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EDITORIAL

Special Issue: Hexavalent Chromium: Sources, Toxicity, and Remediation

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Hexavalent chromium comes into the environment from natural sources and due to anthropogenic activity [1]. Mixed oxide chromite, a normal spinel is the main source of chromium in ultramafic and serpentinite rocks. In 2007, Fendorf et al. experimentally verified the genesis of hexavalent chromium from natural sources in soil and ground water [2]. Ground and surface water hexavalent chromium contamination coming from natural sources has been reported from many parts of the globe [3].

Chromium is used extensively in various small- and large-scale industries [1]. Chromium and its compounds are extensively used in industry, with the most common and important sources coming from the electroplating, catalyst sector, tanning, water cooling, pulp production, dyes and pigments, film and photography, wood preservation, and alloy manufacture industries. Petroleum refining processes and chromite ore processing have introduced chromium into the soil, air, and water. Chrome plating baths are of two types: hexavalent and trivalent baths. Hexavalent chromium baths are of frequent use. Typical hexavalent chromium bath composition is as follows: (a) electrolytic solution: chromic acid, (b) anode: lead with tin up to 7%; (c) operating temperature: 45–60 °C, (d) plating current: 1.5–3.0 kA/m^2. About 35% of used chromium is discharged in the effluent as trivalent and hexavalent chromium. Chromates of barium, lead, and zinc provides the pigments of lemon chromium, chromium yellow, chromium red, chromium orange, zinc yellow, and zinc green glass. Chromium compounds have been used in the formulation of wood preservatives for more than a century. These are ‘‘Wolman compounds’’ (based on sodium fluoride and nitrophenol with sodium dichromate or potassium dichromate), copper chromate (CC), copper–chromium–arsenic (CCA), copper–chromium–boron (CCB), copper–chromium–fluoride (CCF), and copper–chromium–phosphate (CCP). A considerable quantity of tanning powder basic chrome sulfate is used in chrome tanning to convert polypeptide collagen strands in the hide to a cross-linked helix (for more details, see Saha et al. [4]).

Indications of chromium toxicity in plants include reduction of seed germination, retardation of growth, reduction of yield, inhibition of enzymatic activities, weakening of photosynthesis, nutrient, oxidative disparities, and genetic mutation. Breathing hexavalent chromium- containing material can cause perforation of the nasal septum, asthma, bronchitis, pneumonitis, inflammation of the larynx and liver, and increased incidence of bronchogenic carcinoma [4]. Skin contact with hexavalent chromium compounds can produce skin allergies, dermatitis, dermal necrosis, and dermal corrosion. Stomach cancer is the result of the ingestion of hexavalent chromium. The hexavalent form of chromium is more toxic than the trivalent form. This is due to the following reasons:

(a) the structural similarity of chromate with sulphate; hexavalent chromium passes the cell membrane via the sulphate uptake pathway, but trivalent chromium does not, (b) hexavalent chromium ($t_{2g}^0\ e_g^0$) is a labile centre, but trivalent chromium ($t_{2g}^3\ e_g^0$) is an inert centre, and (c) hexavalent chromium is a strong oxidizing agent, and (d) trivalent chromium undergoes precipitation under biological conditions.

The interest in chromium removal processes has increased rapidly over the last 15 years. Several methods are utilized to remove chromium from the contaminated sites [4–6]. These include adsorption and reduction, chemical precipitation, ion exchange, reduction, electrochemical, precipitation, solvent extraction, membrane separation, bioremediation, and by biomimetic recognition using ion imprinted polymers to name but these routes [7].

In this mini-issue there are eight articles. Dhak et al. have reviewed various leaching mechanism of Cr(VI) using the

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dual-domain system model and photocatalytic remediation of Cr(VI) using MOFs with detailed discussion on pH and kinetic studies using the Langmuir–Hinshelwood kinetics model.

Pakade et al. have reported the removal of hexavalent chromium with help of iron-zinc impregnated biochar composite material. The composite was derived by the pyrolysis of bleached *Macadamia* nutshell biomass impregnated with 1-[(cyclohexylamino)methyl]-2-naphtholate–zinc(II) complex and iron(II) chloride at 800 °C. The composite exhibited porous structure, and the presence of zerovalent iron and zinc ferrite. The maximum chromium removal was found to be 89.7% at pH 3.0, indicating great potential of the biochar–zerovalent iron–zinc ferrite composite in the removal of Cr(VI) from aqueous solutions. Thermodynamics and kinetics have also been conducted to understand the removal mechanisms

Fall et al. prepared a magnetic rGO@CNT@Fe_2O_3 nanocomposite by hydrothermal treatement for removing Cr(VI). Adsorption reached 91.7 mg/g, at 25 °C, after 240 min contact time, and was interpreted in terms of synergy between electrostatic interactions and reductive ion exchange.

Biswal et al. prepared an activated carbon from the very abundant morning glory flowers (*Ipomoea carnea*) for the adsorption of Cr(VI) from chrome plating industrial wastewater, containing 100–300 mg/L chromium. Optimal conditions permitted removal of the quasi totality of Cr(VI), at pH 3.5.

Kassimu et al. propose a green reductive approach to transform Cr(VI) into Cr(III) in simulated hexavalent chromium contaminated water, using anthocyanin-rich extract of watermelon rind.

Ndiaye et al. have reported the chromium(VI) content in five species of fish from Soumbédioune Beach (Dakar/Senegal). They have evaluated the Cr(VI) contents in five species of fish caught in this area by UV–visible spectrophotometry. The results obtained show that the average concentrations for the first campaign vary from ~11.1 µg/g with *Pagellus bellottii* (P.b) to ~40.6 µg/g with *Lagocephalus laevigatus* (L.l). However, the values found are much higher than the standard established by the EEC/R No.466/2001 for Cr(VI) which was 5.5 µg/g.

Kwikima et al. have reported hexavalent chromium mobility and distribution behavior in riparian agricultural tropical soils. According to the findings, the increase in Cr(VI) concentration is proportional to the solute's adsorption in the soil. Furthermore, the time it took for the effluent-influent solute concentration equilibrium to be reached was proportional to the rise in influent Cr(VI) concentration. Given that reduction is the dominant process, vertical mobility, transportation, and dispersion of Cr(Vl) in soils may be argued to have a minimal environmental impact. However, due to the apparent soil's high adsorption capacity for Cr(VI) and hence its bioavailability, the metal may contaminate crops planted in the vicinity. Increases in variables that influence the oxidation of Cr(III) to harmful Cr(VI) in the soil, such as pH, may have a significant deleterious effect.

Traoré et al. address the issue of soil pollution by Cr(VI) near artisanal gold mining areas in Côte d'Ivoire. The study reports total concentrations of chromium exceeded the Upper Continental Crusts value of 35 mg/kg. This study warns that children may be exposed to deleterious effects through the soils of miners' stations.

From the above, the SI Editors hope that Chemistry Africa readers will find useful, timely information in this mini issue as it reviews the mechanisms and recent strategies for the removal of hexavalent chromium, and alerts on the health risks caused in aquatic and terrestrial environments.

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