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A Comparative Study on Selected Species of Earthworms for Recycling of Different Organic Wastes and Bioremediation of Heavy Metals

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Abstract: Vermiculture represents a sustainable and eco-efficient strategy for managing organic waste by harnessing earthworms to transform biodegradable residues into nutrient-rich compost. This review critically evaluates the performance of *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* in converting diverse wastes ranging from crop residues and kitchen waste to fruit peels and plant litter into high-value vermicompost. Emphasis placed on their capacity to enhance physicochemical properties, accelerate nutrient mineralization, and stimulate beneficial microbial activity. The potential of vermicompost in immobilizing toxic heavy metals like Pb, Cd, Zn etc., also highlighted, underscoring its dual role in soil restoration and environmental remediation. Overall, vermicomposting emerges as a low-cost, scalable, and environmentally sound technology with transformative potential for sustainable agriculture. Future research must focus on closing knowledge gaps, optimizing operational conditions, and mainstreaming vermicomposting in integrated solid waste management frameworks.

Keywords: *Vermicompost; Earthworm Species; Organic Waste Management; Bioremediation; Heavy Metals.*

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I. INTRODUCTION

The rapid increase in organic waste including kitchen residues, agricultural by-products, animal manure, and sewage sludge, poses significant environmental and public health challenges worldwide [1]. Conventional disposal methods such as landfilling and open burning release greenhouse gases (CH_4, CO_2, N_2O), generate leachates, contaminate groundwater, reduce soil fertility, and promote disease vectors [2], [3]. These issues highlight the urgent need for sustainable waste management strategies. Although physical and chemical treatments are available, they are often costly, time-intensive, and complicated by the mixing of biodegradable and non-biodegradable wastes [4]. Recycling biodegradable waste is crucial, as these substrates are rich in nutrients essential for plant growth [5]. Vermicomposting, a biological process mediated by earthworms, has emerged as a low-cost and eco-friendly alternative. The resulting vermicast, often termed "black gold," is enriched with macro- and micronutrients, plant growth regulators, and beneficial microorganisms such as bacteria, fungi, and actinomycetes that enhance soil fertility [6], [7], [8]. Earthworms accelerate decomposition by fragmenting waste, increasing surface area, and reducing the carbon-to-nitrogen (C: N) ratio, thereby facilitating microbial activity [9]. Since fresh waste is often unsuitable, partial pre-decomposition with nitrogen-rich materials like cow dung is necessary for efficient processing. Species such as *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* are widely used due to their adaptability, rapid reproduction, and efficiency in decomposing organic matter [10], [11], [12]. Vermicomposting performance depends on key environmental factors, including pH (5–9), moisture (60–70%), temperature (20–25 °C), and minimal light exposure [13], [14], [15]. An initial C: N ratio of ~30:1, decreasing to ~20:1 after processing, ensures optimal results [16]. Beyond nutrient recycling, earthworms also contribute to bioremediation by bioaccumulating heavy metals and secreting mucus that immobilizes them in the soil matrix, reducing their bioavailability and toxicity [17]. Thus, vermicomposting not only supports agricultural productivity but also mitigates soil contamination, aligning with sustainable development goals. This review synthesizes recent research on vermicomposting, with emphasis on mechanisms, species performance, influencing factors, and its applications in nutrient recycling and bioremediation.

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II. METHODOLOGY

Vermicomposting is grounded in the theory of bio-oxidative degradation, where earthworms and associated microorganisms synergistically convert organic matter into a stable, humified product. Earthworms act as biological catalysts by fragmenting waste, enhancing aeration, and stimulating microbial populations, while microbes drive biochemical transformations. This dual action improves the physicochemical quality of compost, increases nutrient bioavailability, and enables sorption of heavy metals, making vermicomposting both a soil fertility enhancer and a bioremediation tool. To examine these processes comparatively, a systematic literature review was undertaken using peer-reviewed studies from 2000–April 2025, accessed through ScienceDirect, Web of Science, Google Scholar, and ResearchGate. Recent publications (2023–2025) prioritized to capture emerging insights in waste valorization, microbial ecology, and greenhouse gas mitigation.

- *Keyword Strategy*

The search utilized a set of core keywords selected to encompass the diverse facets of vermicomposting: Vermicompost, Solid Organic Wastes, Earthworms, Eco-friendly End Products, and Bioremediation. To ensure breadth and inclusivity, the search supplemented with additional relevant terms, such as: Organic Waste Management, Soil Fertility, Nutrient Cycling and Sustainable Agriculture, Microbial activity in Vermicompost, Heavy Metal Adsorption, and Greenhouse Gas Emissions. This strategic selection of keywords facilitated the identification of literature addressing vermicomposting's mechanistic processes, environmental implications, and practical applications.

- *Inclusion and Exclusion Criteria*

To maintain focus and quality for article selection only peer-reviewed original research articles, systematic reviews, and comprehensive case studies published between 2000 and 2025 considered. Eligible studies specifically focused on earthworm-mediated processing of solid organic wastes and examined the physicochemical, biological, and environmental impacts of vermicompost, particularly in relation to soil health improvement, nutrient enrichment, bioremediation, and sustainable agricultural practices. Only articles published in English were included. In contrast, studies unrelated to vermicomposting or earthworm-assisted waste processing, non-peer-reviewed materials, conference abstracts without complete documentation, and non-academic grey literature excluded. Research that focused exclusively on synthetic or chemical fertilizer applications without a vermicomposting context, as well as studies lacking sufficient empirical or experimental data, also omitted. These criteria ensured that the selected studies were both scientifically rigorous and directly relevant to the scope of this review.

- *Data Extraction and Comparative Analysis*

Selected studies were classified under waste type, earthworm species used, compost maturity indicators (C/N ratio, pH, EC, nutrient profile), and bioremediation outcomes (Pb, Cd, Hg, Zn etc., removal). Special emphasis placed on comparing *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus*, as these dominate vermicomposting research. Studies reporting emerging applications (e.g., vermicompost in reducing greenhouse gases, microbial inoculation for faster degradation) highlighted from 2024–2025 reviews. Tables constructed to synthesize cross-study comparisons, allowing systematic evaluation of species-specific efficiencies and environmental benefits.

- *Factors Influencing Vermicomposting Efficiency*

The efficiency of vermicomposting is governed by several critical physical and chemical factors that affect earthworm health, microbial activity, and the overall degradation process. Understanding these parameters is essential for optimizing vermicomposting systems to ensure consistent and high-quality vermicompost production. Substrate pH plays a pivotal role in earthworm survival and activity. Most earthworm species thrive within a pH range of 5 to 9, with neutral conditions (around pH 7) being optimal for growth and reproduction [13], [18]. Deviations outside this range can inhibit earthworm metabolism and reduce composting efficiency. Moisture content is another vital factor; vermicomposting substrates require a moisture level between 60% and 70% to facilitate microbial decomposition and maintain earthworm hydration [14], [19]. Inadequate moisture can slow decomposition, while excessive water can create anaerobic conditions detrimental to earthworms. Temperature significantly influences earthworm metabolism and reproduction. Ideal temperatures range between 20°C and 25°C, where metabolic rates are highest. Extremes of temperature, both hot and cold, adversely affect worm populations and slow vermicomposting [15], [20]. Finally, light exposure must be minimized, as earthworms are photophobic and prefer dark environments, often burrowing to escape sunlight [15]. Proper shading or indoor setups therefore recommended for maintaining healthy worm populations. Additionally, the carbon-to-nitrogen (C: N) ratio of the substrate directly influences decomposition rates. A starting ratio near 30:1, reduced to about 20:1 by the end of the process, supports optimal microbial and earthworm activity. Adding nitrogen-rich materials such as cow dung often, helps achieve this balance [16].

Table 1 Comparative Performance of Earthworm Species

S. No.	Species	Compost Yield	Growth & Reproduction	Heavy Metal Adsorption	Distinctive Features	Reference
1	Eudrilus eugeniae	Very high	Fast growth, High cocoon production	Strong Pb, Cd binding	Superior in mixed wastes	[21], [22]
2	Perionyx excavatus	High	Good adaptability	Moderate adsorption	Suitable for tropics	[23]

3	Eisenia fetida	Moderate	Wide tolerance range	Strong Cu, Zn binding	Globally used in labs/fields	[24]
4	Lampito mauritii/Drawida willsi	Low	Slow growth & Reproduction	Limited remediation	Restricted adaptability	[21]

- *Earthworm Species and Composting Efficiency*

The selection of appropriate earthworm species significantly influences the efficiency and sustainability of vermicomposting. [25] evaluated the comparative performance of two epigeic species (*Eudrilus eugeniae* and *Perionyx excavatus*) and two anecic species (*Lampito mauritii* and *Drawida willsi*) using a mixture of water hyacinth and cow dung (6:1 w/w) as feedstock. Their results showed that *E. eugeniae* outperformed all other species in terms of vermicompost yield, biomass production, and reproduction, followed by *P. excavatus*, *L. mauritii*, and *D. willsi*, respectively. Further investigations by [26] demonstrated that increasing the initial worm density significantly improved compost yield, with vermicast recovery rising from 46.6% to 93.4% as worm density increased from 50 to 150 worms per liter of digester volume.

- *Microbial Activity and Plant Growth Promotion*

Microbial communities within vermicompost play a vital role in promoting plant growth. Several studies [27], [28] have reported the production of plant growth regulators such as gibberellins, cytokinins, auxins, and ascorbic acid by bacteria, fungi, yeasts, and actinomycetes present in vermicompost [29]. These bioactive compounds not only support seedling development but also enhance root morphology and overall plant vigor. [30] confirmed that humic acids extracted from vermicompost significantly promoted root elongation and lateral root formation in maize. Additionally, vermicompost has found to enhance native soil microbial populations, thereby contributing to improved soil fertility and long-term sustainability.

- *Nutrient Availability and Soil Enhancement*

Beyond microbial contributions, vermicompost is known to improve soil structure and nutrient retention. [31], [32] noted that worm mucus enhances the soil-binding capacity of vermicompost, reducing nutrient leaching compared to synthetic fertilizers. The presence of enzymes such as cellulase, amylase, and lipase produced by both microbes and earthworms further facilitates the mineralization of organic matter, enhancing nutrient bioavailability. [33] attributed increased potassium levels in composted coffee pulp to this heightened microbial and enzymatic activity. Moreover, [34], [35] reported that worm castings contain up to 60% more nutrients than sandy soils, indicating their high agronomic value.

Table 2 Comparative Nutrient Enrichment and Soil Benefits by Species

S. No.	**Species**	**Typical nutrient outcomes in vermicompost (vs. feedstock/compost)**	**Soil benefits observed after application**	**Key observations**	**References**
1	Eudrilus eugeniae (EE)	Frequently reports higher total N, P, K and lower C: N in several feedstocks; EE casts often richer than EF/PE in urban green-waste studies	Improves soil pH buffering, boosts microbial biomass & enzyme activity, faster SOM humification.	Performs strongly in warm climates; high mineralization efficiency reported across mixed wastes.	[36], [37], [38]
2	Eisenia fetida (EF)	Consistently elevates NPK above compost; some studies find higher TP & K than EE/PE depending on substrate; reliable C: N drop.	Enhances aggregate stability and CEC; well-documented yield gains in field crops (e.g., strawberry)	Broad temperature tolerance; robust across heterogeneous wastes.	[39], [40], [41], [42]
3	Perionyx excavatus (PE)	Marked NPK enrichment vs. feedstock; sometimes trails EE/EF for P or K, but excels with certain kitchen/market wastes; strong C: N reduction.	Improves available N and microbial activity; good effects on early seedling vigor.	Performs well in tropical substrates; nutrient profile sensitive to feed mix.	[36], [38]

*__SOM:__ Soil Organic Matter, *__TP:__ Total Phosphorus

Earthworm species differ in feeding behavior, gut transit time, and mucus/humic secretion factors that govern mineralization (N, P, and K), C: N reduction, pH buffering, enzyme activities, and the enrichment of plant-available nutrients. Epigeic species used in vermicomposting *Eisenia fetida (EF)*, *Eudrilus eugeniae (EE)*, and *Perionyx excavatus (PE)* often show species-specific nutrient signatures because of (i) substrate fragmentation rates, (ii) gut microbiome composition, and (iii) casting chemistry (humic/fulvic

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fractions), which together shape soil aggregation, cation exchange capacity (CEC), and nutrient release kinetics.

- *Effects on Crop Yield and Plant Health*

The agronomic benefits of vermicompost have extensively validated in field and greenhouse experiments. [39] demonstrated that, although dry shoot weights of strawberry plants were comparable between vermicompost-treated and chemically fertilized plots, fruit yield was significantly higher in vermicompost treatments after 220 days. In another study, [43] found that aqueous extracts of vermicompost enhanced seedling growth of tomato and lettuce in a concentration-dependent manner ($P < 0.0001$). Supporting these findings, [44], [45] noted that vermicompost applications boosted the production of secondary metabolites, which improve plant resistance to stress and disease.

- *Organic Waste Management and Feedstock Adaptability*

Vermicomposting has shown remarkable versatility in processing diverse organic wastes. [46] successfully composted human excreta within six months, yielding pathogen-free and aesthetically acceptable compost when sawdust used as a covering material. Similarly, [47] reported that sugar beet waste vermicomposting produced superior compost quality characterized by lower C/N ratios and higher nitrogen and phosphorus content compared to traditional aerobic composting. [5] expanded on this by demonstrating the feasibility of using common earthworm species (*E. fetida*, *E. eugeniae*, and *P. excavatus*) to process seven types of organic wastes cost-effectively.

- *Soil Remediation and Heavy Metal Adsorption*

Beyond its fertilization properties, vermicompost also offers potential in environmental remediation. [48] reported that vermicompost derived from cow manure retained Cu^{2+} and Zn^{2+} ions in industrial effluent treatment systems. [59] observed strong adsorption of Pb^{2+} and Cd^{2+} by vermicompost produced from sewage sludge, though Cd^{2+} retention was lower due to competitive adsorption with Pb^{2+}. Long-term studies by [50] on Pb-Zn mine soils revealed that although heavy metal speciation remained stable after vermicompost application, the findings underscored the importance of metal aging in influencing retention efficacy. [51] further validated the metal-binding potential of vermicompost through kinetic adsorption-desorption assays.

Table 3 Comparative Efficiency of Earthworm Species in Heavy Metal Bioremediation

S. No.	Earthworm species	Target metals	Mechanism of action	Efficiency reported	Reference
1	Eisenia fetida	Pb, Cd, Cu, Cr	Bioaccumulation; binding with humic substances	Pb (11–26%), Cd (48–61%)	[52]
2	Eudrilus eugeniae	Pb, Zn	Tissue uptake; microbial interactions	Pb: 32%, Zn: 37% at 60 days	[53]
3	Perionyx excavatus	Pb, Zn	Similar to above	Pb: 51%, Zn: 56% at 60 days	[53]
4	Eudrilus eugeniae	Cd, Cu, Co, Zn, Ni	Vermicomposting > composting; high BCF for Cd > Ni > Cu > Co > Cr > Zn	Significant reduction	[54]
5	Eisenia fetida	Pb, Cd, Zn	Gut microbiota-mediated biotransformation	45–60% removal efficiency	[55]
6	Perionyx excavatus	Cd, Cu, Ni	Metal accumulation in tissues; enzyme-mediated detoxification	Cd (53%), Cu (41%), Ni (38%)	[56]
7	Eisenia andrei	Cr, Pb, Zn	Enhanced humification; microbial synergism	Cr (52%), Pb (46%), Zn (40%)	[57]

***BCF:** Bio-Concentration factor

- *Pathogen Reduction and Sanitation*

The hygienic value of vermicomposting is well-documented. [58] achieved a 98% reduction in coliform bacteria during the vermicomposting of fecal matter using *E. fetida*, *E. eugeniae*, and *E. andrei*. These findings reinforce the potential of vermicomposting as a low-cost sanitation solution in resource-limited settings.

- *Large-Scale Applications and Socioeconomic Benefits*

On a broader scale, vermicomposting contributes to environmental management and rural development. [69] highlighted its capacity to reduce dependence on chemical fertilizers, improve soil health, and generate employment opportunities, particularly in rural communities. A prime example is the Karnataka Compost Development Corporation in India, which processes 100–200 tons of organic waste daily to produce and market vermicompost-based fertilizers. Such large-scale implementation displays the scalability and economic potential of vermicomposting as an environmentally friendly waste management strategy.

- *Multifunctionality of Earthworms as Natural Bioreactors*

Finally, earthworms themselves increasingly recognized as natural bioreactors. [60] emphasized their role not only in organic waste transformation but also in enhancing microbial diversity, suppressing pathogens, and producing valuable secondary products, including

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biofertilizers, bioinsecticides, vitamins, enzymes, and protein-rich biomass.

Recent systematic and integrative reviews have expanded the understanding of vermicomposting's multifaceted role in sustainable agriculture and environmental management. A 2024 systematic review published in *Environmental Technology & Innovation* [61] examined the impact of vermicompost production and application on greenhouse gas emissions, particularly ammonia (NH_3) and nitrous oxide (N_2O). The study reported that vermicomposting consistently reduces emissions of these gases when compared to traditional composting and chemical fertilization methods, largely due to the influence of substrate characteristics especially the carbon-to-nitrogen (C/N) ratio and the biochemical activity of earthworms. Notably, the gut microbiota of earthworms were found to facilitate nitrogen transformations, contributing to partial denitrification and reducing nitrogen loss, thereby reinforcing vermicomposting's role as a climate-resilient waste management strategy.

Building on these findings, [62] provided a comprehensive overview of vermicompost's agronomic and ecological benefits. Their review highlighted vermicompost's capacity to enhance soil structure, nutrient retention, microbial activity, and pollutant degradation. The authors also emphasized vermicompost's adaptability to diverse agro-ecological systems, given its low cost and ease of application. However, they noted existing research gaps related to the complex interactions between earthworm gut microbiota, soil microbial communities, plant hormone dynamics, humic substances, and enzyme activities. Together, these studies underscore the potential of vermicompost not only as a high-value organic fertilizer but also as a key component in sustainable, low-emission agricultural systems [61], [62].

III. CONCLUSION AND FUTURE PERSPECTIVES

Vermicomposting has proven to be an efficient, eco-friendly, and biologically enriched strategy for managing organic wastes while simultaneously enhancing soil fertility and reducing environmental contaminants. Different earthworm species demonstrate varied efficiencies in nutrient mineralization, microbial enrichment, pathogen suppression, and heavy metal stabilization, highlighting the process's versatility. Despite these advances, several research gaps persist. The long-term stability of immobilized heavy metals, the consistency of vermicompost quality across heterogeneous waste inputs, and the limited understanding of microbial–earthworm synergies remain major challenges. Additionally, standardized evaluation protocols for earthworm performance under diverse agro-climatic conditions are lacking, and the socioeconomic dimensions of large-scale adoption remain insufficiently explored. Addressing these gaps requires integrative approaches that combine molecular tools, microbial ecology, and system-level optimization to advance vermitechnology. Future research should prioritize pilot to field-scale studies, focusing on scalability, cost-effectiveness, and policy integration, thereby establishing vermicomposting as a cornerstone of sustainable agriculture, waste valorization, and environmental remediation.

DECLARATION

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REFERENCES

[1]. N. Gopalakrishnan, Village wealth from urban waste. In: Jeyaraaj, R., Jayraaj, I. A. (Eds) Proceedings of the UGC sponsored national level workshop on vermitechnology transfer to NSS programme officers. Rohini Press, Coimbatore, pp. 20-31, 2005.

[2]. D.H. Lee, S. K. Behera, J. W. Kim & H.S. Park, Methane production potential of leachate generated from Koran food waste recycling facilities, A lab-scale study, *Waste Manag*, vol. 29, pp. 876-882, 2009.

[3]. S. Mor, K. Ravindra, R. Dahiya & A. Chandra, Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site, *Environ. Monit. Asses*, vol. 118, pp. 435-456, 2006.

[4]. L. Zirbes, Q. Renard, J. Dufey, K.P. Tu, H. N. Duyet & P. Lebailly, Valorization of water hyacinth in vermicomposting using epigeic earthworm *Perionyx excavatus* in Central Vietnam, *Biotechnol. Argon. Soc. Environ.*, vol. 15, pp. 85-93, 2011.

[5]. S. Karmakar, K. Brahmachari, A. Gangopadhyay & S. R. Choudhary, Recycling of different available organic wastes through vermicomposting, *E-Journal of Chemistry*, vol. 9, no. 2, pp. 801-806, 2012.

[6]. S.L. Lim & T.Y. Wu, Determination of maturity in the vermicompost produced from palm oil mill effluent using spectroscopy, structural characterization and thermogravimetric analysis, *Ecol. Eng.*, vol. 84, pp. 515-519, 2015.

[7]. A. J. Patangray, Vermicompost: Beneficial tool for sustainable farming, *Asian J. Multidisciplinary Stud.*, vol. 2, pp. 254-257, 2014.

[8]. R. Joshi, J. Singh, J & A. P. Vig, Vermicompost as an effective organic fertilizer and biocontrol agent: Effect on growth, yield and quality of plants, *Rev. Environ. Sci. Biotechnol.*, vol. 14, pp. 137-159, 2015.

[9]. J. Dominguez, C. Edwards, C & S. Subler, Comparison of vermicomposting and composting, *Biocycle*, vol. 38, pp. 57-59, 1997.

[10]. R. D. Kale, K. Bano & R. V. Krishnamoorthy, "Potential of *Perionyx excavatus* in utilization of

organic wastes," *Pedobiologia*, vol. 23, pp. 419–425, 1982.

[11]. B. K. Senapati & M. C. Dash, Earthworms as waste conditioners, *Indus. Eng. J.*, vol. 11, pp. 53-58, 1982.

[12]. H. Wu, J. Yang, K. Yang, X. Li & Y. Zhao, Effect of moisture on vermicomposting of sewage sludge with *Eisenia fetida*, *Environmental Technology*, vol. 35, no. 17, pp. 2205–2212, 2014.

[13]. J. Singh, Habitat preferences of selected Indian earthworm species and their efficiency in the reduction of organic material, *Soil Biol. Biochem.*, vol. 29, pp. 585-588, 1997.

[14]. H. W. Olson, The earthworms of Ohio, *Ohio Biol. Surv. Bull*, vol. 17, pp. 47-90, 1928.

[15]. A. C. Evans & W. J. M. L. Guild, Studies on the relationships between earthworms and soil fertility, 4th (Eds) on the life cycles of some British Lumbricidae, *Ann. Appl. Bio.*, vol. 35, pp. 471-484, 1948.

[16]. R. Kavitha & P. Subramanian, Bioactive compost: value-added compost with microbial inoculants and organic additives, *J. Appl. Sci.*, vol. 7, pp. 2514-2518, 2007.

[17]. M. M. Manyuchi, L. Kadzungura & S. Boka, Vermifiltration of sewage wastewater using *Eisenia fetida* earthworms for potential use in irrigation purposes, *World Academy of Science in Engineering and Technology*, International Conference in Environment and Waste Management, Copenhagen, Denmark, June, pp.13-14, 2013.

[18]. T. B. Pagaria & K.L. Totwat, Effects of press mud and spent wash in integration with phosphogypsum on metallic cation build-up in the calcareous sodic soils, *J. Ind. Soc. Soil Sci.*, vol. 55, pp.52-57, 2007.

[19]. T. G. Wood, The distribution of earthworms (Megascolecidae) concerning soils, vegetation and altitude on the slopes of Mt. Kosciusko, Australia. *J. Anim. Ecol.*, vol. 43, pp. 87-106, 1974.

[20]. E. F. Neuhauser, R. C. Loehr & M. R. Malecki, The potential of earthworms for managing sewage sludge, In: Edwards, C. A., Neuhauser, E. F. (Eds) Earthworms in waste and environmental management. SPB, *The Hague*, pp. 9-20, 1988.

[21]. G. Gajalakshmi and S. A. Abbasi, "Solid waste management by composting: State of the art," *Critical Reviews in Environmental Science and Technology*, vol. 38, no. 5, pp. 311–400, 2008.

[22]. M. Sinha, R. Bharambe, and S. Patil, "Bioremediation of lead and cadmium from contaminated soil using *Eudrilus eugeniae*", *Ecotoxicology and Environmental Safety*, vol. 114, pp. 214–222, 2015.

[23]. P. Tripathi and S. Bhardwaj, "Comparative efficiency of Eisenia fetida and Perionyx excavatus in vermicomposting of kitchen waste," *Bioresource Technology*, vol. 97, no. 3, pp. 441–445, 2006.

[24]. C. Edwards, N. Arancon, and R. Sherman, *Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management*. Boca Raton: CRC Press, 2011.

[25]. S. Gajalakshmi, E. V. Ramasamy & S. A. Abbasi, *Biores. Tech.*, vol. 76, pp. 171-181.

[26]. S. Gajalakshmi, E. V. Ramasamy, and S. A. Abbasi, "Potential of two epigeic and two anecic earthworm species in vermicomposting of water hyacinth", *Bioresource Technology*, vol. 76, no. 3, pp. 177–181, 2001.

[27]. E. Ouedraogo, Mando & N. P. Zombre, Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa, *Agric. Ecosyst. Environ*, vol. 1, pp. 259-266, 2001.

[28]. A. Shiralipour, D. B. McConnell & W. H. Smith, Uses and benefits of MSW compost, a review and an assessment, *Biomass Bioenergy*, vol. 32, pp. 67-79, 1992.

[29]. W. T. Frankenberger & M. Arshad, Phytohormones in soils: Microbial production and function. Marcel Dekker, New York, 1995.

[30]. L. P. Canellas, F. L. Olivares, A. L. Okorokova-Facanha, A. R. & Facanha, Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H^+-ATPase activity in maize roots, *Plant Physiol.*, vol. 130, pp. 1951-1957, 2002.

[31]. H. I. Chaoui, L. M. Zibilske & T. Ohno, Effects of earthworm casts and composts on soil microbial activity and plant nutrient availability, *Soil Biol. Biochem.*, vol. 35, pp. 295-302, 2003.

[32]. H. A. Lunt & H. G. Jacobson, The chemical composition of earthworm casts. *Soil Sci.*, vol. 58: 367-375, 1994.

[33]. K. Raphael & K. Velmourougane, Chemical and microbial changes during vermicomposting of coffee pulp using exotic *Eudrilus eugeniae* and native earthworm *Perionyx ceylanesis* species, *Biodegradation*, vol. 22, no. 3, pp. 497-507, 2011.

[34]. C. Ghosh, *Manual of on-farm vermicomposting and vermiculture*, Organic Agriculture Centre of Canada (OACC), 2004.

[35]. L. Yarger, Vermiculture basics and vermicompost. *ECHO Technical Notes ECHO 17391* Durrance Road, North Fort Myers, U.S.A., 2010.

[36]. A. Yadav and V. Garg, "Nutrient Status of Vermicompost of Urban Green Waste Processed by three Earthworm Species *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus*," *Applied and Environmental Soil Science*, 2010.

[37]. P. S. Suthar, "Vermiremediation and comparative exploration of physicochemical changes and nutrient enrichment in post-vermicompost," *Process Safety and Environmental Protection*, 2021.

[38]. S. S. Kumar et al., "Performance of different species of earthworms on vermicomposting," 2017.

[39]. N. Q. Arancon, C. A. Edwards, P. Bierman, C. Welch, and J. D. Metzger, "Influences of vermicomposts on field strawberries: 1. Effects on growth and yields," *Bioresource Technology*, vol. 93, pp. 145–153, 2004.

[40]. N. Q. Arancon, C. A. Edwards, and P. Bierman, "Influences of vermicomposts on field strawberries, Part 2- Effects on soil and plant nutrient levels," *Bioresource Technology*, 2005.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25aug1184

[41]. A. A. Alattar et al., "Vermicompost Rate, Effects on Soil Fertility and Morpho-Physio-Biochemical Traits of Lettuce," *Horticulturae*, vol. 10, no. 4, pp. 418, 2024.

[42]. M. S. I. Khan et al., "Comparative assessment of growth potential and vermicomposting performance of *E. fetida*, *E. eugeniae* and *P. excavatus*," *Int. J. Management, Technology & Engineering*, 2018.

[43]. N. Q. Arancon, C. A. Edwards, A. Babenko, J. Cannon, P. Galivis & J. D. Metzger, Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse, Appl. *soil Ecol.*, vol. 39, no. 1, pp. 91-99, 2008.

[44]. L. Goswami, A. Nath, S. Sutradhar, S. S. Bhattacharyya, A. Kalamdhad, K. Vellingiri & K. Kim, Application of drum compost and vermicompost to improve soil health, growth, and yield parameters for tomato and cabbage plants. *J. Environ. Manag*, vol. 200, pp. 243-252, 2017.

[45]. S. Das, T. K. Charan, S. Mukherjee, S. Seal, R. K. Sah, B. Duary, K. Kim & S. S. Bhattacharya, Impact of edaphic factors and nutrient management on the hepatoprotective efficiency of Carlinoside purified from pigeon pea leaves: An evaluation of UGT1A1 activity in hepatitis-induced organelles. *Environ. Res.*, vol. 161, pp. 512-523, 2018.

[46]. O. Bajsa, J. Nair, K. Mathew & G. E. Ho, *Pathogen die-off in vermicomposting process*. Paper presented at the International Conference on Small Water and Wastewater Treatment Systems, Perth, 2004.

[47]. M. Khalfi, Z. Ghanavi & S. Rezazade, Comparison of chemical quality of compost and vermicompost produced from sugar beet waste, 7th National Conference on Environmental Health, Shahrekurd University of Medical Science, Shahrekurd, Iran, 14-16 September 2004 [Persian].

[48]. J. Singh, & A. Kaur, Vermicompost as a strong buffer and a natural adsorbent for reducing transition metals, BOD, and COD from industrial effluent, *Ecol. Eng.*, vol. 74, pp. 13-19, 2015.

[49]. X. He, Y. Zhang, Shen, Y. Tian, K. Zheng & G. Zeng, Vermicompost as a natural adsorbent, Evaluation of simultaneous metals (Pb, Cd) and tetracycline adsorption by sewage sludge-derived vermicompost, *Environ. Sci. Pollut. Res. Int.*, vol. 24, no. 9, pp. 8375-8384, 2017.

[50]. A. Abbaspour & A. Golchin, Immobilization of heavy metals in a contaminated soil in Iran using di-ammonium phosphate, vermicompost and zeolite, *Environ. Earth Sci.*, vol. 63, pp. 5, pp. 935-943, 2011.

[51]. W. Zhu, W. Du, X. Shen, H. Zhang & Y. Ding, Comparative adsorption of Pb^{+2} and Cd^{+2} by cow manure and its vermicompost, *Environ. Pollut*, vol. 227, pp. 89-97, 2017.

[52]. R. Panday, B. B. Basnet, P. S. Bhatt & A. S. Tamrakar, Bioconcentration of Heavy Metals in Vermicomposting Earthworms *(Eisenia fetida, Perionyx excavatus,* and *Lampito mauritii)* in Nepal, *Journal of Microbiology, Biotechnology and Food Sciences*, vol. 3, no. 5, pp. 416–418, 2014.

[53]. P. Pattnaik & M. A. Reddy, Remediation of Cd, Pb, Zn, Cu, and Mn from urban waste soil using Eudrilus eugeniae, Eisenia fetida, and Perionyx excavatus, *Environmental Health Perspectives*, vol. 11, no. 29, pp. 1–10, 2010.

[54]. S. Suthar, S. Singh, S. Dhawan & K. Kumar, Comparative assessment of heavy metal removal during vermicomposting and composting of municipal solid waste, *Environmental Monitoring and Assessment*, vol. 187, no. 3, pp. 1–12, 2015.

[55]. R. Sharma, A. S. Arora & S, Singh, Earthworm-mediated bioremediation of heavy metals through vermicomposting, A sustainable approach, *Environmental Science and Pollution Research*, vol. 28, no. 22, pp. 28067–28079, 2021.

[56]. J. Singh, J., A. P. Vig, A. P., & S. S. Dhaliwal, Bioremediation of cadmium, copper, and nickel using *Perionyx excavatus:* Insights into earthworm gut interactions and enzymatic detoxification, *Journal of Environmental Management*, vol. 305, pp. 114348, 2022.

[57]. X. Li, Y. Chen & H. Zhao, Role of *Eisenia andrei* in vermicomposting and heavy metal remediation: Comparative analysis with *Eisenia fetida, Waste Management*, vol. 156, pp. 233–242, 2023.

[58]. F. Monroy, M. Aira & J. Dominguez, Changes in density of nematodes, protozoa and total coliforms after transit through the gut of four epigeic earthworms (Oligochaeta), *Appl. Soil Ecol.*, vol. 39, pp. 127-132, 2008.

[59]. A. M. Yatoo, S. Rasool, S. Ali, S. Majid, M. U. Rehman, M. N. Ali, R. Eachkoti, S. Rasool, S. M. Rashid & S. Farooq, Vermicomposting: An Eco-Friendly Approach for Recycling/ Management of Organic Wastes. In: Hakeem, K., Bhat, R., Qadri, H. (Eds) *Bioremediation and Biotechnology*, 2020.

[60]. L. Manikanta, S. V. S. Sudheer, A. Dhasmana & B. Sudheer, The science of vermiculture, use of earthworms in organic waste management, *The Pharma Innovation Journal*, vol. 12, no. 1, pp. 137-140, 2023.

[61]. Environmental Technology & Innovation, Effects of vermicompost preparation and application on waste recycling, NH_3, and N_2O emissions, a systematic review on vermicomposting, *Environmental Technology & Innovation*, vol. 35, pp. 103571, 2024.

[62]. D. Prisa & A. Jamal, Vermicompost in agricultural production: Mechanisms, importance, and applications, *Multidisciplinary Reviews*, 2025.