



P-ISSN: 2349-8528

E-ISSN: 2321-4902

IJCS 2017; 5(3): 501-503

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Received: 15-03-2017

Accepted: 16-04-2017

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Assessment of chromium fixation capacity of sandy loam soil

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Abstract

The adsorption of chromium species in soils has received much attention because of its toxicity and bioavailabilities, which are adsorption depended. There are very little studies on adsorption of chromium in sandy loam soil. Hence, this paper presents the Cr adsorption capacity of sandy loam soil under chromium spiked condition. A batch technique was used to perform cr adsorption studies. Soil samples were taken and mixed with different concentration of Cr solutions and later the amount of Cr adsorbed was estimated. The results revealed that, the highest Cr (VI) adsorption in soil was found to be 166.54 $\mu\text{g g}^{-1}$ of soil at 300 $\mu\text{g g}^{-1}$ of soil contamination. Adsorption of chromium increased with increasing concentration of Cr in supernatant solution upto 300 $\mu\text{g g}^{-1}$. When pH increases, negative surface charge of the soils increases, so there was an increased adsorption of Cr (III) being positively charged. Similarly, clay and organic matter carry negative functional groups on their surface facilitate the increased adsorption of Cr (III) in soils.

Keywords: Cr (VI), Cr adsorption, sandy loam soil.

Introduction

Heavy metal contamination is one of the major ecological problems worldwide, leading to losses in crop yield. It also affects human health when contaminants enter the food chain. Chromium (Cr) is the 17th most abundant element on earth and the second largest contributor of ground water, soil and sediment contamination (Avudainayagam *et al.*, 2003) [3]. Naturally occurring chromium in soil ranges from 10 to 50 mg kg⁻¹. Heavy metals are main contaminants polluting the environment and are caused by a number of human activities, such as mining, smelting, electroplating, use of pesticides, sludge dumping and use of phosphate fertilizers as well as biosolids in agriculture (Ali *et al.*, 2013) [1]. 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) [5]. Annually about 3 $\times 10^4$, 1.42 $\times 10^5$ and 8.96 $\times 10^5$ tonnes of Cr is released to the atmosphere, water and soil, respectively (Shen, 2002) [10]. Chromium has two stable forms, *i.e.* trivalent Cr (III) and hexavalent Cr (VI) and the later one being more toxic. These two forms are interconvertible in soil due to various microbial activities. The maximum threshold level of Cr (VI) in drinking water is 0.05 mg L⁻¹ (WHO, 1996) [12]. Contamination of agricultural fields with Cr is very toxic to both human beings, plants and has been a major environmental concern over the last few decades (Tiwari *et al.*, 2013) [11].

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. 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. Chromium (Cr) (VI) compounds are strong oxidants and can be quite readily reduced to Cr (III) forms in the presence of electron donors like organic matter and inorganic. Various physical, chemical and biological methods are used for remediation. Chemical process includes chemical like gaseous sulphur-dioxide, sodium sulfite, sodium meta-bisulphite, ferrous sulphate, barium sulphite, lime and limestone for reduction of Cr (VI) to Cr (III) (Jacobs *et al.*, 2001) [6]. The physical method involves

treatment of contaminated system using physicochemical properties of the substances used for remediation. This involves techniques like adsorption, capping, electro kinetic method, membrane filtration, granular activated carbon, photo-catalysis and soil washing for remediation (Rana *et al.*, 2004 [9]; Wang *et al.*, 2008) [13].

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 of soil properties with Cr (III) and Cr (VI) (Avudainayagam *et al.*, 2001[2]; Bolan and Thiagarajan, 2001) [4]. Hence, with these ideas in view, this research was initiated to quantify the relative adsorption of Cr (VI) in sandy loam soil of Erode district of Tamil Nadu, India.

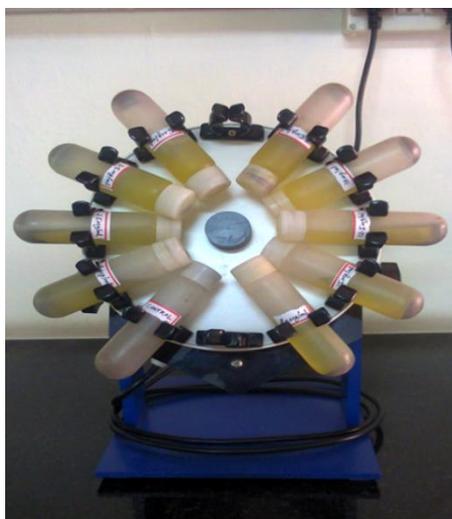


Fig 1: Overview of batch experiment

Materials and Methods

Bulk soil sample representing the acid lateritic soil, was collected from the cultivated field located at Gangapuram village, Erode District of Tamilnadu, India. The initial soil physio- chemical properties were analyzed 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 sample 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, 20, 50, 100, 150, 200, 250, 300, 400 and 500 $\mu g\ ml^{-1}$). Sodium nitrate ($NaNO_3$) 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 ($22^\circ C$). After 20 hours of shaking, the soil suspensions were centrifuged at 10000 rpm for 10 mins, filtered through Whatmann No.40 filter paper and analyzed for Cr by Atomic Absorption Spectrophotometer (AAS, Perkin Elmer A Analyst 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) [8].

Results and Discussion

From the results, the highest Cr adsorption in soil was found to be $166.54\mu g\ g^{-1}$ at $300\mu g\ g^{-1}$ of Cr (VI) addition, (Table 1). There was an increase in the adsorption of Cr with increase in concentration of Cr in supernatant solution up to $300\mu g\ g^{-1}$ Cr concentrations, beyond this concentration a decreasing trend was observed. The sorption data for Cr were fitted in linear equation. A relatively higher correlation coefficient ($R^2 = 0.89$) indicated that the Cr sorption was adequately described by the linear equation.

When pH increases, negative surface charge of the soils increases, so there was an increased adsorption of Cr (III) being positively charged. Similarly, clay and organic matter carry negative functional groups on their surface facilitate the increased adsorption of Cr (III) in soils. Though in this study, Cr was added as Cr (VI) (i.e. $K_2Cr_2O_7$), yet it might have been reduced to Cr (III) with the presence of organic matter (James and Bartlett, 1983) [7] in the soil and later on fixed in the soil and thereby indicated a decreased quantity in the soil solution compared to original quantity added. This study examined the adsorption capacity of Cr from Cr spiked sandy loam soil. Furthermore studies have to be carried out for the Cr interaction between plant and soil with respect to bioavailability, plant uptake and other consequences.

Table 1: Chromium fixation levels in soil

S.No.	Added Cr $\mu g\ ml^{-1}$	Quantity fixed in soil μg	Quantity Cr in Extract (μg)
1	0	0	0
2	20	3.62	16.38
3	50	12.10	37.90
4	100	22.74	77.26
5	150	35.74	114.26
6	200	74.68	125.32
7	250	104.92	142.08
8	300	166.54	133.46
9	400	166.18	233.82
10	500	160.42	339.58

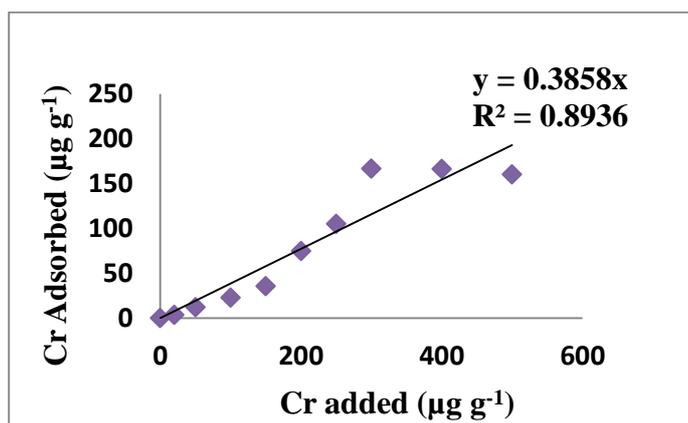


Fig 2: Relationship between the Cr adsorbed and Cr added in soil

Acknowledgment

Authors are grateful to Professor and Head and Scientists of Department of Environmental sciences, Tamilnadu Agricultural University, Coimbatore, India. for providing necessary facilities during the course of investigation.

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