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# FATE OF CHROMIUM IN THE ENVIRONMENT

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## INTRODUCTION

Chromium is an inorganic transition metal pollutant with a complex electronic and valence shell chemistry with valence states ranging from -2 to +6. From this, the most environmentally significant forms of Cr are trivalent (Cr (III)) and hexavalent (Cr(VI)). These two oxidation states differ in their mobility and toxicity. Chromium (VI) is mobile and regarded as carcinogen whereas Cr(III) is relatively immobile and less toxic. Cr (III) has a significant role in lipid and sugar metabolism and regarded as essential trace element for human and animal health and not for the plants. Though Cr (III) has its own beneficial role, its uptake in supererogatory amounts causes health effects as well as skin rashes. Since Cr (III) is less toxic and immobile, the environmental conditions and complex of physical, chemical and biological factors have the capability to convert it into Cr (VI). However, there is a statement that, in drinking water all Cr is converted to Cr (VI) by strong oxidants such as chlorine, ozone and permanganate which are utilized for attaining taste, odour removal and disinfection. Owing to Cr (VI) mobility, it readily leaches down the soil thereby contaminating the groundwater sources.

## CHEMISTRY OF CHROMIUM

Chromium occupies seventh position regarding their abundance in earth crust and sixth in case of transition metal. In serpentine and ultramafic rocks, it is present naturally as chromite or it may form complexes with other elements as in cases like bentorite ($Ca_6(Cr,Al)_2(SO_4)_3$), crocoites ($PbCrO_4$), tarapacaite ($K_2CrO_4$), and vauquelinite ($CuPb_2CrO_4PO_4OH$). This naturally occurring component has a complex electronic and valence shell chemistry with valence states varies from -2 to +6. From this, the most environmentally significant forms of Cr are trivalent (Cr (III)) and hexavalent (Cr(VI)). These two oxidation states differ in their mobility and toxicity. Chromium (VI) is mobile and regarded as a carcinogen whereas Cr(III) is relatively immobile and less toxic. Detailed information on oxidation state and environmental behavior of Cr is given in Table 1. Chromium with oxidation state 0 (metallic Cr) is found in alloys such as stainless steel and chrome plated objects. Cr(III) is regarded as an indispensable/ vital element for human beings which plays a significant role in lipid and sugar metabolism. In addition, it is used to reduce blood glucose (diabetes control) and low density proteins (LDP). Though Cr(III) has its own beneficial role, its uptake in supererogatory amounts causes health effects as well as skin rashes. Presence of Cr(III) is reported in paints, dyes, chrome plating and tanning. On other hand, Cr(VI) is regarded as a strong oxidizing agent which on inhalation leads to perforation of nasal septum, asthma, bronchitis, larynx and liver inflammation, pneumonitis and bronchogenic carcinoma. Cr(VI) compounds on skin contact induce dermatitis. Wastewater from metallurgy industry, hard plating, refractory industry and pigments production shows the dominance of

Cr(VI). Cr(III) and Cr(VI) on reaction with oxidizing or reducing agents produce unstable intermediates of Cr(IV) and Cr(V).

**Table 1. Valency and environmental behaviour of Cr**

| Oxidation state | Environmental behaviour | Comments |
|---|---|---|
| 0 | Unstable | Does not occur naturally |
| +1 | Unstable | - |
| +2 | Can be oxidized to $Cr^{3+}$& if the oxidizing agent is not available, it will be stable | Anaerobic condition is suitable for its Activity |
| +3 | Highly stable | Occurs in nature in ores such as ferrochromite, forms stable compounds & high amount of energy is required for Converting it to other oxidation state |
| +4 | Unstable | Not occur naturally, short half life & intermediate phase |
| +5 | Unstable | Not occur naturally, long half life & intermediate phase |
| +6 | Stable (unstable in the presence of electron donor) | Rarely occurs in nature (crocoite) but produced from anthropogenic sources & strong oxidizing |

## BEHAVIOUR OF CHROMIUM IN SOILS

On an average, 0.02 to 58 µmol g-1 of Cr is reported in soils. The threshold levels of Cr in soils given in some developed countries are described in Table 2. Insoluble Cr(OH)3aq or Cr(III) is the predominant Cr form that is present in the soil . The pH decides the form of Cr i.e. if pH < 4 – Cr (H2O)63+ dominates, pH < 5.5 - hydrolysis product like Cr(OH)2+aq which can easily be adsorbed to clay compounds. In soils having neutral to alkaline reaction, Cr(VI) will be present in soluble form as Na2CrO4 to moderately soluble chromates as CaCrO4, BaCrO4, and PbCrO4. HCrO4- is the dominant form of Cr(VI) in soils of pH < 6.0.

Table 2. Permissible level of Cr (mg kg-1) in soils

| Metals | Country | Permissible limit (mg $kg^{-1}$) |
|---|---|---|
| Total Cr | Australia | 50 |
| Cr(III) | New Zealand | 600 |
| | UK | 600 |
| | Canada | 250 |
| | US | 1500 |
| | Germany | 200 |
| Cr(VI) | New Zealand | 10 |
| | UK | 25 |
| | Canada | 8 |

The transportable forms (CrO42- and HCrO4-) of Cr present in the soils are capable of washing to deeper soil layers causing water pollution. The aforesaid mobile forms can be reduced by reducing compounds like Fe2+ or S2- through dechromification. Dechromification is a vital process and in its absence all atmospheric oxygen threats all life on earth. The donor groups present in the humic acids forms stable complexes with Cr3+ . Cr3+ can be converted to Cr6+ and vice versa under the conditions of oxidation and reduction which depends on factors like pH, concentration of oxygen, the presence of catalyst and ligands (Parameswari, 2009)..

Since Cr(III) salts are utilized in tanning process, the sludge generated from the above process evidenced their presence, which marks a threat to the environment and can't be used safely and efficiently. The next big hurdle is the cost involved in their disposal. Illegal dumping of waste water and sludge from tanneries has led to serious environmental pollution. Among the Indian tanneries, over 60 percent were located in Dindigul, Erode and Vellore districts of Tamil Nadu, where Cr contamination is reported. The analytical results of soil and water samples collected around tanning industries of Vellore district revealed that they are contaminated to the core by Cr, which exceeds the permissible limits given by different countries. Indiscriminate disposal methods contaminate our environment and can easily enter into our food chain.

## EFFECT OF EFFLUENT DISCHARGE INTO THE SOIL

The addition of tannery effluent is reported to have an undesirable effect on soil properties. The total porosity and hydraulic conductivity of the soil decreased as a result of addition of tannery effluent, while the bulk density of soil was increased. This may be attributed to the twin effect of direct accumulation of large quantities of organic and inorganic materials as well as the interaction of Na with exchangeable complex resulting in deflocculation. It is estimated that tanning industry wastes have already degraded over 50,000 ha of Productive agricultural lands in Vellore, Erode and Dindigul districts of Tamil Nadu. As a result, there was a reduction in total cropped area to the extent of 10.5 and 41% in Vellore and Dindigul districts respectively in 20 years. A six-fold increase in the sodium content and EC increase from 0.64 to 2.29 dS m-1 in the soils that are contaminated with tannery effluent was noticed (Sebastian et al., 2009).

## REMEDIATION OF CR CONTAMINATED SOIL

Various conventional methods for remediating chromium, its advantages and disadvantages are given in Table 3.

**Table 3. Management techniques for remediation Cr contaminated soil**

| S.No | Technology | Advantage | Disadvantage |
|---|---|---|---|
| **Cr(VI) removal** | | | |
| 1 | Excavation & Off-site disposal | Applicable for compact soil volumes, timely implementation& complete removal is possible | Through this technique, some Cr(VI) become airborne which causes health hazard, may invoke land disposal restrictions, expensive |
| 2 | Soil washing | Reduction in contaminated soil volumes that needs treatment | Cr from soil can be leached to $H_2O$ & pollute water sources, this method is not suitable when Cr is strongly bound. |
| 3 | Soil Flushing | Insitu method, doesnot require excavation | |
| **Cr(VI) immobilization** | | | |
| 4 | Solidification/ Stabilization exsitu | Inexpensive | Cr(VI) need to be reduced to Cr(III), may become air borne when excavated and causes health hazard, Generates huge volume of solidified mass that requires disposal. |

| | | | |
|---|---|---|---|
| 5 | Solidification/ Stabilization insitu | Excavation is not required, applicable for sites with high water table | Needs reduction of Cr(VI) to Cr(III), inappropriate where there is a need of reducing total Cr levels. |
| 6 | Vitrification | In situ reduction and immobilization of Cr(VI) | High energy requirements and additives, may require soil dewatering |
| Cr(VI) reduction to Cr(III) | | | |
| 7 | Chemical method | Insitu method | Needs reducing agents, inappropriate where there is a need of reducing total Cr levels. |
| 8 | Biological method | In situ method, applicable to the areas with high water table where leaching of Cr(VI) from soil is possible | Slow technique, inappropriate where there is a need of reducing total Cr levels, needs controlled pH, $O_2$ and nutrient levels. |

(Avudainayagam et al.,2003)

## CONCLUSION

Considering the Cr toxicity, it is necessary for regulating it and protecting the health of human and environment. Hence, application of organic amendments viz., Farm Yard Manure, compost, vermicompost, biochar etc may reduce the detrimental effect of chromium in soil and improve crop productivity.

## REFERENCES

Avudainayagam, S., Megharaj, M., Owens, G., Kookana, R. S., Chittleborough, D., & Naidu, R. (2003). Chemistry of chromium in soils with emphasis on tannery waste sites Reviews of Environmental Contamination and Toxicology (pp. 53-91): Springer.

Parameswari, E. (2009). Impact of agricultural drainage water on crops under sequential biological concentration system and use of nanoparticles for wastewater treatment. Tamil Nadu Agricultural University, Coimbatore, India.

Sebastian, S. P., Udayasoorian, C., Jayabalakrishnan, R. M., & Paramesewari, E. (2009). Improving soil microbial biomass and enzyme activities by amendments under poor quality irrigation water. World Applied Sciences Journal, 7(7), 885-890.

USEPA. (1993). Standards for the use or disposal of sewage sludge. Fed Reg ., 58:210–238.