Heavy Metals Concentration Changes during Vermicomposting of Organic Wastes

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Introduction

The problem of solid waste management is one of the most critical environmental issues because of rapid population and economic growth, urbanization, and industrialization. Furthermore, global attitudes are bent on accessing sustainable agriculture and conserving a clean and green environment. Vermicomposting is a process to convert organic waste by the use of earthworms to produce peat-like material which has an added advantage of possessing the potential for improving plant growth as soil conditioner. Earthworms eat, grind, and digest organic waste combined with aerobic and some anaerobic microflora converting it into stable and homogenous biofertilizer. Earthworm cast has a larger microbial population, containing plant growth hormones, higher level of soil enzymes, and also displaying desirable aesthetics. Different species of earthworms can convert various natural and anthropogenic wastes such as crop residue, dairy plant sludge, industry sludge, and cattle manure into a useful product. There is a growing interest in the use of an integrated system approach involving precomposting followed by vermicomposting to achieve specific technical objectives. This approach will be more microbially active besides being of more uniform size, hastening degradation rate, and enhancing pathogen control than either of the individual processes. It is very important having the best quality of vermicompost product to be used appropriately as a stabilized biofertilizer in agricultural applications. Good quality of vermicompost can be obtained by mixing industrial sludge with nitrogen rich material to provide higher nutrient content and an inoculum of microorganisms. Inoculation of suitable strains has been reported to hasten the rate of vermicomposting which reduce the time needed to complete the process of composting and enrichment of nutrients in the final product.

Vermicomposting of solid waste may result in an increase in heavy metal content in the final product due to mineralization of organic matter in the vermicompost obtained from various organic wastes of different chemical composition. So the organic matter mineralization and dry weight loss of the waste during the process has the effect of increasing the level of heavy metal, being the consequence of the decomposition of the waste organic matter by earthworms during vermicomposting. The application of inoculation of microorganisms such as bacteria and fungi in the substrate may accelerate the stabilization process due to biological nitrogen fixation and phosphorus solubilization. Furthermore, the heavy metals content in vermicomposts can accumulate a lot in the body of earthworms and also reduce as a result of extra water drainage. The purpose of the study were to investigate the role of inoculation of active sewage sludge in vermicomposting process to evaluate the changes of the heavy metal content possibly present in this substrate to determine potential environmental hazards. The purpose of the study was to test the technical viability of this system, initially utilizing wheat straw, and later to be employed on other substrates.

Materials and methods

Corn residue, compost, cow dung, and cardboard with various C/N ratios were used as substrate for *Eisenia fetida*, an exotic epigeic earthworm. Corn residue was obtained from the adjacent corn farm. The compost and cow dung were prepared from the biofertilizer plant of Mashhad municipality. Cardboard was obtained from a waste collection site of a compost plant. The organic waste was washed, air-dried, and grounded.

The experiment was conducted in plastic containers with three combinations of substrate (40, 60 and 80% of corn residue and remaining the other available organic material) and four concentrations of active sewage sludge
(0, 2000, 4000, and 6000 mg/l) in three replications. The heavy metal content of organic waste and sewage sludge prior to vermicomposting is presented in Tables 1 and 2. The organic waste was left to decompose for 30 days by the composting process and then 150 pairs of healthy adult E. fetida, of almost equal age were introduced into each container and vermicomposted for 40 more days. Active sewage sludge, as a source of nitrogen fixing and phosphorous solubilizing bacteria, was obtained from a wastewater treatment plant and inoculated into pre-composted organic waste at four concentration levels. During the study, the temperature in the experiment room was maintained from 20 to 25°C that is the optimum temperature range for E. fetida. The moisture content was changed from 60 to 70% by watering when required.

The sampling for the analysis was made on the first day (raw materials) and after stabilization of vermicomposting (70 days). Prior to microbial digestion, each sample was dried out at 80°C for 23 hours, then one gram of each was placed in a digestion tube and 10 ml of HNO₃ was added to analyze heavy metal. The samples were heated for 45 min at 90°C and then 8h more at 150°C until the volume was reduced to about 1 ml. The solution was filtered and transferred to a 25 ml volumetric flask, filling it by adding distilled water. The concentrations of Heavy metal viz. Magnesium (Mg), Calcium (Ca), Sodium (Na), Potassium (K), Manganese (Mn), Lead (Pb), Copper (Cu), Iron (Fe), Zinc (Zn), Chromium (Cr), and Nickel (Ni) in the digested samples were determined by an atomic absorption spectrometer (AAS) using standard calibration curves. The data in this study were analyzed by using the SPSS computer software package. All the values were presented in mean ± SD (standard deviation).

Results and discussion
There is a need to determine the heavy metal concentrations in final vermicompost, before addition to soils due to the inhibitory effect of heavy metal compounds on the growth and performance of the photosynthetic apparatus of plants. The results showed that the growth of E. fetida was not inhibited during vermicomposting of corn residue or by the addition of microorganism inoculants. The present study indicated that the application of sewage sludge in vermicomposting would not have any side effect as the heavy metals stayed within the limits. Although the heavy metals at low content are essential for plant growth, it is likely to have adverse effects at higher concentrations. The periodical changes of the heavy metals during vermicomposting of the organic waste considered herein are presented in Tables 4 and 5. From these results, it is evident that the earthworms were exposed to the heavy metals in all treatments and the heavy metals content was observed to increase in all the samples in the study. An increase of the heavy metals content in final vermicomposts was reported in other studies indicating mass reduction of raw materials due to decomposition of organic matter. The presence of microflora in the gut of earthworms might play an important role in this process; although an increase in total amounts of metal ions may affect bioavailability during vermicomposting. However, the decrease of heavy metals concentration in the final vermicompost was observed with an increasing percentage of corn residues in the substrate. The organic waste also lost its dry weight as CO₂ and moisture due to the mineralization of organic carbon. Therefore, prior to vermicompost addition to the soil, there is a need to determine the heavy metals concentration in the final biofertilizer. The heavy metals content in corn residue is lower than in the other organic substrate materials (especially compost), diluted the heavy metal content in the final product. The increase in the heavy metals in the vermicompost occurred on inoculation of active sewage sludge might be due to enhanced decomposition of organic matter by bacteria leading to an increase in the organic carbon content and dry weight reduction of the substrate. The microorganisms also reduce the bioavailability of heavy metals in substrate for earthworms by bioaccumulation (actively) and biosorption (passively); therefore the heavy metals accumulate in the substrate of the organic waste. The total heavy metal content of the final vermicompost was low in all treatments; thus its application as a biofertilizer is presumed safe in farming according to the chemical and physical specification standards of Spain, the United States of America, the European Union, and Iran.

Conclusion
The information presented here provides a basis for the management of biodegradable waste as vermicomposting process. In the present study, vermicomposting of biodegradable organic waste and active sewage sludge was carried out where heavy metals content was higher than in the initial organic wastes. Our trials demonstrated that vermicomposting using E. fetida is an acceptable option for recycling and environmentally friendly disposal of corn residue. Consequently, the reproducibility of the process and the quality of the final product make it feasible to propose the use of this experimental procedure for further research entailing and facilitating a mass reduction of initial composted waste mixtures. The results also showed that after the addition of active sewage sludge in proper quantities to corn residue, it can be used as a raw material in vermicomposting. Due to adverse effects inferred that heavy metal content changes as a function of initial organic waste and active sewage sludge and comparison of the metal content in final products with stipulated standards, the final vermicompost is usable for
agricultural application as soil conditioner and/or eco-manure. It is assumed that the integrated approach employing microflora and earthworms together may be helpful in converting the waste into value added product in a short time.

**Keywords:** biodegradation, corn residue, heavy metals, sewage sludge, vermicompost.