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International Journal of Current Research
Vol. 5, Issue, 12, pp. 3628-3632, December, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

VERMIREMEDIATION OF MICROELEMENTS AND SOLUBLE SALTS IN SEWAGE SLUDGE BY EARTHWORMS

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ARTICLE INFO

Article History:
Received 25th September, 2013
Received in revised form
04th October, 2013
Accepted 30th November, 2013
Published online 02nd December, 2013

Key words:
Bulking materials,
Earthworm,
Sewage sludge,
Vermiremediation,

ABSTRACT

Municipal sewage sludge is the by-product of wastewater treatment plants, generated in huge quantity, causing health hazards for plants, animals and human beings. It shows presence of trace elements and their salts along with heavy metals at toxic level. The goal of present study was to reduce the high concentrations of phytotoxic trace elements and harmful soluble salts from sewage sludge, making it suitable for agricultural use as fertilizer and protection of the environment by vermiremediation technology. The experimental setup was factorial arrangement with randomized complete block design having three replications. The experiment was conducted during 2012-13 at Department of Environmental Science, University of Pune, India. For vermiremediation, *Eisenia foetida* and *Eudrilus eugeniae* were procured from regional research institutes, Pune and bulking materials (Cow Dung-CD, Sheep Manure-SM and Garden Soil-GS) were obtained from authentic local sources. The findings indicated that the high concentrations of Mg^{+2} and Na^{+} as well as NO_3^{-2}, PO_4^{-2} and SO_4^{-2} were brought to the minimum level at final stage of vermiremediation in all the treatments. Significant reduction (50-80 %) in trace elements and soluble salts was observed in the treatments SM and SG in presences of *E. eugeniae*. It can be concluded that for safe disposal of sewage sludge and its eco-friendly management bioremediation using above mentioned best treatments can be recommended.

INTRODUCTION

Municipal wastewater treatment plants concentrate on sewage wastewater discharged from urban residential complexes. The dissolved organics generate sewage sludge during primary and secondary treatment (Shirazi and Marandi 2012). Municipal sewage sludge is highly contaminated by macro and micro elements, heavy metals, organic matter and soluble salts, which are highly toxic, carcinogenic and hazardous to plants, animals and human beings. But during recent years the methodology of solid waste management is focusing on bioconversion of sludge into value added products (Liang and McClendon 2003). Safe disposal of sewage sludge is an important environmental and economic issue (Reddy *et al.,* 2012). Hence it requires eco-friendly technology like vermiremediation which is a stimulated bio-oxidation of organic matter, transforming the heterogeneous organic material into homogeneous form using earthworms (Alidadi *et al.,* 2005). The earthworms fragment the organic waste substances; simulate microbial activity greatly and increase rate of mineralization, rapidly converting the wastes into humus like substances with a finer structure and it is a well established tool for years together (Atiyeh 2000; Kaushik *et al.*, 2008). The process of vermicomposting is boosted by amendment of bulking materials such as cow dung, sheep manure, garden soil etc. Composted biosolids supply the essential elements to the plants and represent a sustainable alternative for high cost chemical fertilizers. The sewage sludge may come forward as user friendly bioresourec if, toxic elements, posing serious environmental problem are reduced to their minimum level. Considering this fact, the huge quantity of sewage sludge generated in metropolitan city like Pune was thought to convert it into value added product thorough vermiremediation technology.

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MATERIALS AND METHODS

Collection of samples and chemical analysis

About 100 Kg Sewage Sludge (SS) samples, containing 60-80 % moisture, were collected from sewage treatment plants during the year 2012-13, from the sewage treatment plants at (Bopodi) Pune, India. These samples were brought to the laboratory and kept for sun drying (15 days) powdered carefully and sieved through 0.5 mm sieve (Gupta, 2007). The pre and post treatments samples were analyzed for Mg^{+2}, Na^{+}, NO_3^{-2}, SO_4^{-2} and PO_4^{-2} by using the methods of Gupta (2007).

Experimental design

Factorial arrangement with randomized complete block design with three replications was used to conduct the experiment at Department of Environmental Science, University of Pune, India. Treatments included worm species (W0: no worm, W1: *Eisenia foetida* and 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). Each earthen pot (25x25x30cm) was filled with 3 Kg of sewage sludge and bulking materials in the ratio of 2:1 along with 50 earthworms of each species. The experiment was continued for three months. Required moisture for the activities of worm species was maintained by sprinkling water on the pots. The pots were protected carefully and regularly observed.

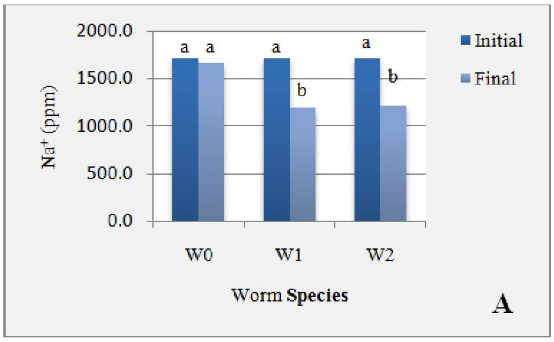
Statistical analysis

The results was analyzed statistically by using MSTATC computer software and a comparison of noted data was done on the basis of Duncan's multiple range tests at Alfa level 5%.

RESULTS AND DISCUSSION

Sodium

The sodium content was significantly reduced at final stage as compare to initial stage in all treatments. The mean comparison of worm species indicated that at final stage Na^+ content was maximum (1664 ppm) in absences of worm species. However in the presence of *E. foetida* it was highly reduced to (1200 ppm) (Fig. 1 A). The mean comparison of bulkings at final stage revealed that highest Na^+ content (1526 ppm) was recorded in the treatment SS + SM and the lowest (1202 ppm) in SS + GS (Fig. 1 B).



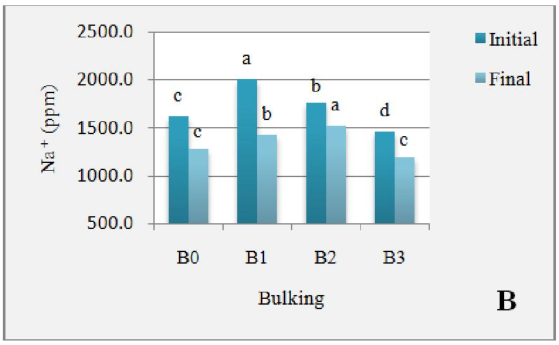


Fig.1. Effect of worm species (A) and bulkings (B) on sodium content in vermicomposting of sewage sludge

Interaction between worm species and bulkings showed highest Na^+ (1940 ppm) in SS + CD and no worm species. The drastic reduction (1065 ppm) was observed in the treatment SS + GS in presences of *E. foetida*, followed by *E. eugeniae* (1125 ppm) (Table 1). The trace element like Na^+ is essential for halophytes while glycophytes are highly sensitive to Na^+. The concentration of Na^+ in soil governs the salinity of soil, hence reduction in Na^+ content of sewage sludge is important when it is applied to crop lands. In present study there was considerable reduction in Na^+ of sewage sludge, both in presence of bulkings and worm species during vermiremediation process. Our results are in agreement with Al-Malack *et al.* (2002) and Mahdi *et al.* (2007). They reported significant reduction in Na^+ during vermicomposting of municipal sludge and tannery sludge respectively. The decrease in Na^+ may be due to biological activities of worm species. This fall in Na^+ content can also be attributed to its exhaustion from sewage sludge and to the decreased bioavailability of Na^+.

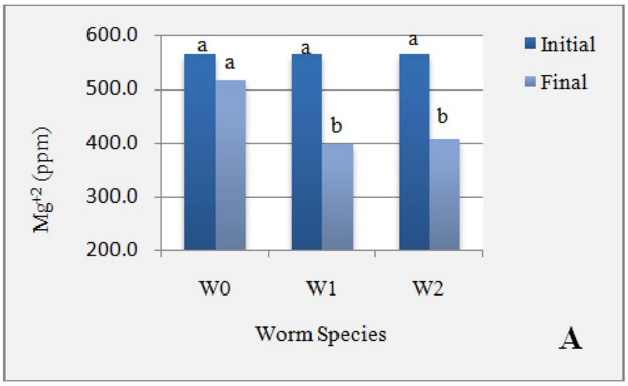
Table 1. Interaction effect of worm species and bulkings on sodium and magnesium content of vermiremediation of sewage sludge

Treatment	Na^+ content (ppm)		Mg^{+2} content (ppm)	
	Initial	Final	Initial	Final
W0B0	1617.0 bc	1581.0 bc	535.0 b	501.3 abc
W0B1	2010.0 a	1940.0 a	590.3 a	552.3 a
W0B2	1764.0 ab	1720.0 b	558.7 ab	527.3 ab
W0B3	1464.0 c	1415.0 c	572.7 ab	482.3 bcd
W1B0	1617.0 bc	1138.0 d	535.0 b	352.3 fg
W1B1	2010.0 a	1188.0 d	590.3 a	401.0 efg
W1B2	1764.0 ab	1406.0 c	558.7 ab	428.0 de
W1B3	1464.0 c	1065.0 d	572.7 ab	407.7 ef
W2B0	1617.0 bc	1146.0 d	535.0 b	380.3 efg
W2B1	2010.0 a	1147.0 d	590.3 a	349.7 g
W2B2	1764.0 ab	1451.0 c	558.7 ab	467.7 cd
W2B3	1464.0 c	1125.0 d	572.7 ab	434.0 de

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

Magnesium

Magnesium was decreased at final stage when compared with initial stage in all treatments. The mean comparison of worm species showed that at final stage Mg^{+2} content was greater than in absences of worm species as compare to in presence of both worm species (Fig. 2 A). Similarly the mean comparison of bulkings at final stage revealed that Mg^{+2} content was highest (474.3 ppm) in SS + SM and the lowest (411.3 ppm) in SS + CD (Fig. 2 B).



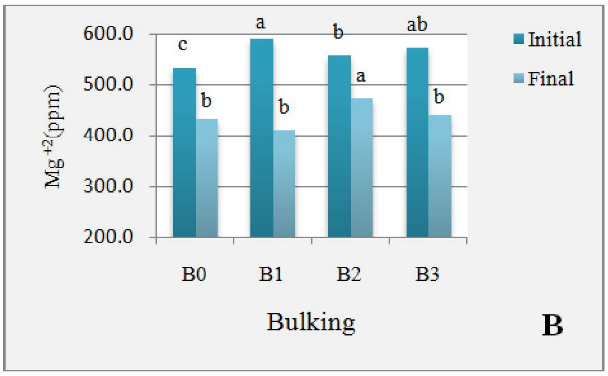


Fig.2. Effect of worm species (A) and bulkings (B) on magnesium content in vermicomposting of sewage sludge

The results of interaction between worm species and bulking materials (Table 1) indicated maximum Mg^{+2} (552.3 ppm) in treatment SS + CD in absence of worm species and the minimum (349.7 ppm) in SS + CD in presence of *E. eugeniae,* followed by SS + *E. foetida*. Magnesium content was decreased during vermicomposting of sewage sludge due to bulkings and biological activities of earthworms in combination with microbes. The decreased Mg^{+2} content in sewage sludge during the treatment was attributed to bioconversion of sludge by the activities of both the worm species. However they showed different patterns of reduction in Mg^{+2} content. The results recorded by Siuris (2011), Wei *et al.* (2012) and Moreno-Resendez *et al.* (2013) indicated similar trend and supported the findings of present investigation. Sinha *et al.* (2002) claimed that vermistabilization of sewage sludge by earthworms converted it into nutritive and safe biofertilizer for farms. Reduction in Mg^{+2} makes the sewage harmless, improving growth and yield of crop plants.

Nitrate

Nitrate is one of the most important forms of nitrogen available to the plants. Sewage sludge is very rich in nitrate (Lombard *et. al.,* 2011). Hence composted sewage sludge (biosolids) is one of the alternative sources for plants. The result of present investigation showed that nitrate content at final stage was reduced than initial stage in all treatments. The highest NO_3^{-2}(823.1 ppm) was reported in absence of worm species and it was reduced almost by 50 % in presence of *E. eugeniae* at final stage (Fig. 3 A). The mean comparison of bulking materials at final stage showed highest NO_3^{-2} (688.2 ppm) in SS + CD and the lowest (584 ppm) in SS + SM and SS+ GS (Fig. 3 B). The impact of interaction between worm species and bulking materials indicated maximum NO_3^{-2} (916.3 ppm) in SS + CD in absences of worm species. However more than 70 % reduction was noted in SS + SM in presence of *E. eugeniae* (Table 2). Alidadi *et al.* (2005) reported that the nitrogenous wastes are accumulating in sewage sludge but it decreases thorough the process of vermicomposting. Results of present investigation are inconformity with above studies. The bioconversion of sewage sludge by earthworms and activities of the nitrifying bacteria might be responsible for lowering the nitrate contents. Siuris (2011) studied the nitrate content of aqueous extract of sewage sludge and noted reduction during treatment. He further claimed that the organic substances, microelements, heavy metals and different salts in sewage sludge varied according to locality and urban activities, recycling of sewage wastewater and finally the sewage sludge.

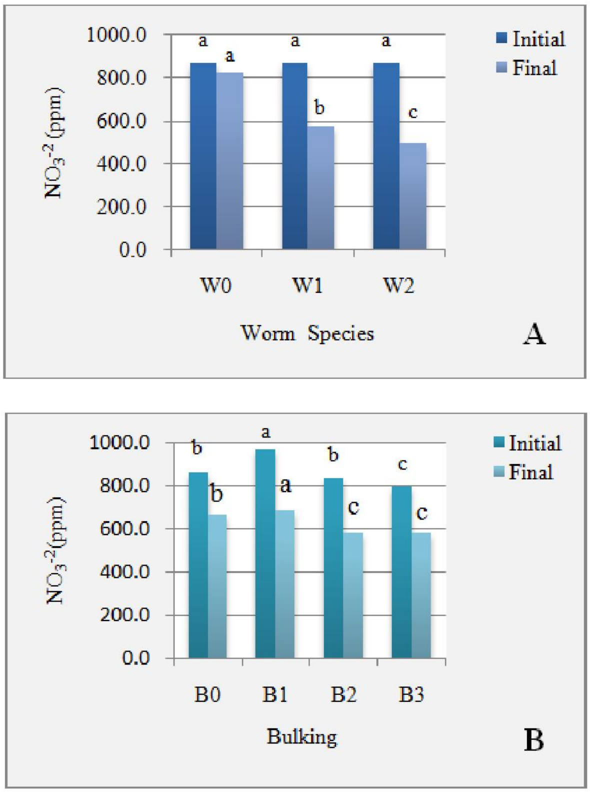
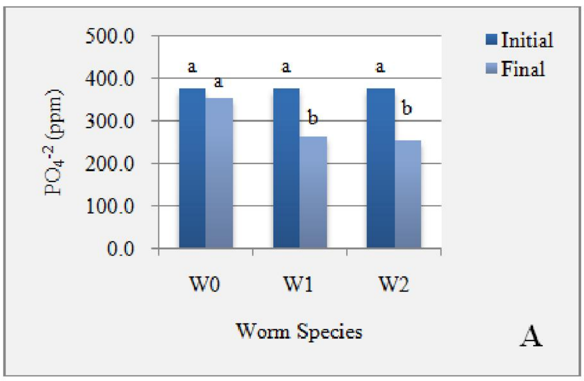


Fig. 3. Effect of worm species (A) and bulkings (B) on nitrate content in vermicomposting of sewage sludge

Phosphate

The results clearly showed that PO_4^{-2} content at final stage was decreased in all the treatments over initial. The mean comparison of worm species revealed that PO_4^{-2} was 25 and 28 % more in absence of worm as compare to E. *fortida* and *E. eugeniae* respectively (Fig. 4 A). The effect of bulking materials at final stage indicated that PO_4^{-2} in SS was 28.4, 25 and 33 % higher as compare to SS + CD, SS + SM and SS + GS respectively (Fig. 4 B). The data presented in Table 2 regarding the interaction between bulking materials and worm species showed highest PO_4^{-2} (435.7 ppm) in SS and no worm species. However it was highly reduced (191.3 ppm) in SS + GS in presences of *E. eugeniae*. The results of present study were in agreement with Sinha *et al*. (2010) who reported reduction of phosphate at final stage of vermicomposted sludge.



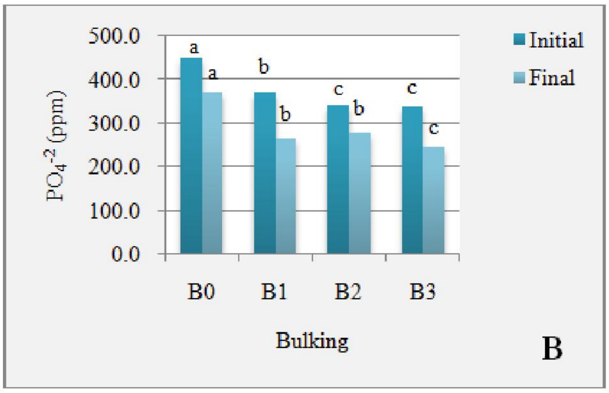


Fig. 4. Effect of worm species (A) and bulkings (B) on phosphate content in vermicomposting of sewage sludge

They further claimed that the worms were more active in presence of bulking material like cow dung and garden soil. The phosphate reduction was significant in presences of CD and GS. These amendments might be providing additional feed for the worms resulting into their stimulated activities leading to reduction in phosphate. Kaushik *et al.* (2008) noted significant reduction in phosphate content in textile mill sludge during vermicomposting by using cow dung and nitrogen fixing as well as phosphate solubilising bacteria.

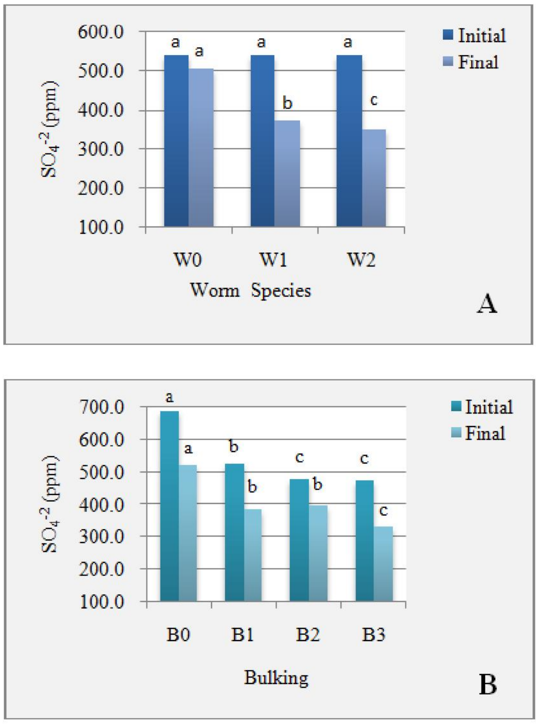


Fig. 5. Effect of worm species (A) and bulkings (B) on sulphate content in vermicomposting of sewage sludge

Table 2. Interaction effect of worm species and bulkings on nitrate, phosphate and sulphate content in vermiremediation of sewage sludge

Treatment	NO_3^{-2} content (ppm)		PO_4^{-2} content (ppm)		SO_4^{-2} content (ppm)	
	Initial	Final	Initial	Final	Initial	Final
W0B0	866.0 b	844.3 b	451.0 a	435.7 a	687.0 a	643.3 a
W0B1	975.7 a	916.3 a	372.3 b	340.7 bc	525.7 b	506.3 b
W0B2	835.0 b	799.7 c	342.7 b	312.3 c	479.3 c	434.0 c
W0B3	799.0	732.0 d	339.7 b	323.7 bc	476.3 c	441.0 c
W1B0	866.0 b	575.3 fgh	451.0 a	345.7 b	687.0 a	459.7 c
W1B1	975.7 a	594.3 f	372.3 b	238.7 e	525.7 b	338.7 e
W1B2	835.0 b	649.7 e	342.7 b	244.0 e	479.3 c	376.7 d
W1B3	799.0	479.7 i	339.7 b	225.3 e	476.3 c	313.7 e
W2B0	866.0 b	580.7 fg	451.0 a	330.7 bc	687.0 a	466.0 c
W2B1	975.7 a	554.0 gh	372.3 b	217.0 ef	525.7 b	316.3 e
W2B2	835.0 b	302.7 j	342.7 b	281.0 d	479.3 c	377.3 d
W2B3	799.0 b	540.3 h	339.7 b	191.3 f	476.3 c	238.7 f

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

Sulphate

At final stage the SO_4^{-2} content was decreased considerably over initial stage in all treatments used. The highest SO_4^{-2} content (506.2 ppm) was found in absence of worm species and it was reduced to (349.6 ppm) in presence of *E. eugeniae* (Fig. 5 A). The influence of bulking materials at final stage showed SO_4^{-2} decreased in SS + CD, SS + SM and SS + GS by 26, 24 and 37 % as compare SS respectively (Fig. 5 B). The effect of interaction between worm species and bulkings indicated highest SO_4^{-2} (643.3 ppm) in SS and no worm species but it was greatly reduced almost by 80 % in the treatment SS + GS in presence of *E. eugeniae* (Table 2). Results of present study are similar to Siuris (2011) and Reddy *et al.* (2012). They observed reduction in SO_4^{-2} in sewage sludge obtained from urban wastewater treatment plants. Masciandaro *et al.* (2000) reported very high content of SO_4^{-2} in biological sludge. Also, Sinha (2010) stated that the organic wastes rich in sulphar get converted into sulphate during the process of reduction, which accumulate in sewage sludge. The process such as bioconversion, mineralization, and bioaccumulation might be responsible for reduction of sulphate found in sewage sludge. The worm species may also be consuming sulphate in sewage sludge for their metabolic processes leading to lowering the sulphate content.

Summary and Conclusion

Sewage sludge has great potential as fertilizer apart from its hazardous and phytotoxic nature. The toxicity is due to very high content of microelements, salts and heavy metals. Application of sewage sludge in agriculture or for soil reclamation is an effective solution for its management. Many researchers had advocated the use of sewage sludge for agriculture by vermiremoval of phytotoxic elements and pollutants. This potential was screened using different species of earthworms and bulking materials. From the results it is concluded that microelements like Na^{+} and Mg^{+2} as well as salts like NO_3^{-2}, PO_4^{-2} and SO_4^{-2} can be brought to their lowest level in the treatments SM and SG in presences of *E. eugeniae*.

The vrmicomposted sewage sludge may be suitable to use as a source of essential nutrients to the plants and a good soil conditioner.

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