

Chromium as a Pollutant and its Management- A Review

¹Aysh Raj, ²Pankaj Kumar, ³Shivam Rajesh Mishra

¹³UG Student, ²Assistant Professor

¹²³Department of Civil Engineering

¹²³Subharti Institute of Technology & Engineering, Swami Vivekanand Subharti University, Meerut, Uttar Pradesh-250005 (India)

Abstract: The use of chromium (Cr) in several anthropogenic activities has been increased in the past decades and consequent contamination of soil and water have become a concern problem. Chromium (Cr) exists in several oxidation states, but the most stable and common forms are Cr (0), Cr (III) and Cr (VI) species. It is very considerable pollutants which are non-biodegradable and bioaccumulation in nature. Hence the persistent nature of Chromium (VI) makes it accumulate in the food chain which with time reaches harmful levels in living beings resulting in serious health hazards such as irritation in lungs and stomach, cancer of the digestive tract, low growth rates in plants and death of animals. Chromium (Cr) toxicity in plants depends on its valence state. Cr (VI) as being highly mobile is toxic, while Cr (III) as less mobile is less toxic. The main intention of this review to provide a whole sale information about chromium pollution level and its management.

Keywords- chromium, pollution, air, water, soil, remediation.

I. INTRODUCTION

Heavy metals are very hazardous to the human as well as environment at minor concentration. Some of important heavy metals are given in Table 1 with associate disease. One of them is Chromium which is the 17th most abundant element in the earth's mantle. Chromium is used on a large scale in many industries including metallurgy, electroplating, production of paints and pigments, tanning, wood preservation, chemical production and pulp and paper production. Now days chromium is polluting water soil and air by several anthropogenic activities (Bhalerao, Sharma et al. 2015). Main sources of chromium which contaminate the environment are two types. First one is the natural like minerals in the Earth's crust and Ferro-chromite ($\text{Fe}_2\text{Cr}_2\text{O}_4$) another second one is associated with industrial application of chromium, mainly in metallurgy, tanning and textile pigment production. The persistent nature of Chromium (VI) makes it accumulate in the food chain which with time reach harmful levels in living beings resulting in serious health hazards such as irritation in lungs and stomach, cancer in digestive tract, low growth rates in plants and death of animals (Oliveira, 2012). Chromium (VI) is 500 times more toxic than chromium (III) (Sen and Dastidar 2010). According to the Occupational Safety and Health Administration (OSHA), The oral lethal dose of chromium (VI) is 71mg/kg (Vinodhini and Das 2009). Chromium (III) is an essential element in a human diet. The Institute of Medicine of the National Academy of Sciences determined an adequate intake of chromium (III) of 20–45 $\mu\text{g}/\text{day}$ for adolescents and adults. It is found to be crucial in sugar metabolism as a component of glucose tolerance factor (GTF) (Meena and Rajagopal 2003). There are many convention method available for removing heavy metal but they have some its own their limitations (Augustynowicz, Grosicki et al. 2010). Microbial Bioremediation of Chromium has been done by several researchers but these method is not widely use because some factors affect the biological remediation (Zayed and Terry 2003, Khan, Ahmad et al. 2013, Jobby, Jha et al. 2018). The concentration of Cr in industrial waste water varies in the ranges from 0.5 to 270 mg/L.

Table 1: Diseases Associated With Heavy Metal after Maximum Contaminant Level (MCL) (Tripathi and Ranjan 2015)

Heavy metal	Toxicity	MCL (mg/L)	Anthropogenic sources
Zinc (Zn)	Vomiting, Depression, lethargy, neurological signs and increased thirst	0.80	mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes (Loska and Wiechula 2003)
Copper	Liver damage, Wilson disease, Insomnia	0.25	Pesticides, fertilizers(Khan, Ahmad et al. 2007, Malik 2007)
Nickel (Ni)	Dermatitis, nausea, chronic coughing, human carcinogen	0.20	Industrial effluents, kitchen appliances, surgical instruments, steel alloys, automobile batteries(Gopal Rathor 2014, Poonkothai and Vijayavathi 2015)
Arsenic (As)	Skin manifestations, visceral disease	0.05	Pesticides and wood preservatives(Thangavel and Subbhuraam 2004, Hering, Katsoyiannis et al. 2017)
Chromium	A headache, diarrhea, vomiting, carcinogenic	0.05	Tanneries, steel industries, fly ash(Zayed and Terry 2003, Khan, Ahmad et al. 2007)
Cadmium (Cd)	Kidney damage, renal disorder, human carcinogen	0.01	Paints and pigments, plastic stabilizers, electroplating, incineration of cadmium-containing plastics, phosphate fertilizers(Pulford and Watson 2003)
Lead (Pb)	Damage the fetal brain, kidney, circulatory system and nervous system	0.006	Aerial emission from combustion of leaded petrol, battery manufacture, herbicides and insecticides(Thangavel and Subbhuraam 2004)
Mercury (Hg)	Rheumatoid arthritis and disease of kidneys, circulatory and nervous system	0.00003	volcanoes, forest fires and fossil fuels such as coal and petroleum, hydroelectric.(Chigbo, Smith et al. 1982)

1.1 Application of Chromium

The Chromium as wide range of application at macro as well as micro industry level. The following are the application areas of chromium:

1. In metal ceramics(Jing, Xue et al. 2010)
2. In chrome plating(Zhang, Lang et al. 2010)
3. As dyes and paints(Kocaokutgen and Özkinali 2004, Liang, Zhong et al. 2012)
4. In alloys, e.g., stainless steel(Sohgawa, Hirashima et al. 2012)
5. To manufacture molds for the firing of bricks
6. As a catalyst in dyeing and tanning of leather
7. In metallurgy to provide corrosion resistance and a shiny finish

II. CHROMIUM AS POLLUTANT

2.1 Chromium in Water

Chromium may enter the natural waters by weathering of chromium containing rocks, direct discharge from industrial operations, leaching of soils, among others. In the aquatic environment chromium may suffer reduction, oxidation, sorption, desorption, dissolution, and precipitation. The aqueous solubility of Cr (III) is a function of the pH of the water. Under neutral to basic pH, Cr (III) will precipitate and conversely under acidic pH it will tend to solubilize. The forms of Cr (VI) chromate and dichromate are extremely soluble under all pH conditions, but they can precipitate with divalent cations. The recommended limits for Cr concentration in water are $8 \mu\text{g L}^{-1}$ for Cr (III) and $1 \mu\text{g L}^{-1}$ for Cr (VI).

1.2 Chromium in Soil

The concentration of Cr in the soils may vary considerably according to the natural composition of rocks and sediments that compose them. The levels of chromium in the soil may increase mainly through anthropogenic deposition, as for example atmospheric deposition, also dumping of chromium-bearing liquids and solid wastes as chromium byproducts, ferrochromium slag, or chromium plating baths. Generally, Cr in soil represents a combination of both Cr (III) and (VI). As in aquatic environment, once in the soil or sediment, Cr undergoes a variety of transformations, such as oxidation, reduction, sorption, precipitation, and dissolution. The oxidants present in the soil (e.g., dissolved oxygen and MnO_2) can oxidize Cr (III) to Cr (VI); however, it seems that oxidation of Cr (III) by dissolved O_2 is residual when compared with MnO_2 . The forms of Cr (VI) are on the other hand reduced by iron, vanadium, sulphides, and organic materials. However, when the reducing capacity of the soil is overcome, Cr (VI) may persist in the soil or sediment for years, especially if the soils are sandy or present low levels of organic matter.

III. SOLUTION OF POLLUTION OF CHROMIUM

Various methodologies are used for the removal of Chromium which are given below with advantage and disadvantage. These Methodologies are enlist:

1. Electrodialysis
2. Phytoremediation
3. Reverse osmosis
4. Ion exchange
5. Oxidation-reduction
6. Chemical precipitation
7. Membrane filtration
8. Photo-catalysis
9. Adsorption

1.1 Electrodialysis

Electrodialysis is accomplished by placing cation and anion selective membranes alternatively across the path of an electric current (Amor, Bariou et al. 2001). When current is applied, the electrically attracted cations pass through the cation-exchanging membranes in one direction and the anions pass through the anion-exchange membranes in the other direction. The result is that salinity decreases between one pair of membranes and increases between the next pair. Water can then pass through several such membranes until the required salinity is removed. Many research work have reported removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electro coagulation.

1.2 Phytoremediation

Phytoremediation ('phyto' means plant) is a generic term for the group of technologies that use plants for remediating soils, sludges, sediments and water contaminated with organic and inorganic contaminants. Phytoremediation can be defined as "the efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical or physical activities and processes of the plants". Plants are unique organisms equipped with remarkable metabolic and absorption capabilities, as well as transport systems that can take up nutrients or contaminants selectively from the growth matrix, soil or water. Phytoremediation involves growing plants in a contaminated matrix, for a required growth period, to remove contaminants from the matrix, or facilitate immobilization (binding/containment) or degradation (detoxification) of the pollutants. The plants can be subsequently harvested, processed and disposed.

1.3 Reverse osmosis

Reverse osmosis is pressure driven membrane process in which a feed stream under pressure is separated into a purified stream and a concentrated stream by selective permeation of water through a semi-permeable membrane. Reverse osmosis enjoys wide spread popularity in the treatment of numerous diverse wastewaters. Kang reported arsenic removal from aqueous solution by reverse osmosis (Kang, Kawasaki et al. 2000). In plating chemical recovery application reverse osmosis units separate the valuable metal salts from rinse solutions, yielding a concentrated metal solution, which can be recycled to the plating bath. Reverse osmosis has also been successfully demonstrated for the removal of Cr, Pb, Fe, Ni, Cu and Zn from vehicle wash-rack water. This process is very costly and requires regular maintenance. (Rad, Mirbagheri et al. 2009)

1.4 Ion exchange

Ion exchange (IX) processes are reversible chemical reactions for removing dissolved ions from solution and replacing them with other similarly charged ions. In water treatment, it is primarily used for softening where calcium and magnesium ions are removed from water; however, it is being used more frequently for the removal of other dissolved ionic species.

1.5 Oxidation-reduction

Certain ions such as arsenite, chromate and dichromate have least tendency for precipitation and cannot be removed efficiently by any other removal technology. On the other hand, adsorption is a feasible process but there isn't many adsorbent available for removal of arsenite and dichromate ions since arsenite and dichromate are very selective towards bio-adsorption. To overcome these difficulties, researchers are working on chemical reduction methods. In recent years chemical methods of arsenite and chromate reduction using zero-valent metal like iron

1.6 Chemical precipitation

Chemical precipitation of heavy metals and metalloids as their hydroxides using lime or sodium hydroxide is widely used in this process. Lime is generally used for precipitation purpose due to its low cost and easy control pH in the range of 8-10. The efficiency of the process depends on a number of factors, which include the ease of hydrolysis of metal and metalloids ions, nature of the oxidation state, pH, and presence of complex forming ions, standing time and filtering characteristics of the precipitate. This method has been used for the removal of metals and metalloids such as iron, copper, chromium, arsenic, cadmium and zinc from the effluents of the industries

1.7 Adsorption

Adsorption is a physical or chemical process of accumulation of atom and molecules or ion of gas, liquid or dissolved solid to form a thin film on the surface of the solid or sometime liquid. In the adsorption, one substance (Adsorbate) is accumulated on the surface (phase) of another substance (Adsorbent). Adsorption terminology is very confusable so first all we should understand

about adsorbate, adsorbent and surface. Adsorbate is substance which is going to remove from the aqueous solution with help of the forces of attraction which is generated by another substance i.e. adsorbent. Adsorbent is the substance on which surface another substance is accumulated by the attraction forces. This attraction forces mainly come in the category of the electrostatic forces. Surfaces- it is the layer between two phases. Absorption is process by which atoms, molecules or ions enter a bulk phase of liquid, gas or solid. Example-when tissue paper will be dipped in water then absorption will be occurred. Adsorption is process by which atom, molecule or ion accumulates a bulk phase of liquid gas or solid. Example-when plane paper will be dipped in water then adsorption will be occurred

IV. CONCLUSION

As the day by day anthropogenic activity is increasing as result of modern urbanization and hence the environment as well as human being affect by these activities and its products unintentionally. One of the major problems are arising due to contamination of environment in various way by chromium from last few decades. The problem is becoming a serious issue day by a because of the lack of knowledge of its contamination level and its management. The main aim of the paper to provide a brief knowledge of the chromium as pollutant and its management.

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