PERFORMANCE EVALUATION OF MICROBIOLOGICA-LLY DEGRADED PAINT SLUDGE COMPOST FOR APPLICATION TO NON-EDIBLE PLANTS

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ABSTRACT

A typical automotive industry paint sludge was composted with rice bran and EM bacteria. The compost was analysed for nitrogen, oxygen, carbon, phosphorous, etc. and toxic metals. The compost was mixed with soil in 1:16 ratio and used for growing Neem, Madhuka and Pongamia in pots and in the field. The plant growth was monitored regularly and it was established that the compost treated plants showed a robust growth. Presence of insects, ants and pupae etc., were noticed on the plants. Lead, zinc other toxic metals were analysed in the soil, compost, roots, stem and leaves once every month. Typical transport ratios for toxic element pick up, absorption and translocation for several elements have been established.

Key Words : Paint sludge, Compost, Plant growth, Heavy metals, Toxicity

INTRODUCTION

Industrial paints are used in automotive industries essentially for aesthetic appeal and corrosion resistant properties. Various types of paints including primers and stoving enamels are used in large quantities for this purpose. In spray painting, approximately 40 percent of paints get wasted and collect as a semisolid heterogeneous sludge of varying composition. According to Government of India Hazardous waste (Management and Handling) rules 2008, paint sludge is classified as a category 7 hazardous waste.[1] Currently there are no established guidelines for the treatment of paint sludge. Disposal in landfills can cause leaching, increase in the toxicity of the soil etc. Incineration is also not favoured because of the generation of organic vapours and toxins. Over the years, concerns about the public health have given way to the utilization of environment friendly chemicals in paints also. Therefore except the metallic pigments, most of the organic constituents of paints are amenable to biological treatment. Microbial remediation of hazardous organic compounds using EM (Effective micro-organisms) is an attractive option.[2] Several paint pigments contain metal salts such as copper, zinc, boron, vanadium etc. An EM treated paint compost has the potential to serve as a soil nutrient provided other toxic metals are within their tolerance levels. Therefore it was thought worthwhile to compost automotive paint sludge using rice bran medium with EM bacteria. This product is known as Bokashi. In this work, a heterogeneous paint sludge obtained from an automotive industry was composted with rice bran, nutrients and water. The compost was successfully utilized to grow non-edible plants such as Neem, Pongamia and Madhuka. The experiment was carried out under strict controlled conditions. The growth of the plants and distribution of metal ions in the soil, stem and leaves were monitored periodically.

AIMS AND OBJECTIVES

To prepared compost from paint sludge using EM bacteria and to test the effect of application of the compost on the growth characteristics of non-edible plants. It was also decided to study the uptake of nutrients and to observe symptoms of heavy metal toxicity, if any.

MATERIAL AND METHODS

Analar reagents, deionised water and standard solutions were used throughout the study unless stated otherwise.

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EM culture was obtained from Maple Orgtech (India) Pvt. Ltd., Dehradun and used as such Bokashi was prepared by mixing 20 kg of rice bran, 1 kg of jaggery and 5 litres of water. EM culture was sprayed on the mixture and allowed to ferment at 20^0C for 2 weeks. The mixture was sprayed with EM twice a week until the bokashi developed a fine musky smell. A typical heterogeneous paint sludge containing 45% resins, 30% solvent and vehicle and 25% pigments and additives was used in this study. Paint sludge and bokashi were manually mixed in 1:1 ratio for approximately 3 hours. The mixture was allowed to compost for another 8 weeks with occasional stirring and remixing followed by 1 liter of EM spray twice a week. The compost was characterized by using only BIS tests. *Pongamiaia pinnata*, *Madhuka indica* and Neem (*Azadirachta indica*) were selected for experimentation. 5 saplings of each species were treated with the compost and planted in separately dug pits. Care was taken to ensure that leachates would not mix either with the parent soil or other plants. 5 control saplings were also planted separately for comparison. An equal number of potted saplings were also grown for subsequent destructive analysis **(Fig. 1** to **Fig. 6)**. The saplings were planted in a 3′x3′x3′ pit dug for each sapling. About 66% of the pit corresponding to 18 cft was filled with the parent soil and the balance 9 cft was filled with 1:1 soil-compost mixture.

Fig. 1 : Field plant – Madhuka

Fig. 2 : Field layout – 1

Fig. 3 : Field layout – 2

Fig. 4 : Growth of compost and control Neem plants

Fig. 5 : Growth of compost and control Pongamia plants

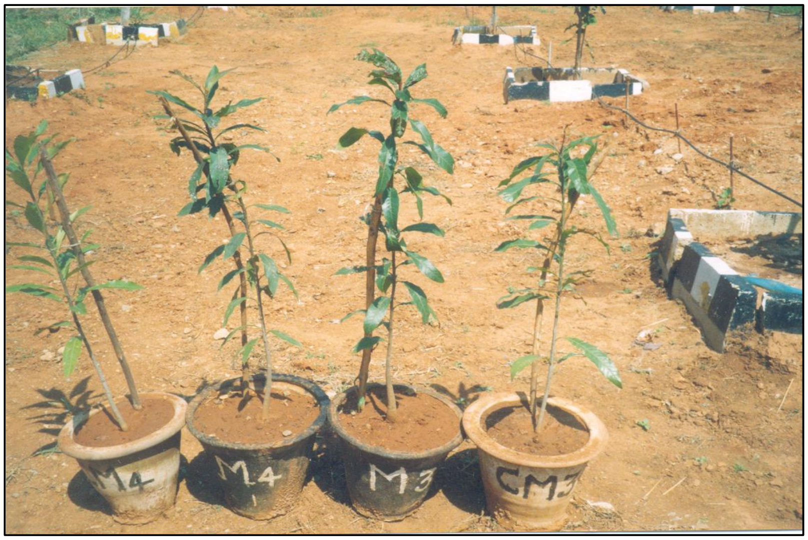

Fig. 6 : Growth of compost and control Madhuka plants

All the metallic elements were analysed by JOBIN-YVON JY-24 SEQUENTIAL ICP-AES and GBC AWANTA 632 AAS using standard parameters. A Milestone MLS 1200 microwave digester attached with EM-45/A exhaust module was employed for dissolution of the samples. Typical digestion programs are given in **Table 1** and **Table 2.**

Table 1 : Digestion program for soil

Steps for Soil	Time (min)	Power (w)	Reagents
1	6	250	(5-6 ml) +HCl 30% (1-2 ml) +H_2O (1ml)
2	6	400	
3	5	550	
	Vent : 10		

Table 2 : Digestion program for plants

Steps for plants	Time (min)	Power (w)	Reagents
1	2	250	HNO_3 65% (5-6 ml) + H_2O_2 30% (1-2 ml) + H_2O (1ml)
2	2	0	
3	6	250	
4	5	400	
5	5	550	
	Vent : 10		

Sample weight: 500 mg

Procedure

Coning and quartering technique was used for obtaining representative sample of rice bran, bokashi, compost and soils. Plant growth characteristics such as height and girth were monitored for both field and potted plants at regular intervals. Various parts of both the treated and untreated plants such as leaves and stems were collected for analysis only from the potted plants. The soil from control and experimental plant were manually crushed and sieved to obtain the desired particle size. All the samples were oven dried at 100^0C for 3 hours and subsequent analysis was carried out for various parameters. Standard analytical procedures were adopted for the analysis of all samples. Using prescribed test conditions, the samples were digested in a microwave digester under pressure to obtain complete dissolution. Trace metals analysis of samples was carried out by ICP-AES and AAS.

RESULTS AND DISCUSSION

Plant growth characteristics

Typical characteristics such as height and girth of the saplings were recorded every month for six months and the data is listed in **Table 3**. From the above data, it is clear that the growth rate increases dramatically after 2 months of application of the compost. This period is acclimatization stage. It was noticed that compost treated plants were 100-300% taller than the control plants and girth had also increased similarly. Similar growth rates were observed for potted plants also as shown in **Table 4**. All the plants were found to be healthy and did not exhibit any toxic effects. Several plants treated with the compost showed the presence of insects and ants in good measure.

Table 3 : Field plant growth characteristics

Month	I month				II month				III month				IV month			
	Control		Exp		Control		Exp		Control		Exp		Control		Exp	
	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr
Neem																
Plant1	77	2.5	78	2.0	78	2.7	85	2.5	86.5	3.5	86.5	2.7	87	3.9	88	3
Plant2	76	3.0	76	3.0	78	3.6	77	3.2	78	3.5	78	3.8	80.5	4.2	87.5	3
Plant3	64	2.8	77	2.5	65	3.0	84	3.1	75.5	3.6	86	3.3	775	4.0	89.5	3
Plant4	85	2.8	84	2.2	86	3.1	85	2.4	87.5	3.5	93	2.7	89	3.7	96	3
Plant5	104	3.2	110	3.0	105	3.8	112	3.5	106	4.6	114.5	4.1	107	4.8	116.5	4
Madhuka																
Plant1	72	2.1	60	1.9	76	2.7	64	2.4	91.5	3.7	69	3.3	93.6	4.2	71.5	3
Plant2	70	2.0	80	3.0	73	2.2	85	3.8	86.5	2.8	90	4.2	88	3.3	101	4
Plant3	89	2.6	73	2.5	89	2.8	73	3.4	105	3.3	85	4.0	106	3.6	94	4
Plant4	76	2.7	78	3.0	76	3.1	78	3.1	81.5	3.6	94.5	3.6	84.5	3.9	98	4
Plant5	76.5		77	3.0	76.5		82	3.3	91		87.5	3.7			89	4
Pongamia																
Plant1	87	2.6	62	2.0	88	3.1	64	2.3	88.5	3.8	65	3.0	89.5	4.0	66.5	3
Plant2	84	4.0	42	1.7	87	4.5	46	2.0	131.56.1		53.5	2.7	134	6.3	55	3
Plant3	78	2.9	100	3.0	78	3.0	102	4.0	81	3.5	124	5.1	82	3.8	126.5	5
Plant4	58	2.8	106	3.0	58	2.7	115	3.9	64	2.8	144	4.7	67	3.2	147	5
Plant5	48	2.1	70	3.0	51	2.4	74	3.3	64.5	3.0	88.5	3.5	66	3.3	90	4

*All units in cm

Table 4 : Pot plant growth characteristics

Month	I month				II month				III month				IV month			
	Control		Exp		Control		Exp		Control		Exp		Control		Exp	
	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr	Ht	Gr
Neem																
Plant2	79	1.8	76	2.6	81	2.0	78	2.7								
Plant3	68	1.7	75	2.3	71	1.7	76	2.3	81	2.0	77	2.6				
Plant4	63	1.9	86	1.9	65	2.0	88	2.1	66	2.0	88	2.5	68	2.2	92	
Madhuka																
Plant2	63	2.3	72	2.3	65	2.5	74	2.5								
Plant3	60	2.5	76	2.2	63	2.6	77	2.0	65	2.6	82.5	2.8				
Plant4	61	2.4	72	2.2	64	2.5	72	2.1	66	2.5	76	7.6	68	3.0	78	
Pongamia																
Plant2	55	2.9	68	2.0	56	3.1	70	2.2								
Plant3	52	1.9	70	2.4	53	2.0	72	2.5	54.5	2.7	72.4	2.6				
Plant4	54	1.9	68	2.5	51	1.8	70	2.8	53.5	2.1	71	2.9	55.5	2.3	72	

All units in cm.

Proximate analysis

Proximate analysis of the typical stoving paints is given in **Table 5. Table 6** shows the proximate analysis of Bokashi, compost and soil.The data in **Table 6** indicates that the mixed compost is a good source of micronutrients for plants as elements like nitrogen, phosphorous, potassium, sodium etc. are present in significant concentrations. It is evident that increased volatile carbon content in both bokashi and the compost resulted in robust growth of treated plants as indicated in section 4.1.

Trace element profile

Essential trace elements such as copper, iron, molybdenum, nickel, boron, chromium, lead, cobalt etc. were analyzed for soils and plants. In these investigations, a known amount of sample (≅ 500 mg) was digested in a microwave digester using suitable reagents to extract the trace metals. The extracts were made up to 50 ml. Various trace metals present in the sample were analyzed and quantified using AAS and AES-ICP. Arsenic, selenium and cadmium were not present in either the soil or composts. Chromium, lead, cadmium, copper, zinc, molybdenum and boron were detected and quantized in each sample. The analytical concentrations of soils, bokashi and compost are given in **Table 7**

Table 5 : Proximate analysis of paints

Sample	% Volatile at 105^0 C	% Ash at 900^0C
Semi black 1	42.118	2.71
Semi black 2	44.368	2.76
Green 1	52.958	1.31
Green 2	52.797	1.33
Silver 1	52.93	0.82
Silver 2	52.98	0.85

* Company trade names

Table 6 : Proximate analysis of bokashi, composts and soil

Parameter	Bokashi	Compost (1-2 weeks)	Compost 1 (8 weeks)	Compost 2	Mixed compost	Pure soil
Moisture (%)	46.07	39.33	14.96	18.29	22.43	4.44
Volatile (%)	75.19	76.60	77.00	74.12	77	5.73
Ash (%)	22.50	23.88	21.83	23.41	22.17	92.13
Nitrogen (%)	1.52	2.97	3.27	3.25	2.52	0.16
Phosphates(%)	1.16	0.62	1.17	1.11	0.57	0.12
Potassium (%)	0.77	0.47	0.46	0.46	0.3	1.92
Sodium (%)	0.06	0.05	0.19	0.17	0.18	0.89
pH (10% sol)	---	---	---	---	7.48	7.63
Organic carbon (%)	---	---	---	---	23.21	3.28
Fe (%)	0.1	0.25	0.19	0.13	0.20	3.0
Cu (ppm)	25	100	ND	50.00	ND	6
Mn (ppm)	150	100	60	100	ND	350
Zn (ppm)	75	420	100	400	ND	88
Electrical Conductivity (umhos/cm)	---	---	---	---	134.50	22.20

Table 7 : Trace element profiles of Bokashi, composts and soil

S/N	Sample	B	Cr	Mo	Cu	Zn	Pb	Fe
1	Rice Bran	0.4	ND	0.1	ND	43.1	ND	0.2
2	Bokashi	0.4	ND	0.2	ND	50.9	ND	0.1
3	Compost 1(2 wk)	0.7	10.1	0.4	67.5	316.4	10.8	0.2
4	Compost 1(8 wk)	0.5	12.9	0.5	56.2	377.8	12.4	0.4
5	Mixed Compost (10 wk)	0.4	12.5	0.4	91.5	334.4	15.0	0.4
6	Pure soil	1.8	1.3	3.1	ND	21.0	ND	2.7
7	Control soil (1 mo)	1.9	1.4	3.2	ND	26.3	ND	2.6
8	Exptl soil (1 mo)	1.9	1.4	3.1	ND	60.7	ND	2.5
9	Control soil (2 mo)	2.0	2.4	3.0	ND	39.3	ND	3.0
10	Exptl soil (2 mo)	1.9	1.9	3.1	ND	56.0	ND	2.6
11	Control soil (3 mo)	1.9	2.2	1.7	ND	105.9	ND	2.9
12	Exptl soil (3 mo)	2.7	2.6	2.4	ND	106.4	ND	3.2
13	Control soil (4 mo)	1.8	2.4	2.5	ND	85.0	ND	2.5
14	Exptl soil (4 mo)	1.6	2.3	2.4	ND	53.4	ND	2.4

Unit of B, Cr, Mo, Cu, Zn, Pb in (μg/g) and Fe in (%) and * ND – Not Detected wk-weeks, mo-months It is evident from **Table 7** that boron, chromium, molybdenum, zinc, lead and iron are present in very low quantities, well below the tolerance levels of MOEF standards for compost specifications. This shows that the composted paint sludge is not toxic to the plants. On the contrary it seems to be beneficial for good growth. This is along the expected lines because most of the soils are normally deficient in one or two metal ions and application of paint sludge immediately compensates for the deficient metal ions resulting in healthy growth of the plants.

Neem

The concentration of boron, chromium, molybdenum, zinc and iron in roots, stem and leaves of Neem sample are presented in **Table 8**.

Approximately 25% of Boron was stored in roots from the soils. The Boron concentration ratio of roots:stem:leaves is 50:25:100. The concentration of boron in the soil and leaves was same indicating cent percent translocation in the leaves.

Chromium concentration was negligible in both control and experimental plants. The distribution ratio of chromium in the leaves to soil was approximately only 1%.

The concentration of molybdenum did not vary much in control and experimental plants. The pickup rate of soil : roots : stem : leaves was 30 : 3 : 1 : 1. The experimental plants picked up zinc in good amounts as compared to control plants in roots and stem. The uptake rate of zinc from soil to roots was about 10% and the concentration levels in stem and roots were very low.

Table 8 : Trace element profile of neem

Month	Control Root					Experimental Root				
	B	Cr	Mo	Zn	Fe	B	Cr	Mo	Zn	Fe
I.	0.5	0.3	0.3	7.9	0.03	0.7	0.3	0.5	3.9	0.03
II.	0.5	0.2	0.2	23.0	0.02	0.5	0.3	0.2	18.8	0.03
III.	0.5	0.1	0.2	ND	0.01	0.5	0.1	0.2	10.8	0.01
IV.	0.5	0.2	0.2	ND	0.02	0.8	0.1	0.3	29.1	0.02
	Control Stem					**Experimental Stem**				
I.	0.2	ND	0.1	ND	0.0004	0.3	ND	0.1	ND	0.002
II.	0.2	0.1	ND	ND	0.006	0.2	ND	ND	2.0	0.002
III.	0.4	ND	0.3	11.0	0.002	0.3	ND	0.1	19.8	0.003
IV.	0.3	ND	0.1	ND	0.003	0.3	ND	ND	ND	0.001
	Control Leaves					**Experimental Leaves**				
I.	1.32	ND	0.1	4.0	0.002	1.0	ND	ND	5.0	0.003
II.	1.1	ND	ND	7.0	0.002	0.9	ND	0.1	2.0	0.004
III.	1.6	ND	0.1	26.0	0.004	1.6	ND	0.1	15.0	0.005
IV.	2.2	ND	0.1	20.7	0.004	1.4	ND	0.1	19.8	0.005

Madhuka

The trace element concentrations in Madhuka are listed in **Table 9**. Distribution of boron in soil: roots: stem: leaves were 1:0:1:1. Most of the Boron was completely metabolized in the compost.

The uptake ratio from soil to roots was about 20%.Chromium levels were very negligible in both stems of zinc. Therefore it is clear from the data that chromium is not metabolized nor is it translocated in treated plants. The uptake rate of soil: roots: leaves was 7: 3: 1 and approximately 20% of molybdenum was translocated in treated plants. The uptake ratio of zinc in roots and stems compared to soil was 20%. The concentration of zinc in leaves was negligible. The concentration ratio of iron in treated plants was hardly 1% compared to soil.

Table 9 : Trace element profile of Madhuka

Month	Control Root					Experimental Root				
	B	Cr	Mo	Zn	Fe	B	Cr	Mo	Zn	Fe
I.	0.9	0.4	0.4	16.0	0.04	0.7	1.5	0.5	8.0	0.02
II.	1.1	0.4	0.5	27.0	0.05	0.7	0.2	0.2	17.0	0.02
III.	0.6	0.2	0.3	ND	0.01	1.0	0.2	0.3	37.8	0.02
IV.	0.7	0.2	0.2	ND	0.01	0.4	0.1	0.2	22.2	0.01
	Control Stem					**Experimental Stem**				
I.	0.5	ND	ND	5.0	0.0002	0.3	ND	1.0	21.8	0.0004
II.	0.3	0.1	ND	20.7	0.004	0.5	0.1	ND	15.0	0.0043
III.	0.3	ND	0.1	10.7	ND	0.3	ND	1.0	20.0	ND
IV.	0.3	ND	ND	2.0	0.0002	0.3	ND	1.0	53.6	ND
	Control Leaves					**Experimental Leaves**				
I.	0.8	ND	0.1	ND	0.003	0.9	ND	ND	1.0	0.002
II.	3.9	ND	ND	ND	0.004	1.7	ND	0.1	ND	0.002
III.	3.8	0.1	0.1	ND	0.005	2.2	ND	0.1	1.0	0.002
IV.	4.8	ND	0.2	5.0	0.004	3.7	ND	0.1	9.5	0.002

Pongamia

The analytical values for trace elements in Pongamia are displayed in **Table 10**. Boron concentration in experimental plants was higher than the control plants. The ratio of boron in roots : stem : leaves was 1:1:2. The distribution of boron was uniform in roots and stems and fully translocated in the plants. The uptake ratio of chromium in soils to roots was 25%. But stems and leaves did not show the presence of chromium. This again means that, it was not translocated in stems and leaves. The concentration of molybdenum did not very much in experimental and control plants. From the data, it was concluded that most of the molybdenum concentration was held in roots.

The ratio of zinc in soil : roots : leaves in experimental plants worked out to be 5: 0.5: 1 and it was clear that zinc did participate in the metabolism of Pongamia in a very significant way. There was not much variation in iron concentration in both control and experimental plants. Therefore all the plants behaved uniformly with respect to iron.

Table 10 : Trace element profile of Pongamia

Month	Control Root					Experimental Root				
	B	Cr	Mo	Zn	Fe	B	Cr	Mo	Zn	Fe
i.	0.6	0.4	0.5	62.3	0.2	0.6	0.4	0.5	37.2	0.03
ii.	0.4	0.1	0.2	12.0	0.01	0.5	0.3	0.4	45.1	0.05
iii.	0.5	0.1	0.3	17.0	0.01	0.7	0.3	0.4	42.0	0.02
iv.	0.4	0.2	0.3	9.67	0.02	0.6	0.1	0.3	25.9	0.01
	Control Stem					**Experimental Stem**				
i.	0.4	ND	0.1	9.9	0.0006	0.6	ND	0.2	23.0	0.003
ii.	0.7	ND	0.1	64.9	0.003	0.6	ND	0.1	39.7	0.0009
iii.	0.7	ND	0.3	19.0	ND	0.5	ND	0.3	17.6	ND
iv.	0.4	ND	0.1	15.2	0.0009	0.6	ND	0.1	26.3	0.0003
	Control Leaves					**Experimental Leaves**				
i.	1.4	ND	0.1	5.0	0.003	0.9	ND	ND	7.0	0.003
ii.	1.2	ND	ND	17.0	0.002	0.8	ND	ND	13.1	0.003
iii.	1.5	ND	0.1	22.9	0.003	1.0	ND	0.1	23.0	0.002
iv.	2.7	ND	0.1	27.3	0.005	3.2	ND	0.1	16.9	0.003

Most of the other toxic elements such as arsenic, selenium and cadmium were not present in either the soil or composts. The concentrations of toxic elements were well within the standard prescribed limit of MOEF Guide line of S. O. 908 (E), 2000 for Municipal Solid Wastes (Management and Handling) Rules.Most of the other elements like boron, iron, zinc etc were labilized completely in the soil. Therefore paint sludge-compost is a suitable supplier of micronutrients for plants.[3-5]

CONCLUSION

Composts have a major role to play in farming. The advantage of using paint sludge compost is to provide the deficient micronutrients to the plants, which could result in healthy growth. In this study, it has been conclusively established that the growth rate of all the investigated plants increases dramatically after 2 months of application of the composts. This may be called acclimatization stage. Chromium values are not significant enough to be toxic and most of other elements are labilized completely in the soil. This means that the paint sludge has been rendered completely harmless with the current level of application.

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We generate our own environment. We get exactly what we deserve. How can we resent a life we've created ourselves? Who's to blame, who's to credit but us? Who can change it, anytime we wish, but us?

Richard Bach