balanced growth performance. With a growth rate of 3.84 mg worm-1day-1, Dendrobaena rubida is a noteworthy species when compared to other species, however it is not as fast as E. fetida. At mg worm-1day-1, Perionyx ceylanensis exhibits the lowest growth rate, indicating a slower rate of biomass accumulation under comparable conditions. The efficacy of E. fetida in vermicomposting processes is highlighted by its much greater growth rate, which speeds up the decomposition of organic materials and improves the yield of nutrient-rich compost. Using its quick growth and capacity for nutrient cycling in agricultural and environmental applications, this comparative investigation identifies E. fetida as a potential species for sustainable waste management and soil fertility augmentation techniques.

4. Conclusion

This study concluded that earthworms can proficiently transform cattle dung into vermicompost. However, bio earth samples (75%) must mixed with cattle dung bulking material in the applicable quantity (25%); otherwise, evolution of earthworms and fertility may be harmfully exaggerated. The vermicompost contain lesser amounts of NPK, TOC, and C: N gratified. Earthworm growth increased gradually at the initial stage up to 30 days, but after that, it was monitored at the regular intervals of every 30 days. However, the soil nutrient in vermicompost was significantly maximum than compost prepared absence of earthworms. After the successful earthworms reproduction in the bioearth + cattle dung treatment groups reduced and bioconcentrated, the elevated levels of heavy metals such as chromium, lead, mercury, nickel, copper present in vermicompost able to pose possible environmental harmful during and enhanced in the rehab of degraded bioearth samples. The proposed study has advantages of improved richness of soil using organic matters, reduced heavy metal concentrations, improved soil nutrient and structure by enhancing the activity of earthworm for sustainable waste management practices. However, there are drawbacks, such as the long 108-day trial period that can restrict its usefulness in situations where faster answers are needed. Furthermore, in larger-scale implementations, the process's reliance on ideal climatic conditions and regular manual maintenance may present logistical difficulties. The scope of future research can be done by converting vermicompost feedstock into stable products which can be utilized in agricultural domain to increase soil fertility and productivity of crops. Moreover, it is important to look into the scalability and economic feasibility of vermicomposting technologies in various agricultural contexts in order to promote wider adoption and sustainable soil management techniques.

Author Contribution

S. Banupriya – Formal analysis, Methodology, Writing – Original draft, Investigation, conceptualization, Data analysis. S.Kanmani – Supervision, Visualization, Validation, Resources, Reviewing and Editing.

Declaration of competing interest

The authors declare no relevant competing interests.

Data availability statement

Data sharing is not applicable to this article as no data sets were generated or analysed during the current study.

Funding

The authors gratefully acknowledge Tamil Nadu Initiative and Innovative (TANII), Tamil Nadu for providing financial assistance under major research project (3655/CTDT-2/2020) to accomplish the work successfully.

Ethical approval

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

References

1. Achsah, R.S. and Prabha, M.L., 2013. Potential of vermicompost produced from banana waste (Musa paradisiaca) on the growth parameters of Solanum lycopersicum. *Int. J. Chem. Tech. Res*, *5*.
2. Adam, J.C., Stephens, J.C., Brady, M.P., Chung, S.H., Evans, R.D., Kruger, C.E., Lamb, B.K., Liu, M., Stockle, C.O., Vaughan, J.K. and Chen, Y., 2014. BioEarth: a regional biosphere-relevant earth system model for understanding the Impacts of agricultural and natural resource management decisions. *Climatic Change*.
3. Amouei, A.I., Yousefi, Z. and Khosravi, T., 2017. Comparison of vermicompost characteristics produced from sewage sludge of wood and paper industry and household solid wastes. *Journal of Environmental Health Science and Engineering*, *15*. https://doi.org/10.1186/s40201-017-0269-z
4. Allen, E., Kruger, C., Leung, F.Y. and Stephens, J.C., 2013. Diverse perceptions of stakeholder engagement within an environmental modeling research team. *Journal of Environmental Studies and Sciences*, *3*, 343-356. https://doi.org/10.1007/s13412-013-0136-x
5. Allen, E., Stephens, J., Yorgey, G., Kruger, C., Ahamed, S. and Adam, J., 2017. Climate science information needs among natural resource decision-makers in the Northwest US. *Climate Services*, *5*. https://doi.org/10.1016/j.cliser.2017.03.002
6. Asgharzadeh, F., Ghaneian, M.T., Amouei, A. and Barari, R., 2014. Evaluation of cadmium, lead and zinc content of compost produced in Babol Composting Plant.
7. Barthod, J., Rumpel, C. and Dignac, M.F., 2018. Composting with additives to improve organic amendments. A review. *Agronomy for Sustainable Development*, *38*. https://doi.org/10.1007/s13593-018-0491-9
8. Boruah, T., Barman, A., Kalita, P., Lahkar, J. and Deka, H., 2019. Vermicomposting of citronella bagasse and paper mill sludge mixture employing Eisenia fetida. *Bioresource technology*, *294*. https://doi.org/10.1016/j.biortech.2019.122147
9. Byun, D. and Schere, K.L., 2006. Review of the governing equations, computational algorithms, and other components of the Models-3 Community Multiscale Air Quality (CMAQ) modeling system. *Applied mechanics reviews*, *59*. https://doi.org/10.1115/1.2128636
10. Garg, V.K. and Kaushik, P., 2005. Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm Eisenia foetida. *Bioresource Technology*, *96*. https://doi.org/10.1016/j.biortech.2004.09.003

11. Guenther, A.B., Jiang, X., Heald, C.L., Sakulyanontvittaya, T., Duhl, T.A., Emmons, L.K. and Wang, X., 2012. The Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGAN2.1): an extended and updated framework for modeling biogenic emissions. *Geoscientific Model Development*, *5*. https://doi.org/10.5194/gmd-5-1471-2012
12. Gusain, R. and Suthar, S., 2020. Vermicomposting of duckweed (Spirodela polyrhiza) by employing Eisenia fetida: Changes in nutrient contents, microbial enzyme activities and earthworm biodynamics. *Bioresource technology*, *311*. https://doi.org/10.1016/j.biortech.2020.123585
13. Hamlet, A.F. and Lettenmaier, D.P., 1999. Effects of climate change on hydrology and water resources in the Columbia River Basin 1. *JAWRA Journal of the American Water Resources Association*, *35*. https://doi.org/10.1111/j.1752-1688.1999.tb04240.x
14. Hanc, A. and Dreslova, M., 2016. Effect of composting and vermicomposting on properties of particle size fractions. *Bioresource technology*, *217*. https://doi.org/10.1016/j.biortech.2016.02.058
15. Kavitha, P., Ravikumar, G. and Manivannan, S., 2010. Vermicomposting of banana agro-waste using an epigeic earthworm Eudrilus eugeniae (kinberg). *Int. J. Recent Sci. Res*, *1*.
16. Kooch, Y., Parandosh, Z. and Zarafshar, M., 2022. The effect of changing forest vegetation to rangeland on soil flora and fauna activities of the mountainous part of Kinj-Nowshahr. *Journal of Rangeland/Nashriyyah-i Martá*, *16*. DOR: 20.1001.1.20080891.1401.16.3.6.2
17. Liu, M., Rajagopalan, K., Chung, S.H., Jiang, X., Harrison, J., Nergui, T., Guenther, A., Miller, C., Reyes, J., Tague, C. and Choate, J., 2013. What is the importance of climate model bias when projecting the impacts of climate change on land surface processes? *Biogeosciences Discussions*, *10*. doi:10.5194/bgd-10-17145-2013
18. Liu, M., Rajagopalan, K., Chung, S.H., Jiang, X., Harrison, J., Nergui, T., Guenther, A., Miller, C., Reyes, J., Tague, C. and Choate, J., 2014. What is the importance of climate model bias when projecting the impacts of climate change on land surface processes? *Biogeosciences*, *11*. https://doi.org/10.5194/bg-11-2601-2014
19. Mullis, T., Liu, M., Kalyanaraman, A., Vaughan, J., Tague, C. and Adam, J., 2014. Design and implementation of Kepler workflows for BioEarth. *Procedia Computer Science*, *29*. https://doi.org/10.1016/j.procs.2014.05.157

20. Ndegwa, P.M. and Thompson, S.A., 2001. Integrating composting and vermicomposting in the treatment and bioconversion of biosolids. *Bioresource technology*, *76*. https://doi.org/10.1016/S0960-8524(00)00104-8
21. Negi, R. and Suthar, S., 2018. Degradation of paper mill wastewater sludge and cow dung by brown-rot fungi Oligoporus placenta and earthworm (Eisenia fetida) during vermicomposting. *Journal of cleaner production*, *201*. https://doi.org/10.1016/j.jclepro.2018.08.068
22. Omrani, G.H. and Asgharnia, H.A., 2005. Capability of earth worm (Eisenia fetida) in processing of household wastes to vermicompost. *Journal of School of Public Health and Institute of Public Health Research*, *3*, 59-66.
23. Rajagopalan, K., Chinnayakanahalli, K., Adam, J.C., Barber, M.E., Yorgey, G., Stockle, C., Nelson, R., Brady, M., Dinesh, S., Malek, K. and Kruger, C., 2011, December. Assessing the impact of climate change on Columbia River Basin agriculture through integrated crop systems, hydrologic, and water management modeling. In *AGU Fall Meeting Abstracts*.
24. Parthasarathi, K., Balamurugan, M., Prashija, K.V., Jayanthi, L. and Ameer Basha, S., 2016. Potential of Perionyx excavatus (Perrier) in lignocellulosic solid waste management and quality vermifertilizer production for soil health. *International Journal of Recycling of Organic Waste in Agriculture*, *5*. https://doi.org/10.1007/s40093-016-0118-6
25. Pigatin, L.B.F., Atoloye, I.A., Obikoya, O.A., Borsato, A.V. and Rezende, M.O.O., 2016. Chemical study of vermicomposted agroindustrial wastes. *International Journal of Recycling of Organic Waste in Agriculture*, *5*. https://doi.org/10.1007/s40093-016-0117-7
26. Saravanan, G. and Ramesh, S.T., 2023. Statistical analysis of seasonal variation in the characteristics of soil like material and refuse derived fuel recovered from landfill mining. *Stochastic Environmental Research and Risk Assessment*. https://doi.org/10.1007/s00477-023-02569-z
27. Sharma, K. and Garg, V.K., 2017. Management of food and vegetable processing waste spiked with buffalo waste using earthworms (Eisenia fetida). *Environmental Science and Pollution Research*, *24*. https://doi.org/10.1007/s11356-017-8438-2
28. Singh A, Akansha Jain, Birinchi K. Sarma, P.C. Abhilash, Harikesh B. Singh, 2013. Solid waste management of temple floral offerings by vermicomposting using Eisenia fetida. *Waste Management*, *33,* 1113-1118. https://doi.org/10.1016/j.wasman.2013.01.022

29. Singh, N.K., Shahi, K., Kumar, K. and Suthar, S., 2021. Enhanced vermicomposting of leaf litter by white-rot fungi pretreatment and subsequent feeding by Eisenia fetida under a two-stage process. *Bioresource Technology Reports*, *13*, 100609. https://doi.org/10.1016/j.biteb.2020.100609
30. Suthar. S, 2009. Vermicomposting of vegetable-market solid waste using Eisenia fetida: Impact of bulking material on earthworm growth and decomposition rate. *Ecological Engineering*, 35, 914-920. https://doi.org/10.1016/j.ecoleng.2008.12.019
31. Suthar, S., Sajwan, P. and Kumar, K., 2014. Vermiremediation of heavy metals in wastewater sludge from paper and pulp industry using earthworm Eisenia fetida. *Ecotoxicology and Environmental Safety*, *109*, 177-184. https://doi.org/10.1016/j.ecoenv.2014.07.030
32. Suthar, S., Kumar, K. and Mutiyar, P.K., 2015. Nutrient recovery from compostable fractions of municipal solid wastes using vermitechnology. *Journal of Material Cycles and Waste Management*, *17*, 174-184. https://doi.org/10.1007/s10163-014-0238-x
33. Stöckle, C.O., Kemanian, A.R., Nelson, R.L., Adam, J.C., Sommer, R. and Carlson, B., 2014. CropSyst model evolution: From field to regional to global scales and from research to decision support systems. *Environmental modelling & software*, *62*, 361-369. https://doi.org/10.1016/j.envsoft.2014.09.006
34. Tague, C.L. and Band, L.E., 2004. RHESSys: Regional Hydro-Ecologic Simulation System—An object-oriented approach to spatially distributed modeling of carbon, water, and nutrient cycling. *Earth interactions*, *8*, 1-42. https://doi.org/10.1175/10873562(2004)8<1:RRHSSO>2.0.CO;2
35. UMA MAGESWARI, S.D., SURESH, M., KUMAR, U.R., KRISHNAMOORTHY, N., PADHI, S., BAMANE, K.D., MUNJAL, N. and RAJARAM, A., 2023. STUDY ON THE PHYTOEXTRACTION OF SOIL CONTAMINATED WITH SELECTED HEAVY METALS: EFFECTS OF BIOCHAR. Oxidation Communications, 46(4).
36. Walkley, A.J. and Black, I.A., 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci*. 37, 29-38.
37. Wang, P., Changa, C.M., Watson, M.E., Dick, W.A., Chen, Y. and Hoitink, H.A., 2004. Maturity indices for composted dairy and pig manures. *Soil Biology and Biochemistry*, *36*, 767-776. https://doi.org/10.1016/j.soilbio.2003.12.012

38. ISMAIL, Y., MEENA, M., MEGALA, J., SATHYASEELAN, P., NANDHA KUMAR, S.K., SANTHANAKRISHNAN, M., RAJAKUMAR, P.T. and RAJARAM, A., 2023. DERIVATION OF CHITOSAN-BASED COMPOSITE MATERIAL WITH ROOT EXTRACTS OF Calotropis gigantea ACCELERATING WOUND HEALING. Oxidation Communications, 46(4).
39. Wang, Z., Chen, Z., Niu, Y., Ren, P. and Hao, M., 2021. Feasibility of vermicomposting for spent drilling fluid from a nature-gas industry employing earthworms Eisenia fetida. *Ecotoxicology and Environmental Safety*, *214*, 111994. https://doi.org/10.1016/j.ecoenv.2021.111994
40. Yadav, A. and Garg, V.K., 2019. Biotransformation of bakery industry sludge into valuable product using vermicomposting. *Bioresource technology*, *274*, 512-517. https://doi.org/10.1016/j.biortech.2018.12.023
41. ISMAIL, Y., SURESH, M., DIWAKAR, G., KARTHIKEYAN, S., PANDIAN, R., KARTHICK, M., HALDER, S. and RAJARAM, A., 2023. BIOFORTIFICATION OF IRON IN PLANTS UNDER DROUGHT STRESS CONDITIONS-INFLUENCE OF BIOCHAR. Oxidation Communications, 46(4).
42. Yadav, A., Suthar, S. and Garg, V.K., 2015. Dynamics of microbiological parameters, enzymatic activities and worm biomass production during vermicomposting of effluent treatment plant sludge of bakery industry. *Environmental Science and Pollution Research*, *22*, 14702-14709. https://doi.org/10.1007/s11356-015-4672-7
43. VIJAYALAKSHMI, A., SAMBATH, S., JEGAN, C.D., NAGAVENI, N., SAKTHIVEL, D., KUMAR, S.S., THIRUSELVAM, K. and RAJARAM, A., 2023. BIOETHANOL PRODUCTION FROM AQUATIC WEED WATER HYACINTH (Eichhornia crassipes) THROUGH ENZYME HYDROLYSIS AND FERMENTATION METHOD. Oxidation Communications, 46(4).
44. Yang, Z., He, X. and Ashraf, M.A., 2020. Land-use change in plateau lake basin and its impact on urban ecological security. *Arabian Journal of Geosciences*, *13*, 1-8. https://doi.org/10.1007/s12517-020-5113-6
45. Debnath, S. and Chaudhuri, P.S., 2020. Growth and reproduction of Perionyx excavatus (Perrier) during vermicomposting of different plant residues. *Nature Environment and Pollution Technology*, *19*(5), pp.1937-1943.

46. Bhat, S.A., Vig, A.P., Li, F. and Ravindran, B. eds., 2020. *Earthworm Assisted Remediation of Effluents and Wastes*. Singapore: Springer Singapore.