ISSN: 0973 - 7049

The Bioscan: Special issue, Vol. 3; 651-658; 2010
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

TOXIC EFFECT OF HEXAVALENT CHROMIUM ON COMPOSTING OF SEGREGATED ORGANIC WASTE

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Compost

Hexavalent chromium

MSW

Lignocellulosic material.

Paper presented in International Conference on Environment, Energy and Development (from Stockholm to Copenhagen and beyond)
December 10 - 12, 2010, Sambalpur University

The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

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ABSTRACT

The effect of chromium on the microbial and physico-chemical characterization of substrate composting material was assessed. The present study indicated the toxic effect of hexavalent chromium on the composting of segregated organic waste. During composting, addition of chromium had influenced adversely the microbial growth and activity. The experimental results indicated that among the different parameters only the degradation rate of cellulose was affected because of chromium toxicity. Cr (VI) affects the degradation rate of lignocellulosic material and microbial activity. The existence and importance of this phenomenon has been evaluated by studying the toxic effect of hexavalent chromium on composting.

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INTRODUCTION

Heavy metals are common in industrial applications such as in the manufacture of pesticides, batteries, alloys, electroplated metal parts, textile dyes, steel, and so forth. Chromium has been recognized as an essential microelement for animals and humans (Anderson, 1989), potentiating the action of insulin and therefore being effective in carbohydrate and lipid metabolism (Ducros, 1997). On the other hand, recent works point to the severe toxicity of hexavalent chromium, a form utilized in several industrial activities (electroplating, chemicals, varnish, leather tanning).Chromium is one of the most common metal contaminants in the environment. When a high Cr (VI) level is readily available, in polluted soil in particular, it can seriously affect the plant growth and metabolic functions (Abdel-Sabour and Zohry, 2003). Composting has become a potentially viable disposal route for some organic wastes. Chromium exists in two environmentally stable oxidation states, Cr (III) and Cr (VI), having very different toxicities and mobilities (Kozuh *et al.,* 2000). Hexavalent chromium is regarded as one of the major hazardous chemical due to its carcinogenic and mutagenic effects on living organism and human beings. Hexavalent chromium is known to be skin irritant and to induce allergic contact dermatitis and is considered a class ‘A’ human carcinogen by inhalation (James *et al.,* 1997). In contrast, Cr (III), having a limited hydroxide solubility and lower toxicity, and hence it is generally regarded as a less dangerous pollutant (Mohan and Pittmann, 2006).

As trace elements, some heavy metals (*e.g.* copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metals are dangerous because they tend to bioaccumulation. Although contamination from MSW can be minimized through sorting before composting, a major environmental concern associated with biosolids and MSW remains the presence of heavy metals that can be toxic to plants (Bazzar *et al.,* 1974, Carlson *et al.,* 1975), enter food chain (Xian 1989) and can affect human health. Many studies have been carried out on the specification of heavy metals in soils and soil amended with composted municipal waste (Tessier *et al.,* 1979). It is found that metals are present in urban and industrial waste and when discharged, the soil and water pollution take place (A.G.H.T.M., 1985; Navarro and Revin, 1986; District de Tunis, 1984). Composting is the oldest and best way of disposal, recycles and reuse for management of MSW. The paper aims at identifying the toxic effect of Cr (VI) on microbial and composting of organic wastes.

MATERIALS AND METHODS

Substrate

Vegetable waste was collected, and shredded manually in the range of 25 mm to 75 mm, the most desirable range of particle size for composting (Tchobanoglous *et al.,* 1993). Shredded MSW was kept for air-drying and later mixed with dried and crushed leaf waste in ratio 4(vegetable):1(leaves).

Composting

In the beginning the moisture content of composting material was adjusted at 55%. (700 mL water per 500g of composting sample).A minimum moisture content of 50 to 55 percent is usually recommended for high rate composting of MSW (Richard, 1996). Concentrations of hexavalent chromium were taken as 5ppm, 25ppm, 75ppm, and 125ppm in respective experimental composter. Vegetable waste was then allowed to decompose in all of the composters. Temperature of all composter was measured daily with the help of thermometers. Care was taken to get the uniformly composted sample for all laboratory scale studies were obtained.

Preparation of compost samples for chemical analysis

Samples were drawn from all composters once in a week up to 21 days and were analyzed for Physico-chemical parameters. The pH of a suspension of compost in water (1:10 v: v) was measured (IS: 10158, 1982). Moisture content was assessed weakly (IS: 10158, 1982). The organic carbon content of the compost was estimated by combustion method (New Zealand formula, 1951; Nelson and Sommers, 1982) and total nitrogen was estimated by Kjeldahl method (Bremner and Mulvaney, 1982). Cellulose was analyzed by digestion with nitric acid and glacial acetic acid (Liu, 2004). Klason's method was used for extraction of lignin content (Kirk and Obst, 1988). Crude fiber was made up primarily of plant structural carbohydrates such as cellulose and hemicellouse and lignin, which was a highly indigestible material. Crude fiber was determined gravimetrically after chemical digestion and solubilisation of other materials present. The fiber residue weight was then corrected for ash content after ignition (Holst, 1982). A colorimetric method, as described in the standard method (Clesceri *et al.*, 1998), was used to measure the concentrations of the different Cr species. The pink colored complex, formed from 1, 5-diphenylcarbazide and Cr (VI) in acidic solution, was spectrophotometrically analyzed at 540nm (GENESYS TM 5, Spectronic Inc., USA).

RESULTS AND DISCUSSION

Physico-chemical characterization of compost

The physicochemical characterization of substrate is presented in Table 1. The results showed that the material selected for composting trial was a highly lignocellulosic material. The selected material was also analyzed for the presence of various heavy metals. Although, these toxic metals were present in the composting material there concentrations were not significant. The concentration of chromium was below detection limit as indicated in Table 2. The composting process was periodically monitored for the change in the physicochemical characterization of the composting material. The changes observed in physicochemical characterization of material during composting are presented in Table 3.

Temperature variation during composting

The operating temperature ranges were as follows: > 55°C to maximize sanitation, 45-55°C to maximize the biodegradation rate, and 35-40°C to maximize microbial diversity (Stentiford, 1996). Schematically, the process of aerobic composting could be divided into three major steps, a mesophilic-heating phase, a thermophilic phase and a cooling phase (Alberti, 1984; Mustin, 1987, Leton and Stentiford, 1990). Heat was released during the process of composting. The initial temperature of compost was observed to be 28 °C. This indicates the mesophilic phase. After that temperature rose up to 44 °C (Fig.1), this indicated the thermophilic phase. After that the temperature was reduced to 27 °C and then no fluctuation was observed in temperature. This indicates maturation or cooling phase of the composting process.

Toxic effect on composting

During composting, the complex organic molecule cellulose was degraded into its simpler form by the activity of microorganism involved in the process. The presence of any toxicant could lower the microbial activity and hence could lower the cellulose degradation. The initial concentration of cellulose, (55.48%) was reduced to 46.02% in control with a cellulose reduction rate of 17.10 %. Chromium added compost treatment showed reduction in cellulose percentage gradually. Similarly, the rate of reduction of crude fiber concentration also showed gradual decrease as the period of composting increases. The reduction in the concentration of cellulose and crude fiber indicated that the degradation process was affected due to the toxicity of hexavalent chromium. Hexavalent chromium is a known toxicant, which affect the growth, development and activity of microorganism there by affecting the rate of degradation process.

Like cellulose microorganisms present in composting process also degraded the hemicellulose According to Eiland *et al.*, (2001), hemicellulose components tend to be degraded more easily than cellulose components or lignin. In the present investigations gradual decrease in hemicellulose percentage was observed. Hemicellulose content in the beginning of composting process was insignificant however, with increasing duration, rapid degradation of hemicellulose took place. Unlike cellulose and hemicellulose concentration, lignin did not show any remarkable change. Increasing concentration of chromium did not produce any remarkable change in the concentration of lignin.

Organic Carbon, Nitrogen and C/N ratio

The concentration of organic carbon in the composting mixture was found to be steadily decreased over the

Table1 Physico chemical characterization of the substrate material (Vegetable+ Leaf Waste)

Parameters	Values
Cellulose (%)	54.85
Hemicellulose (%)	34.11
Lignin (%)	23.15
Crude fiber (%)	11.00
Nitrogen (%)	0.96
Carbon (%)	43.00
C/N ratio	44.79
pH	7.5

Table 2 Initial concentration of Heavy Metals in substrate material

Heavy Metals	Concentration(ppm)
As	0.667
Zn	o.258
Pb	0.156
Cd	0.012
Co	0.099
Mn	0.798
Fe	5.89
Cr	0.015
Cu	0.075

Table 3: Changes in the Physico-chemical characterization of substrate during composting

Days	Composter (%)	Cellulose(%)	Hemicelluloses	Lignin(%) (%)	Crude fiber (%)	Carbon (%)	Nitrogen	C/NRatio
0	Control	55.48	33.28	24.18	12.48	43.75	0.96	45.57
	5ppm	55.36	33.46	24.1	12.74	44.12	1.01	43.68
	25ppm	54.95	34.11	24	11.65	43.58	0.95	45.87
	75ppm	55.17	33.63	24.15	12.78	43.08	0.94	45.82
	125ppm	54.84	33.43	24.11	12.34	44.17	1.03	42.88
4	Control	51.44	32.98	24.09	11.24	42.93	1.38	31.11
	5ppm	52.48	33.11	24.11	11.31	43.26	1.4	30.9
	25ppm	51.99	33.02	23.98	11.29	43.2	1.36	31.76
	75ppm	51.05	33.47	24.01	11.86	42.36	1.39	30.47
	125ppm	51.88	32.85	24.06	11.23	41.74	1.36	30.69
8	Control	49.06	33.54	24.3	9.81	41.28	1.58	26.13
	5ppm	49.89	33.57	23.99	9.99	41.85	1.5	27.9
	25ppm	49.66	32.89	23.84	9.58	42.01	1.52	27.63
	75ppm	49.11	32.47	23.88	9.35	41.38	1.53	27.04
	125ppm	49.78	33.15	23.94	9.57	41.25	1.54	26.78
12	Control	47	33.09	23.99	8.38	39.34	2.06	19.09
	5ppm	47.65	33.11	23.87	8.69	40.81	2.11	19.34
	25ppm	47.65	32.94	23.79	8.83	40.26	2.02	19.93
	75ppm	47.55	33.14	23.81	8.75	40.88	2.19	18.66
	125ppm	48.32	31.85	23.88	8.63	40.73	2.16	18.85
15	Control	46.92	32.22	23.95	7.87	39.04	2.64	14.78
	5ppm	47.37	32.31	23.81	7.53	40.22	2.59	15.52
	25ppm	46.39	31.87	23.77	8.02	39.89	2.61	15.28
	75ppm	47.28	31.25	23.8	8.19	39.92	2.63	15.17
	125ppm	48.12	31.45	23.79	8.12	40.02	2.61	15.33
20	Control	46.02	31.25	23.85	7.67	39.1	2.63	15.45
	5ppm	46.28	30.56	23.74	7.56	40.09	2.61	15.36
	25ppm	46.08	30.45	23.71	7.26	39.24	2.69	14.58
	75ppm	46.58	30.15	23.76	8.1	39.16	2.65	14.77
	125ppm	47.75	30.02	23.77	8.09	39.88	2.61	15.27

period of composting. Organic carbon was reduced from 44% to 39.1% at the end of composting process by means of microbial degradation process. The results indicated that higher chromium concentrations affect microorganism during degradation process and therefore the carbon concentration of the material remain unchanged or slightly increased. While the organic carbon concentration showed a decrease with increasing composting duration.

The total nitrogen concentration showed an increasing trend. However there could not be seen any influence of different concentration of nitrogen. Total C and N both showed a little or no subsequent decrease after the initial sharp drop within the first 2 weeks; total C generally declined over the whole composting period while total N stabilized after week 4. This indicated the curing phase which occurs after the active composting

Table 4: Analysis of compost samples for Chromium (VI)

Composter	Initial Conc. (ppm)	Final
Control	5.45	6.7
5ppm	8.4	12.45
25ppm	15.95	21.55
75ppm	41.5	61.45
125ppm	81.96	70.8

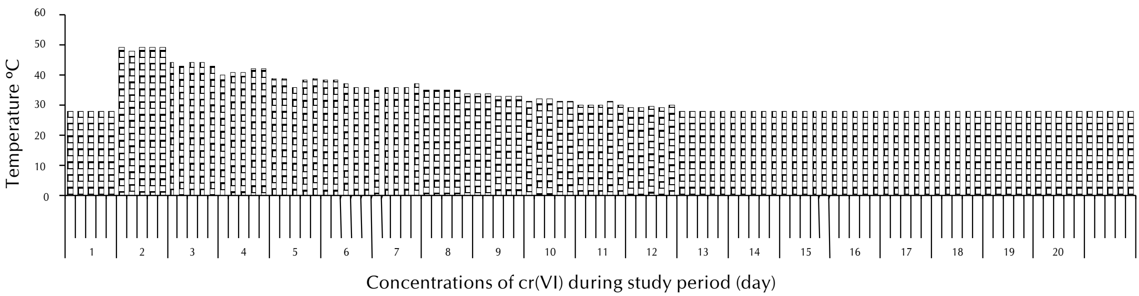

Figure 1: Temperature variation of samples with different Cr (VI) concentrations

phase, when the availability of labile organic matter limits the rate of microbial mineralization and the slow formation of humic-like substances occurs (Tognetti *et al.,* 2007). During composting microorganisms required carbon for growth and energy, nitrogen for protein synthesis. Thus, the rate of decomposition of organic wastes depends on a proper balance of carbon and nitrogen. Rapid composting was achieved when wastes or mixture of wastes have a C: N ratio of between 15 and 35. Lower ratios can result in the loss of ammonia (NH_3), while higher ratios can slow rate of composting shows the effect of different concentrations of chromium in composters on C/N ratio. The results obtained showed a decrease in C/N ratio with increase in days of composting. Dorfmann and Batsch, 1985; Bernal *et al.,* 1996; Amir and Hafidi, 2001; concluded similar results. There is more decrease in C/N ratio in case of control. Increasing concentration of chromium affected C/N ratio. The experiment with highest concentration of chromium (125ppm) showed less decrease in C/N ratio as compared to other experiments.

The background concentration of chromium of the experimental material was (0.015ppm). Addition of different concentrations of chromium to this material increased the initial concentration of chromium to the range of 5.5ppm to 81.96ppm as shown in Table 4.

Among the different concentrations tested, all the concentrations except 125ppm showed a slight increase in the final concentration of chromium. This might be due to the decrease in bulk density. During composting, the material was mostly dried in later stage due to substantial evaporation leading to decreased bulk density (Epstein, 1997; Lau *et al.,* 1992). The reduction in bulk density of compost could have increased the concentration of chromium.

CONCLUSION

The effect of chromium on the physico-chemical characterization of substrate material (composting material) was assessed. The present study indicated the toxic effect of hexavalent chromium on the composting of segregated organic waste. During composting, addition of chromium had influenced the microbial growth and activity. Due to this, the degradation rate of lignocellulosic material was decreased. Decreased rate of degradation of organic matter showed the toxic effect of chromium on composting. The results indicated that among the different parameters only the degradation rate of cellulose was affected because of chromium toxicity. This could be due to the effect of chromium on cellulolytic micro-organisms, which could not either survive or active on exposure to chromium. Further works are contemplated to understand the exact mechanism by which the composting process is affected due to chromium toxicity.

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