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# Vermiremoval of Macroelements and Heavy Metals in Municipal Sewage Sludge

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ABSTRACT

**Background:** Sewage sludges have a potential nutrient value for recycling into food production and they do not meet the criteria and are therefore not acceptable for direct foodland application. One of the options available for such sludges is the production of compost and one of these composting processes involves worms (vermicomposting). Vermiremoval is an enhancement of the natural process that integrates earthworm's and microbe's role as an efficient tool in accumulating heavy metals in the earthworm's tissues. Vermicompost or vermicast produced from the process is stable and homogenous, has desirable aesthetics, reduced levels of contaminants, and furthermore is a valuable, marketable and superior plant growth medium. **Objective:** The main objective of present study was to reduce the phytotoxic concentrations of macroelements like $Ca^{+2}$ and $K^{+}$ as well as heavy metals such as $Fe^{+2}$ and $Zn^{+2}$ from sewage sludge using vermitechnology. **Results**: The highest reduction in calcium content was in the treatment of *E. foetida* and *E. eugeniae* along with amendment of garden soil, which was by 61 and 57 % respectively. Both the worm species had shown 67 and 52 % reduction in $K^{+}$ in the treatment *E. foetida* and *E. eugeniae* in combination with garden soil. Regarding removal of heavy metal like $Fe^{+2}$, it was observed that the reduction was by 77 and 83 % in the combination treatment of *E. foetida* and *E. eugeniae* with cow dung respectively while the reduction of $Zn^{+2}$ was by 55 and 50 % in the same treatment for $Fe^{+2}$. **Conclusion:** Both the worm species viz *Eisenia foetida* and *Eudrilus eugeniae* had good potential to reduce the content of calcium and potassium as well as heavy metals like $Fe^{+2}$ and $Zn^{+2}$ when sewage sludge is amended with bulking materials like garden soil and cow dung.



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## INTRODUCTION

The metropolitan cities like Pune generate huge quantity of sewage sludge after the treatment of sewage wastewater (Anonymous, 2009). The sewage sludge poses a great problem for safe disposal due to the presence of various types of soil contaminants, heavy metals, macroelements and salts like sulphates, phosphates, nitrates which are cause soil and human health hazards (Hait and Tare, 2011). The toxicity of heavy metals and the danger of bioaccumulation in the food chain represent a major environmental health problem. Disposal of sewage sludge by spreading it on land cause environmental hazards to terrestrial ecosystems (Azizi *et al*., 2013). The biosolids can be put into its best use if heavy metals and risky pollutants are removed/reduced with eco-friendly technology like vermiremediation (Al-Malack *et al*., 2002). This method if amended with bulking materials will play a key role in vermiremoval of different pollutants (Suthar and Singh, 2009). Disposal of sewage sludge is growing concern in developing countries as there is substantial increase in sludge production, hence removal of potentially toxic hazardous wastes is an urgent need of the time (Wei *et al*., 2012). It is widely identified as one of the potential activities to reduce the quantity of heavy metals (Jamaludin and Mahmood, 2010). In this process bio-oxidation and stabilization of sewage sludge takes place in presence of joint action of earthworms and microorganisms and the presence of earthworms doubles the rate of bio-chemical reactions and accelerates the mineralization (Aira *et al*., 2007). The high concentration of $K^{+}$, $Ca^{+2}$, $Fe^{+2}$ and $Zn^{+2}$ is toxic to the plants if the sewage sludge is applied to the crop plants without vermicomposting (Suthar, 2009). Therefore present investigation was focused on vermiremoval of macroelements and heavy metals existing in sewage sludge using two different species of earthworms and bulking materials such as CD, SM and GS.

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*Methodology:*

The Sewage Sludge (SS) samples were collected from Sewage Treatment Plant situated in Pune city (Bopodi area) during the year 2012 in the month of March-April and brought to the laboratory for the remediation study. After sun drying these samples were crushed into fine powder and used for vermitreatment (Gupta, 2007). These samples were used for pre and post treatment and analysis of $K^+$ and $Ca^{+2}$ by the method of Simard (1993) while $Fe^{+2}$ and $Zn^{+2}$ by using the methods of APHA, AWWA, WEF, (2005) respectively. The bulking materials such as Cow Dung (CD), Sheep Manure (SM) and Garden Soil (GS) were collected from local sources. The species of earthworm viz *Eisenia foetida* and *Eudrilus eugeniae* were procured from Vasantdada Sugar Institute (VSI) and Institute of Natural Organic Agriculture (INORA), Pune.

The experiment was conducted by using factorial arrangement with randomized complete block design with three replications at Department of Environmental Science, University of Pune (MS), India. The treatments details are as follows: W0: no worm, W1: *Eisenia foetida,* W2: *Eudrilus eugeniae* and for bulking materials B0: sewage sludge, B1: sewage sludge + cow dung, B2: sewage sludge + sheep manure and B3: sewage sludge + garden soil.

The earthen pots (25x25x30cm) were filled with sewage sludge and bulking materials in proportion of 2:1 along with 50 earthworms of each of earthworm species and the duration of experiment was 90 days. The results obtained were analyzed statistically by using MSTATC computer software and applying Duncan's multiple range tests at Alfa level 5 %.

## RESULTS AND DISCUSSION

*Potassium:*

The results revealed that $K^+$ content was reduced at final stage of vermicomposting as compare to initial stage in all the treatments. The mean comparison of worm species clearly shown that at final stage, the $K^+$ content in sewage sludge was higher in absence of worm species. However in presence of *E. foetida* and *E. eugeniae* it was reduced by 37.7 and 28 % respectively. This clearly indicates the greater efficiency of *E. eugeniae* than *E. foetida* (Fig. 1 A). The results of amendment of bulking materials on reduction of $K^+$ content shown that cow dung was less effective (322.8 ppm) as compare to garden soil (217.9 ppm) (Fig. 1 B). The results presented in Table 1 revealed that interaction between worm species and bulking materials had great influenced on reduction of $K^+$ content. Amongst the treatments highest $K^+$ (473 ppm) was recorded in SS and in absence of worm species while the lowest (155 ppm) was observed in SS + GS in presence of *E. foetida* (Table 1).

The decrease in $K^+$ content at final stage of vermicomposting was recorded by Vig *et al*., (2011) for tannery sludge along with cow dung in presence of *E. foetida*. They further explained that the decrease was due to metabolic activities of earthworm. Singh *et al*., (2010) also supported above view. According to Reddy *et al*., (2012) $K^+$ content was decreased during vermicomposting due to addition of biomass in sewage sludge. Similar trend was also observed by Sangwan *et al.*, (2010a). They attributed this to the difference in bioconversion and chemical nature of amended biomass. The result of present study corroborate with above findings.

*Calcium:*

The results illustrated on $Ca^{+2}$ content showed that there was significant reduction at final stage in all the treatments over control. The mean comparison of worm species also revealed that at final stage $Ca^{+2}$ content was maximum (1553 ppm) in absence of worm species. However in presence of *E. foetida* it was greatly reduced to the minimum (1086.4 ppm) (Fig. 2 A). The mean comparison of bulking materials at final stage indicated that the $Ca^{+2}$ content was higher in treatment SS + GS (42 %) it was followed by SS + SM (35 %) and SS + CD (33.5 %) (Fig. 2 B). The interaction effect of inclusion of worm species and bulking materials had paramount effect on reduction of $Ca^{+2}$. The highest $Ca^{+2}$ content was recorded in absence of worm species and bulking materials (2042 ppm). However in the treatment SS + GS in presence of *E. foetida* it was lowest (799.3 ppm). It was followed by the treatment SS + GS in presence of *E. eugeniae* (885 ppm) (Table 1).

Reduction in $Ca^{+2}$ content was recorded by Kaushik and Garg (2003) in vermicomposting of mixed solid textile mill sludge along with cow dung and *E. foetida*. They further claimed that vermicomposting could be the best technology for transformation of sludge into valuable products. Elvira *et al*., (1997) supported the above trend for vermicomposting of wastewater sludge from paper pulp industry. They ascribed the decrease in $Ca^{+2}$content to leaching thorough drained water. Elvira *et al*., (1998) stated that bioconversion of sewage sludge and bulking material by the worm species may be playing a key role during vermicomposting. The results of present study are in agreement with above work.

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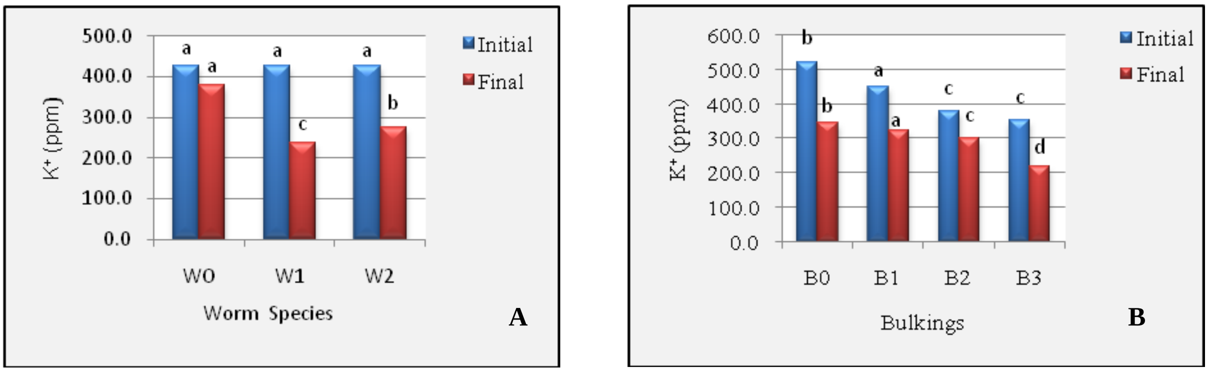


**Fig. 1:** Effect of different worm species (A) and bulking materials (B) on potassium content of vermicompost of sewage sludge

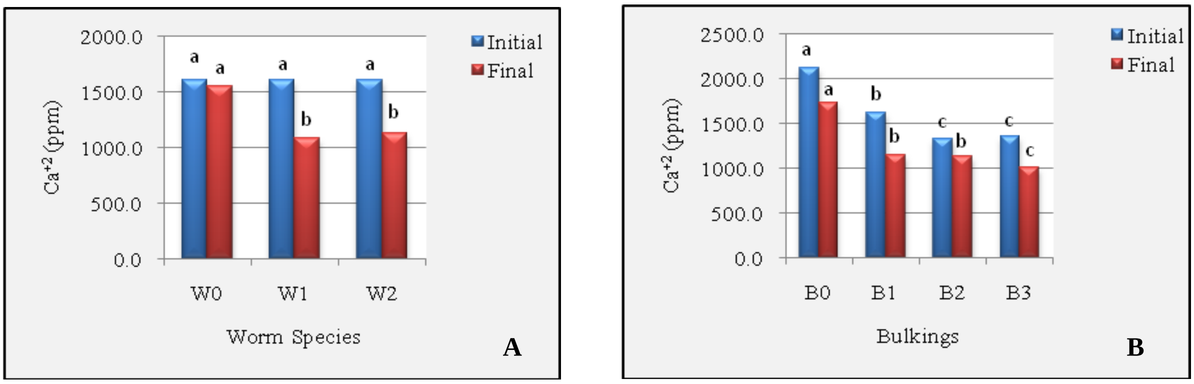


**Fig. 2:** Effect of different worm species (A) and bulking materials (B) on calcium content of vermicompost of sewage sludge

**Table 1:** Effect of worm species and bulking materials on potassium and calcium content of sewage sludge during vermiremediation

| Treatment | $K^+$ (ppm) | | $Ca^{+2}$ (ppm) | |
|---|---|---|---|---|
| | Initial | Final | Initial | Final |
| W0B0 | 522.7 a | 473.0 a | 2128.5 a | 2042.0 a |
| W0B1 | 451.0 b | 432.0 a | 1625.0 b | 1545.0 b |
| W0B2 | 378.0 c | 344.0 b | 1326.0 c | 1301.0 c |
| W0B3 | 352.0 c | 272.7 d | 1358.0 c | 1325.0 c |
| W1B0 | 522.7 a | 289.7 cd | 2128.5 a | 1537.0 b |
| W1B1 | 451.0 b | 263.3 de | 1625.0 b | 972.3 de |
| W1B2 | 378.0 c | 240.0 ef | 1326.0 c | 1037.0 d |
| W1B3 | 352.0 c | 155.0 g | 1358.0 c | 799.3 f |
| W2B0 | 522.7 a | 280.7 d | 2128.5 a | 1625.0 b |
| W2B1 | 451.0 b | 273.7 d | 1625.0 b | 944.3 de |
| W2B2 | 378.0 c | 315.7 c | 1326.0 c | 1054.0 d |
| W2B3 | 352.0 c | 226.0 f | 1358.0 c | 885.0 ef |

Means with different letters are significantly different at P=0.05, using Duncan's Multiple Range Test.

*Iron:*

Results shown in Table 2 indicated reduction in $Fe^{+2}$, when compare with initial stage in all the treatments. Amongst the worm species at final stage of vermiremediation maximum amount of $Fe^{+2}$ noted was (504 ppm) in absence of worm species. But in presence of both worm species it was greatly reduced to its minimum level (347.2 ppm) (Fig. 3 A). The type of bulking materials amended in sewage sludge had greatly influenced the $Fe^{+2}$ content. At final stage $Fe^{+2}$ content was highest (760.6 ppm) in absence of bulking materials, but it was highly reduced (221.8 ppm) with addition of bulking materials like cow dung (Fig. 3 B). The results of interaction effect between worm species and bulking materials on $Fe^{+2}$ content indicated highest amount (944.3 ppm) in absence of worm species and no bulking material. However highly significant reduction (157.3 ppm) was noted in SS + CD in presence of *E. eugeniae*.

Mahdi *et al*., (2007) in their studies on vermicomposting of industrial tannery sludge reported reduction in heavy metals. Zorpas *et al*., (2003) also reported similar trend for primary sewage sludge and different bulking materials. The reduction in heavy metals may be beneficial when vermicompost is used as fertilizer in agriculture and monitoring of heavy metals in sewage sludge may be possible by using biomass and worm

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species (Lukkari *et al.*, 2006). Similarly Sultan *et al.*, (2007) explained that concentration of heavy metals in sludge is deciding factors for its utilization in agriculture, because they damage crops and enter in human food chain. The vermiremoval of different heavy metals like $Fe^{+2}$ from sewage sludge is highly advantageous to manage the sludge disposal (Sinha *et al.*, 2005). In present investigation reduction in heavy metals and macroelements like $Fe^{+2}$, $Zn^{+2}$, $K^{+}$ and $Ca^{+2}$ was achieved thorough nature friendly vermitechnology. Findings of present study are inconformity with above work.

*Zinc:*

The results indicated that $Zn^{+2}$ content was maximum (179.6 ppm) in absence of worm species at final stage. However with the help of *E. foetida* and *E. eugeniae* it was significantly reduced up to 138.6 ppm (Fig. 4 A). The mean comparison of bulkings at final stage clearly showed that the highest $Zn^{+2}$ (191 ppm) was recorded in absence of bulking materials, but in presence of cow dung it was highly decreased (129 ppm) (Fig. 4 B). The impact of bulking materials and worm species revealed that $Zn^{+2}$ content was highest in absence of worm species and bulking materials (215ppm). It was reduced drastically (96 ppm) in presence of *E. foetida* and cow dung, which was significantly followed by *E. eugeniae* and cow dung (107.7 ppm) (Table 2).

The results of present study are in agreement with Jamaludin and Mahmood (2010), Mahdi *et al.*, (2007) and Vaca *et al.*, (2011). They reported reduction in $Zn^{+2}$ content of sewage sludge and tannery sludge by using bulking materials and worm species. They further explained that the reduction in $Zn^{+2}$ was attributed to its reaction with organic compounds in sewage sludge, which control its speciation, mobility and bioavailability. Zinc also react with organic acid from wastes, substances with O- functional groups and other molecules that form metal complexes, which reduce the activity of $Zn^{+2}$ (Martinez and McBride, 1999). Heavy metals are important trace elements for well being of plants but their excess is known to have toxic effects (Kizilkaya, 2005). The heavy metal toxicity is not caused only by its presence, but it depends on metal concentration, toxicity, mobility in free form, the route of uptake mechanism and bioavailability to plants (Alloway and Ayers, 1994). They further claimed that immobilization of metals in contaminated sewage sludge using earthworms seem to be a valuable alternative in place of all these more expensive and laborious remediation methods.

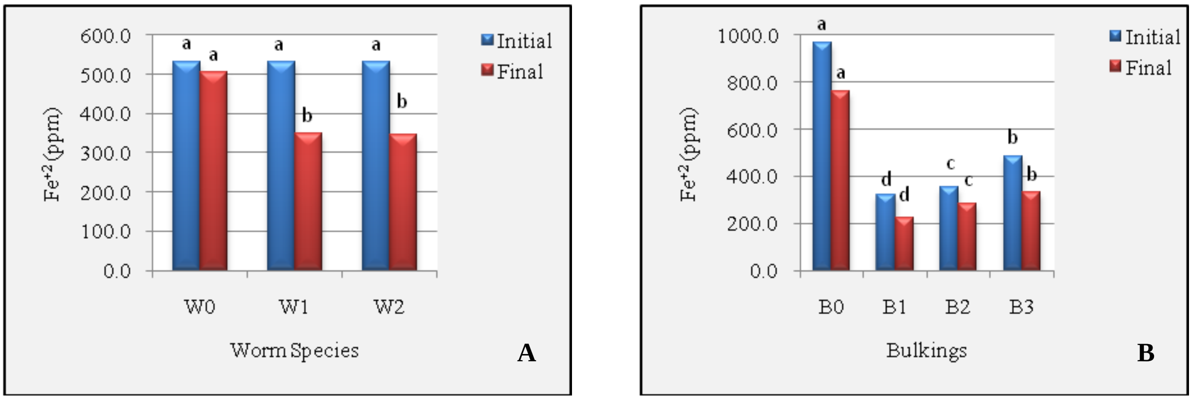


**Fig. 3:** Effect of different worm species (A) and bulking materials (B) on iron content of vermicompost of sewage sludge

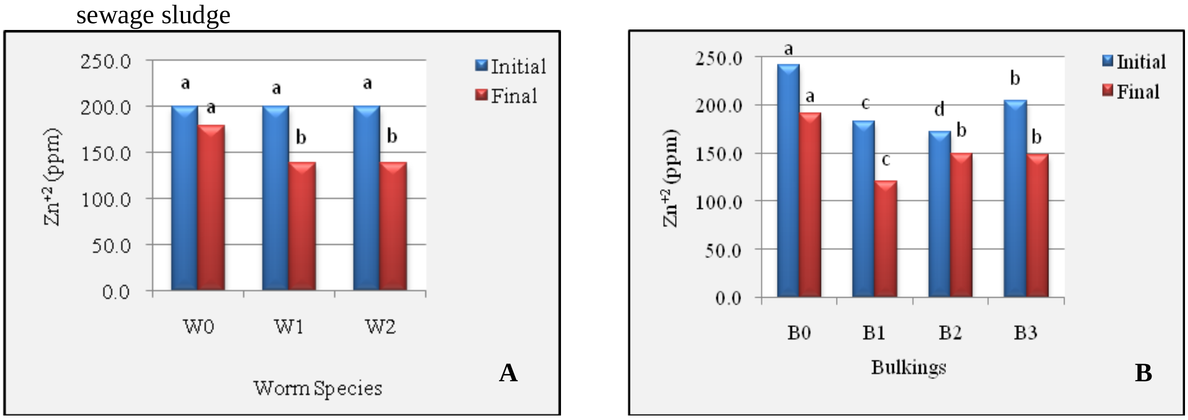


**Fig. 4:** Effect of different worm species (A) and bulking materials (B) on zinc content of vermicompost of sewage sludge

**Table 2:** Effect of worm species and bulking materials on iron and zinc content of sewage sludge during vermiremediation

| Treatment | $Fe^{+2}$ (ppm) | | $Zn^{+2}$ (ppm) | |
|---|---|---|---|---|
| | Initial | Final | Initial | Final |
| W0B0 | 967.0 a | 944.3 a | 242.0 a | 215.0 a |
| W0B1 | 320.7 c | 291.3 de | 182.3 c | 157.0 c |
| W0B2 | 355.3 c | 328.7 d | 171.7 c | 155.0 c |
| W0B3 | 485.3 b | 452.0 c | 204.3 b | 191.3 b |
| W1B0 | 967.0 a | 677.7 b | 242.0 a | 183.0 b |
| W1B1 | 320.7 c | 216.7 f | 182.3 c | 96.0 f |
| W1B2 | 355.3 c | 250.7 ef | 171.7 c | 150.7 c |
| W1B3 | 485.3 b | 245.7 ef | 204.3 b | 124.7 e |
| W2B0 | 967.0 a | 659.7 b | 242.0 a | 175.0 b |
| W2B1 | 320.7 c | 157.3 g | 182.3 c | 107.7 f |
| W2B2 | 355.3 c | 274.7 de | 171.7 c | 143.0 cd |
| W2B3 | 485.3 b | 297.0 de | 204.3 b | 128.7 de |

Means with different letters are significantly different at P=0.05, using Duncan's Multiple Range Test.

*Conclusion:*

The overall results of present investigation have clearly shown that the content of macroelement like $K^{+}$, $Ca^{+2}$ and heavy metal like $Fe^{+2}$ and $Zn^{+2}$ were significantly reduced from sewage sludge due to the amendment of different types of bulking materials like cow dung, sheep manure and garden soil along with earthworm species. Vermitechnology may be promoted as an eco-biotechnological tool to manage toxic heavy metals in sewage sludge. The sewage sludge after vermicomposting is becoming suitable resource in agriculture to improve the crop yield. The present investigation suggest that the earthworm species viz *E. foetid* and *E. eugeniae* exhibits good potential in combination with cow dung to reduce heavy metals from municipal sewage sludge.

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