

## Assessment of Chromium Fixation Capacity of Acid Lateritic Soil

V. KARTHIKA<sup>1</sup> AND P. THANGAVEL<sup>2</sup>

<sup>1</sup>Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

<sup>2</sup>Dept. of Soil Science, Anbil Dharamalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India  
email: sanjanakarathi@gmail.com

### ABSTRACT

**Chromium (Cr) is an environmental pollutant that ranks seventh abundance element in the earth crust. Naturally occurring chromium in soil ranges from 10 to 50 mg kg<sup>-1</sup>. The adsorption of chromium species in soils has received much attention because of its toxicity and bioavailability, which are adsorption depended. There are very little study adsorption of chromium in acid lateritic soil had been contacted. Hence this paper presents the Cr adsorption capacity of acid lateritic soil under chromium spiked condition. The result reveals that, the highest Cr (VI) adsorption in soil was found to be 161.7 µg g<sup>-1</sup> of soil at 300 µg g<sup>-1</sup> of soil contamination. Adsorption of chromium increased with increasing in concentration of Cr in supernatant solution upto 300µg g<sup>-1</sup>. The increase in Cr sorption at acidic pH could be attributed due to strong electrostatic attraction between positively charged groups of soil like Ca<sup>2+</sup> and negatively charged HCrO<sub>4</sub><sup>-</sup> ions.**

**Key words** Cr (VI), Cr Adsorption, Acid lateritic soil

Heavy metal contamination is one of the major ecological problems Worldwide, leading to yields losses in agricultural crops and harmfully affecting human health, when contaminants enter the food chain. Chromium is the seventh most abundant element on earth; and the second largest contributor of ground water, soil and sediment contamination (Shrivastava and Thakur, 2006). Release of Cr compounds to the environment is mainly due to electroplating, leather tanning, metal finishing, corrosion control and pigment manufacturing industries (Liu *et al.*, 2011). Annually about  $3 \times 10^4$ ,  $1.42 \times 10^5$  and  $8.96 \times 10^5$  tons of Cr is released to the atmosphere, water and soil respectively (Shen, 2002). Cr has two stable forms, i.e. trivalent Cr (III) and hexavalent Cr (VI) form, later one is more toxic. The maximum threshold level of Cr (VI) in drinking water is 0.05 mg L<sup>-1</sup> (WHO, 1996). Chromium Contamination in agricultural fields is

very toxic to plants, microbes, human being and animals and has been led a major environmental concern over the last few decades (Tiwari *et al.*, 2013).

Soil is a complex mixture of mineral and organic, aqueous and gaseous components and it is a dynamic system with changing moisture content, pH and redox potential etc. These properties interfere with the form and availability of metals. The interaction between soil and heavy metal can be understood on the basis of ion exchange, surface adsorption and chelation reactions. As well as the soil humic substances, which have the ability to form complexes with heavy metals due to their functional groups like phenolic, alcoholic and carboxyl structures. Heavy metal retention by soil also depends on ionic strength, pH, type of clay minerals present, type of functional groups and competing cations (Alloway, 1990; Evangelou, 1998).

While Cr (III) is strongly retained in soil particles, Cr (VI) species such as chromate (CrO<sub>4</sub><sup>2-</sup>), bichromate (HCrO<sub>4</sub><sup>-</sup>) and dichromate (Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>) are weakly sorbed to soils under alkaline to slightly acidic conditions, leading to their movement to sub surface environments (Carey *et al.*, 1996). Cr (VI) is more stable form in equilibrium with atmospheric oxygen, but in the presence of soil organic matter it is reduced to Cr (III) (Bolan *et al.*, 2003; Banks *et al.*, 2006; Jiang *et al.*, 2008).

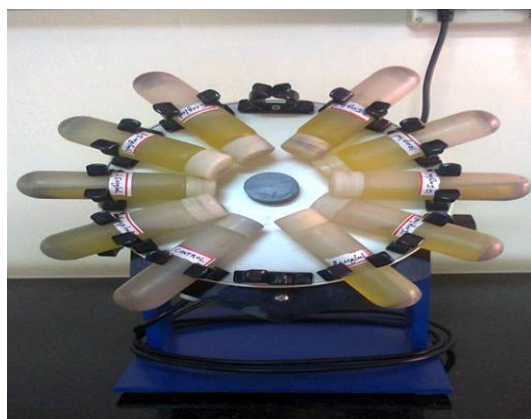
Oxidation-reduction (redox) reactions are largely controlled by the adsorption of Cr species in soils, by supplying of redox compounds and microbial activity. The detoxification of Cr (VI) through reduction to Cr (III) and its subsequent adsorption has been considered as an effective method for remediation management of Cr contaminated soils. The study of adsorption of Cr (VI) and Cr (III) is important in soils to understand the bioavailability of these two species. Despite the persistence of Cr contamination in Australian soils, little data exist in the literature about the interaction



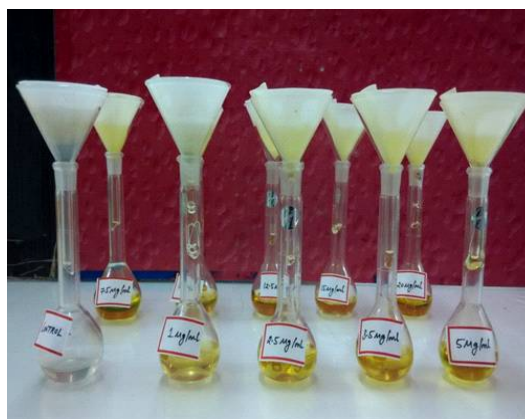
Cr Solution



Centrifuge tubes with Cr



End-over-end Shaker



Filtration

Fig. 1. Overview of Batch Experiment

of soil properties with Cr (III) and Cr (VI) (Avudainayagam *et al.* 2001; Bolan and Thiagarajan. 2001). Hence the objective of this research was therefore to quantify the relative adsorption of Cr (VI) in acid lateritic soil of Ooty, the Nilgris district of Tamil Nadu, India.

## MATERIALS AND METHODS

Bulk soil sample representing the acid lateritic soil, was collected from the cultivated field located at Wood House Farm of Horticultural Research Station of Ooty, Nilgris. The initial soil physico chemical properties were analysed and adsorption studies were carried out as explained below.

### Batch Sorption

A batch technique was used to perform Cr adsorption studies. One gram of soil samples was taken in duplicate in 50 mL centrifuge tube, mixed with 20 mL of Cr solutions ( $K_2Cr_2O_7$  for Cr (VI))

at different concentrations (0, 1, 2.5, 3.5, 5, 7.5, 10, 12.5, 15, 20, 25 and 30  $\mu\text{g ml}^{-1}$ ). Sodium nitrate ( $\text{NaNO}_3$ ) at 0.03 M was used as the background electrolyte solution. The Centrifuge tubes were shaken on an end-over-end shaker (Fig. 1) at room temperature ( $22^\circ\text{C}$ ). After 20 hours of shaking, the soil suspensions were centrifuged at 10000 rpm for 10 min, filtered through Whatmann No.40 filter paper and analysed for Cr by Atomic Absorption Spectrophotometer (AAS, Perkin Elmer AAnalyst 400). The amount of Cr adsorbed was estimated from the difference between the amount added and the amount remained in the supernatant solution (Naidu *et al.*, 1994).

## RESULTS AND DISCUSSION

From the results, the highest Cr adsorption in soil was found to be  $161.7 \mu\text{g g}^{-1}$  at  $300 \mu\text{g g}^{-1}$  of Cr (VI) addition. Table 1 shows increase in the adsorption of Cr with increase in concentration of

**Table 1. Chromium fixation levels in soil**

S. No.	Added Cr $\mu\text{g ml}^{-1}$	Quantity fixed in soil $\mu\text{g}$	Quantity Cr in Extract ( $\mu\text{g}$ )
1	0	0	0
2	20	3.04	16.96
3	50	13.46	36.54
4	70	24.78	45.22
5	100	37.98	62.02
6	150	57.14	92.86
7	200	89.06	110.94
8	250	109.68	140.32
9	300	161.74	138.26
10	400	161.64	238.36
11	500	158.56	341.44

Cr in supernatant solution up to  $300 \mu\text{g g}^{-1}$  Cr concentrations, beyond this concentration there was a decreasing trend was observed. Bajpai, *et al.*, 2012 also reported same results that the increase in Cr sorption at acidic pH could be attributed to strong electrostatic attraction between positively charged groups of soil like  $\text{Ca}^{2+}$  and negatively charged  $\text{HCrO}_4^-$  ions. However, the decrease in adsorption due to increase in pH may be the result of decrease of electrostatic attraction, and competitiveness between Cr anionic species ( $\text{CrO}_4^-$ ,  $\text{Cr}_2\text{O}_7^{2-}$ ) and the  $\text{OH}^-$  ions in the bulk solution for sorption on active sites of soil.

Adriano, 2001 and many researchers have been supported the above result when pH increases, negative surface charge of the soils increases, so there was an increased adsorption of Cr (III). Similarly clay and organic matter carry negative functional groups on their surface, thereby increasing the adsorption of Cr (III) in soils. Zachara *et al.*, 1989 also reported that the increase in Cr sorption at acidic pH could be attributed to strong electrostatic attraction between positively charged groups of soil (i.e.  $\text{Ca}^{+2}$  and negatively charged  $\text{HCrO}_4^-$  ions. This study examined the

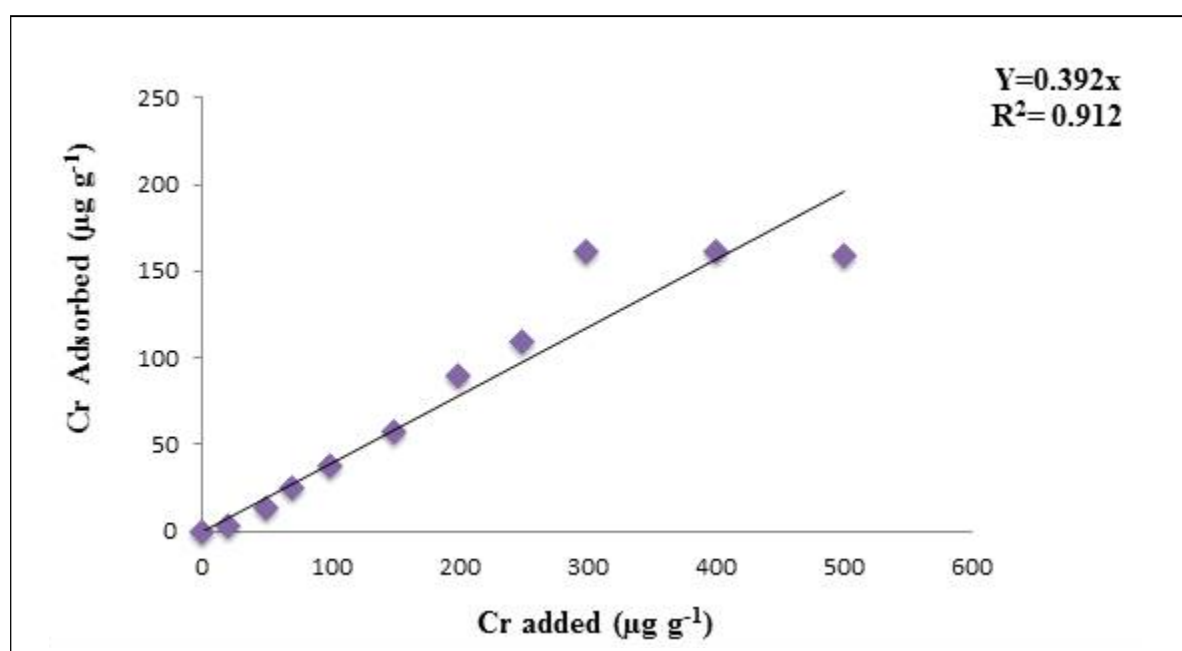


Fig. 2. Relationship between the Cr Adsorbed and Cr added in soil

adsorption capacity of Cr from Cr spiked acid lateritic soil. Further more studies to be carried out for the Cr interaction between plant and soil with respect to bioavailability, plant uptake and other consequences.

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