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Review

Comparison of heavy metals content in compost against vermicompost of organic solid waste: Past and present

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ABSTRACT

Disposal of the municipal organic solid waste is a serious problem worldwide. Composting is one of the most preferred methods of solid waste management practice, principally due to the high percentage of organic material in the waste composition. Composting has advantages over land-filling and incineration in Mauritius because of lower operational costs, less environmental pollution, beneficial use of the end product, high humidity and organic content of household waste. Vermicomposting is a comparatively enhanced method in composting, and involves the stabilization of organic solid waste through earthworm consumption that converts the waste into earthworm castings. In both composting and vermicomposting processes, the presence of heavy metals and different toxics substances limits its land use without processing. The production and application of compost potentially contaminate the environment with heavy metals. There is a high-degree of consensus in the past and present literatures that composting increases metal concentrations but whether similar changes in metal concentration and availability occur during vermicomposting has not been fully resolved. This review deals with various total metal contents present in composting compared to that present in vermicomposting of organic solid wastes from past and present years.

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1. Introduction

The increased affluence of the Mauritian society over the last decades has meant that greater quantities of waste are generated per year. In 1997, the first and only landfill became operational at Mare Chicose which is now being filled to capacity. Presently modest recycling and composting of Municipal Solid Waste (MSW) is carried out so that waste facility is now becoming inadequate to accommodate MSW. The proper management and disposal of solid waste is definitively one of the most challenging environmental tasks for the scientists and municipalities of the Republic. Composting offers the opportunity to decrease the cost of landfill disposal and produce a beneficial material, compost which has the capacity to boost agricultural yields as soil conditioner. In Mauritius, composting has priorities over incineration because Mauritius MSW has low calorific value and high moisture content. Heavy metals are abundant in waste due to mixing of industrial wastes and changing life style (McGrath et al., 2000). This is cause of main concern as their long-term use can cause heavy metal accumulation in soil

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(Lopez-Mosquera et al., 2000). Once accumulated in soil, heavy metals may be transferred at elevated levels to the food chain (Page et al., 1987), which may pose a variety of human health problems (Wang et al., 2003). The environmental problem with heavy metals is that they are unaffected during degradation of organic waste and has adverse effects on living organisms when exceeding the threshold permissible limits. When the compost from municipal solid waste (MSW) is used as manure, some heavy metals are being subject to bioaccumulation and may cause risk to human health when transferred to the food chain. Exposure of heavy metals may cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage (NIEHS, 2002). Therefore, heavy metal needs serious attention before the application of compost prepared using MSW as raw material. In certain cases the metal contents exceed the specified limits (Merian, 1991; Cebula et al., 1995). The occurrence of cadmium, cobalt, manganese, nickel, lead and zinc in MSW compost has been reported by Ciba et al. (1999). The levels of heavy metals in MSW composts have been reported for several nations (Krogmann, 1999; Koivula et al., 2000). The metal content increased with the volume reduction during biodegradation (Das et al., 2002). Therefore the finished product before its application has to be tested for its metal content. Similar study by Pascal et al. (1997) has shown that the compost generated from urban MSW contains heavy metals less than the regulatory limits. Over the last 30 years, interest has increased progressively in the potential of a related process, which is known as vermicomposting that involves the use of earthworms to break down organic solid wastes in a mesophilic process. However, there is a lack of research on the solubility and potential bioavailability of heavy metals during vermicomposting. Due to the inherent limitations of the individual processes, the integration of composting and vermicomposting together is increasingly receiving attention for stabilization of various wastes including for decreased duration of treatment process, increased pathogen reduction and better product quality (Hait and Tare, 2011a,b; Lazcano et al., 2008; Nair et al., 2006; Ndegwa and Thompson, 2001). Additionally, it is widely speculated that the integrated system is capable of increasing the nutrients availability and reducing the availability of heavy metals in substrate. Though several studies revealed the high concentrations of heavy metals pollutants in urban waste and sewage sludge (Smith, 2009; Reddy and Pattnaik, 2009), the problems associated with bioaccumulation and vermiremediation have received very little attention and is poorly understood (Fries, 1982). Moreover, adequate information is not available on the vermiremediation as well as bioaccumulation of heavy metals in earthworm body tissue particularly in tropics (Shahmansouri et al., 2005). Esakku et al. (2003) already assessed heavy metals in MSW and this present review deals with various aspects concerning total metal contents present in composting and vermicomposting processes from past and present studies worldwide. Furthermore, conclusions from this review clarifies the comparison of heavy metals content in compost against vermicompost and shows the feasibility of implementing vermicomposting of organic solid waste in Mauritius.

2. Vermicomposting and earthworm species suitable for vermicomposting

Although Darwin (1881) first drew attention to the great importance of earthworms in the decomposition of dead plants and the release of nutrients from them, it was necessary to wait more than a century until this was taken seriously as a field of scientific knowledge or even a real technology. Vermicomposting is comparatively new method in composting involving the production of vermicompost through stabilization of organic waste by earthworm activity. Microorganisms produce the enzymes that cause the biochemical decomposition of organic matter, but earthworms are the crucial drivers of the process activity (Lazcano et al., 2008) as they are involved in the indirect stimulation of microbial populations through fragmentation and ingestion of fresh organic matter, which results in a greater surface area available for microbial colonization, thus dramatically increasing microbiological activity.

The choice of the right species of earthworm and proper selection of earthworm for vermicomposting is the prime step as it affects the rate of waste stabilization. There are lots of earthworm's species having the potential to be used in waste management and sludge stabilization practices. The earthworm's species having the capability to colonize organic throw away naturally, high rates of organic matter consumption, digestion and assimilation, able to tolerate a wide range of environmental stress, having high reproductive rates by producing large number of cocoons having short hatching time, rapid growth and maturation rate of hatchlings to adults (Domínguez and Edwards, 2004) are suitable to be used in vermicomposting process. Epigeic species of earthworms, with their natural ability to colonize organic wastes; high rates of consumption, digestion, and assimilation of organic matter; tolerance to a wide range of environmental factors; short life cycles; high-reproductive rates; and endurance and tolerance of handling, show good potential for vermicomposting. Few earthworm species display all these characteristics, and in fact only five have been used extensively in vermicomposting *Eisenia andrei* (Bouché), *Eisenia fetida* (Savigny), *Dendrobaena veneta* (Savigny), and, to a lesser extent, *Perionyx excavatus* (Perrier), and *Eudrilus eugeniae* (Kinberg). Several epigeic species of earthworms have been investigated for their potential to stabilize organic wastes and produce vermicomposts. Research has shown that many organic wastes can supply the large populations of microorganisms that are necessary for the growth and reproduction of species of earthworms of the genera *Eisenia*, *Eudrilus*, *Dendrobaena*, *Perionyx*, and *Pheretima* (Edwards, 2004). Several epigeic earthworms, e.g., *E. fetida*, *P. excavatus*, *Perionyx sansibaricus*, *E. eugeniae*, and *E. andrei* have been identified as detritus feeders and can be used potentially to minimize the anthropogenic wastes from different sources (Suthar, 2008b; Gupta and Garg, 2008). But *E. fetida* was, and still remains, the favoured earthworm species for laboratory trail experiments on vermicomposting due to its wide tolerance of environmental variables (pH, moisture content, temperature).

3. Metal accumulation by earthworms

There is ample evidence that earthworm species belonging to each of the three eco-physiological categories (epigeic, endogeic, and anecic), including epigeic vermicomposting species such as *E. fetida* and *D. veneta*, are capable of accumulating a number of essential and nonessential metals from plant growth media and soils ranging from uncontaminated "background controls" to those that are highly metalliferous due to anthropogenic activities (Morgan et al., 1993; Peijnenburg, 2002; Peijnenburg and Vijver, 2009). Tissue metal accumulation is a reflection of the detritivorous lifestyle, coupled with their highly permeable body walls and an extensive tissue comprised of chloragocytes with organelles able to sequester high concentrations of certain metals in relatively insoluble states (Morgan et al., 2002). Both soil pH and organic matter content contribute significantly to the accumulation of certain metals, notably Pb and Cd, but not others (Peijnenburg, 2002). The important general point is that bioaccumulation is both physiologically and physicochemically driven. Environmental parameters, the target species, and the properties of individual metals and metalloids combine dynamically to modulate bioaccumulation (Luoma and Rainbow, 2005). Concentration factors (CF_{WS}; also referred to as *bioconcentration factors*, BCFs, or *uptake factors*, UFs) are the