Background Technical Information for

Hexavalent Chromium (Cr-6)

Background

CASRN: 18540-29-9

Synonyms: Hexavalent chromium, chromium (VI), Cr (VI), Cr^{6+}

Chromium is an odorless and tasteless metallic element (heavy metal) found naturally in rocks, plants, soil, volcanic dust, humans, and animals (Cal/EPA 2011, EPA 2013a). The most common forms of chromium in natural waters are trivalent chromium (chromium-3) and hexavalent chromium (chromium-6) (EPA 2013a). The hexavalent form is relatively toxic, while the trivalent form has very low toxicity and is a required nutrient; the two forms can be inter-converted in the environment (Cal/EPA 2011). There are currently no federal drinking water criteria for chromium-6 specifically, but total chromium, including chromium-6 and chromium-3, is regulated in drinking water. Current guidelines issued by the EPA state that chromium-6 carcinogenicity is classified as Group A (known carcinogen) by the inhalation route of exposure and as Group D (cannot be determined) for the oral route of exposure (EPA 1987).

Key Issues

Concerns have been expressed about the potential carcinogencity of chromium-6 and about known exposure to this chemical as a contaminant in drinking water. There currently is no federal drinking water standard for chromium-6 specifically, but rather for total chromium. Enough uncertainties surrounded the potential health effects of chromium-6 that they are currently under review at the federal level and in California to determine whether updated standards are necessary based on newer information specifically for chromium-6.

Occurrence

Chromium-6 is the second most stable oxidation state of chromium. It rarely occurs naturally; most hexavalent chromium compounds are manufactured or are manufacturing by-products. Chromium-6 compounds are used widely in applications including pigment for textile dyes, paints, inks, and plastics; corrosion inhibitors; wood preservatives; metal finishing and chrome plating, and leather tanning. Chromium-6 may occur as an impurity in Portland cement and can be generated (converted to hexavalent state) and released during casting, welding and cutting operations (e.g., for stainless steel) (IARC 2012).

Physico-chemical properties of various chromium-6 compounds have been reviewed elsewhere (IARC 1990). They vary greatly in their water solubility, ranging from insoluble to highly soluble (IARC 2012).

Chromium-6 can be reduced to the more stable chromium-3 in the presence of oxidizable organic matter or reducing agents like iron. (IARC 2012).

The concentration of chromium in uncontaminated waters is extremely low (< 1 μg/L), but anthropogenic activities (see above) and leaching of wastewater (e.g., from landfills) can lead to drinking water contamination (IARC 2012). Sedman et al. (2006) reported that 38% of municipal drinking water sources in California had chromium-6 concentrations greater than 1 μg/L (detection limit). The World Health Organization reported that total chromium concentrations in drinking water are usually less than 2 μg/L, but levels as high as 120 μg/L have been measured (WHO 2011).

Populations residing near anthropogenic sources of chromium-6 may be exposed via inhalation of contaminated ambient air or ingestion of contaminated drinking water (IARC 2012).

According to the American Water Works Association (AWWA 2013), USEPA Unregulated Contaminant Monitoring Rule (UCMR3), which required water systems serving greater than 10,000 persons and a subset of smaller systems to monitor for hexavalent chromium and total chromium, is ongoing (through 2015). UCMR3 is expected to provide a more complete understanding of chromium occurrence nationally. AWWA (2013) also reviewed available occurrence data in greater detail than is presented here.

Health Effects

According to the International Agency for Research on Cancer (IARC 2012), concern has been raised about the potential hazards related to ingestion of drinking water contaminated with chromium-6. However, there is little evidence of an association between exposure to chromium-6 and stomach cancer or any other cancer in humans. There is only one study (and subsequent re-analysis) that seems to indicate a somewhat elevated risk of stomach cancer in a population in China chronically exposed to drinking water heavily contaminated with chromium-6 from a ferrochromium plant. IARC concluded that that this one study does not constitute sufficient evidence of an association between oral exposure to chromium-6 and stomach cancer.

The oxidation state of chromium appears to be the most important factor in its bioactivity. Chromium-6, but not chromium-3, compounds exert genotoxicity both in vivo and in vitro. Chromium-6 does not react with DNA under physiological conditions. The reduction of chromium-6 to chromium-3 may exert oxidative stress on cells. IARC concluded that there is sufficient evidence in experimental animals for the carcinogenicity of chromium-6 compounds and that chromium-6 compounds are carcinogenic to humans. (IARC 2012)

Current guidelines issued by the EPA state that chromium-6 carcinogenicity is classified as Group A (known carcinogen) by the inhalation route of exposure and as Group D (cannot be determined) for the oral route of exposure (EPA 1987). The health effects of chromium-6 are currently under review by the EPA to aid in determining whether a new drinking water standard is needed for hexavalent chromium.

Guidelines

The EPA has an enforceable drinking water standard (maximum contaminant level, or MCL) of 0.1 mg/L (100 ppb) for total chromium, which includes chromium-6 and chromium-3). According to the EPA (2013a), the current standard, established in 1991, "was based on the best available science at the time which indicated that some people who use water containing chromium in excess of the drinking water standard over many years could experience allergic dermatitis (skin reactions). The health effects of chromium-6 are currently under review to determine whether this standard should be updated. The EPA also has 1-day and 10-day health advisories of 1 mg/L for total chromium (Cal/EPA 2011).

The State of California has established an MCL of 0.05 mg/L (50 µg/L) for total chromium based on a non-cancer risk estimate and a public health goal (PHG) of 0.02 µg/L for chromium-6 based on risk associated with ingestion of drinking water, with a very small contribution from inhalation of aerosol droplets during showering. The PHG represents a *de minimis* lifetime cancer risk from exposure to chromium-6 in drinking water, based on studies in laboratory animals. The PHG is intended to help guide in the development of an MCL for the State, not as a target level for cleanup (Cal/EPA 2011). The State of California has proposed an MCL for chromium-6 at 0.010 mg/L (10 µg/L) and is now in the process of rulemaking, with an enforceable MCL anticipated in 2014 (CDPH 2014).

The World Health Organization (WHO) has set a provisional guideline at 50 µg/L for total chromium in drinking water (WHO 2011). The guideline is designated as provisional because of uncertainties in the toxicological database (WHO 2011).

Detection Methods in Water and Removal via Water Treatment

Limits of detection in the range of 0.05-0.2 µg/L have been reported for total chromium by atomic absorption spectroscopy (AAS) (WHO 2011). EPA Method 218.7 can be used for determination of hexavalent chromium in drinking water by ion chromatography with post-column derivatization and UV-visible spectroscopic detection (EPA 2011). With that method, laboratories can attain a detection limit as low as 0.005 µg/L and a reporting limit of 0.03 µg/L.

According to the EPA (2013a), some point-of-use treatment devices for use in the home are certified by NSF International and the Water Quality Association to remove chromium-6. They are only certified to remove chromium-6 to current drinking water standards of either 50 or 100 µg/L. The Food and Drug Administration (FDA) has adopted EPA's total chromium standard of 100 µg/L for bottled water as well.

AWWA (2013) reviewed analytical detection methods for hexavalent chromium and water treatment methods that are effective for removal of hexavalent chromium. Conventional treatment (coagulation or lime softening followed by filtration) did not appear to be effective for hexavalent chromium as it is for total chromium removal. Reduction coagulation filtration (RCF), strong base anion-exchange (SBA), and single use weak base anion-exchange (WBA) appear to be effective based on limited information. See AWWA (2013) for more details.

Action Items

According to the EPA (2013b), the agency began a rigorous and comprehensive review of the health effects of chromium-6 following the 2008 release of toxicity studies by the Department of Health and Human Service's National Toxicology Program. In September 2010, the EPA released a draft of the scientific human health assessment, entitled "Toxicological Review of Hexavalent Chromium," for public comment and external peer review. When this human health assessment is finalized, the EPA will review the conclusions and consider all relevant information to determine whether a new standard is needed for drinking water. In the meantime, the EPA has provided guidance to public water systems (PWSs) for monitoring chromium-6 in addition to the required monitoring for total chromium to so that the PWSs can "better inform their consumers about the levels of chromium-6 in their drinking water, evaluate the degree to which other forms of chromium are transformed into chromium-6 in their drinking water and assess the degree to which existing treatment is affecting the levels of chromium-6."

The EPA has released presentation materials associated with the Integrated Risk Information System (IRIS) Chromium VI Workshop held in September 2013 and the IRIS Systematic Review Meeting held in August 2013. To view these presentation materials and other information regarding recent or upcoming IRIS public meetings, please visit the public meetings webpage at the following URLs:

http://www.epa.gov/iris/publicmeeting/
http://www.epa.gov/iris/irisworkshops/cr6/index.htm

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