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Vermistabilization of paper mill wastewater sludge using *Eisenia fetida*

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HIGHLIGHTS

- ▶ Vermistabilization caused significant changes in chemical constituents of paper mill sludge, resulting in a stable end product.
- ▶ The end material was rich in microbial population (fungal, bacterial and actinomycetes).
- ▶ The end product would be suitable for land applications.

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ABSTRACT

Vermistabilization of paper mill wastewater sludge (PMS) spiked with cow dung (CD) at ratios of 0%, 25%, 50%, 75%, and 100% was carried out employing the earthworm, *Eisenia fetida*. A total of five treatments were established and changes in chemical and microbial properties of mixtures were observed. Vermistabilization caused decreases in total organic carbon, C:N ratio and cellulose by 1.2–1.5, 4.6–14.6, and 2.3–9.7-fold, respectively, but increases in pH, electrical conductivity, ash content, $_{tot}$N, $_{avail}$P, $_{tot}$P, $_{exch}$K, Ca, Na, and N—NO_3^- of 1.06–1.11, 1.2–1.6, 1.3–1.6, 3.8–11.5, 4.1–6.5, 5.7–10.3, 1.7–2.0, 1.16–1.24, 1.23–1.45, 4.2–13.4-folds, respectively. PMS with 25–50% of CD showed the maximum mineralization rate. The fungal, bacterial and actinomycetes population increased 2.5–3.71, 3.13–8.96, and 5.71–9.48-fold, respectively after vermistabilization. The high level of plant-available nutrients indicates the suitability of vermistabilized material for agronomic uses.

1. Introduction

The pulp and paper industry is considered one of the most polluting industries (Thompson et al., 2001). A variety of liquid and solid wastes are produced during different processes of paper manufacturing. In general, pulping and bleaching are the two main steps in production of paper in industry and a huge quantity of fresh water is utilized resulting a large quantity of wastewater, sludge and other solids. The solid wastes from pulp and paper industries are mainly treatment sludges, lime mud, lime slaker grits, boiler and furnace ash, scrubber sludges, and wood processing residuals. The paper production generates around 45% wastewater sludge (0.2–1.2 kg dry matter (DM)/kg of biological oxygen demand (BOD) removed), 25% ash, (Zambrano et al., 2003), 15% wood cuttings and waste, and 15% other solid waste. The sludge from wastewater treatment units (20–60% solid fractions, pH $\approx$ 7) includes wood fibers, biosludge, calcium carbonate, clay and other inorganic materials (Nurmesniemi et al., 2007). Dry sludge amounts to approximately 4.3% of the final product, increasing to 20–40% for recycled paper mills (World Bank, 2007). The primary methods of disposal for this type of sludge have been land application and landfilling. The unsafe disposal of these solid wastes cause environmental problems because of high organic content, partitioning of chlorinated organic, pathogens, ash and trace amounts of heavy metals. The pulp and paper industry faces a growing solid waste disposal problem as environmental regulations become increasingly stringent and landfill space grows scarcer. The chemical analysis (high organic matter content, pH, buffer capacity, nitrogen and phosphorous level, and low concentrations of heavy metals and organic pollutants) have revealed that pulp mill sludge may be utilized as a soil amendment, improving soil fertility (Zhang et al., 2004) but stabilization involving decomposition of an organic waste to the extent that biological and chemical hazards are eliminated is required (Benito et al., 2003; Suthar, 2010; Gomez-Brandon et al., 2011).

Composting or vermicomposting have been promoted as a potential methodology for generating a product from wastes that can be used as a soil amendment (Sinha et al., 2010). Vermicomposting involves the biooxidation and stabilization of organic materials but, in contrast to composting, it depends on the joint action of earthworms and microorganisms and does not involve a thermophilic stage (Dominguez, 2004). Loehr et al. (1985) concluded that in a vermicomposting system, the earthworms maintain aerobic

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