TOXIC EFFECT OF HEXAVALENT CHROMIUM ON COMPOSTING OF SEGREGATED ORGANIC WASTE

S. U. Patki et al.

Compost
Hexavalent chromium
MSW
Lignocellulosic material.

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 weekly (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 hemicellulose 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 their 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
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
The mechanism by which the composting process is affected due to chromium toxicity.

Further works are contemplated to understand the exact 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. 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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<th>Composter</th>
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<th>Final</th>
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<tbody>
<tr>
<td>Control</td>
<td>5.45</td>
<td>6.7</td>
</tr>
<tr>
<td>5ppm</td>
<td>8.4</td>
<td>12.45</td>
</tr>
<tr>
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<td>15.95</td>
<td>21.55</td>
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<tr>
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**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.

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

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


