MiningWatch Canada
Chromite Series
Fact Sheet # 01

Potential Environmental IMPACTS OF MINING AND PROCESSING[1]

Introduction

Chromite is a mineral that contains the element chromium. The major use for mined chromite is the production of ferrochrome, an iron-chromium alloy used to make stainless steel.

Recently, chromite deposits have been identified in Northern Ontario, Canada. Located 500 km north-east of Thunder Bay in a pristine area dubbed the "Ring of Fire", they are the largest deposits found in North America. Plans by Cliffs Natural Resources for an open pit/underground chromite mine and ore processing facility in the Ring of Fire and a ferrochrome production facility (includes a chromite smelter) to be located somewhere in Ontario are currently undergoing economic feasibility studies and environmental assessments. Other companies also have plans for mining chromite and other metals in the same area.

This fact sheet is part of a series produced by MiningWatch Canada about the risks of chromium exposure. Additional fact sheets and a more extensive review of relevant scientific research entitled *An Overview of Chromium, Chromite and Toxicity*, are also available on our website (www.miningwatch.ca/chromium). References for the information presented in this fact sheet can be found in the full review.

Is chromium dangerous?

The two most environmentally significant forms of chromium are trivalent chromium (Cr-III), which is found in the mineral chromite, and hexavalent chromium (Cr-VI). All forms of chromium measured together are called total chromium.

[1] Information taken from: An Overview of Chromium, Chromite and Toxicity by MiningWatch Canada, 2012.

Too much Cr-III can be toxic to plants and animals. Human activities such as chromite mining and ferrochrome manufacture can convert Cr-III into Cr-VI, which is also toxic and is known to cause cancer. Cr-VI can more easily move into the cells of plants, animals and micro-organisms, so it has a greater potential for toxicity.

Though the intent of chromite mining is to remove the chromite from the ore for production of ferrochrome, the process is not 100% efficient, so mining and smelting wastes including dust, wastewater, tailings, waste rock and slag (produced during ferrochrome separation from the ore) can still contain chromium, including Cr-VI. Other heavy metals and chemicals of concern may also be in the wastes. As with other types of mining wastes, chromite mine wastes have the potential to cause serious environmental contamination. This has occurred in places around the world where these wastes have been inadequately managed.

In 1995, ferrochrome and stainless steel plants in Finland emitted 14.58 tonnes of chromium into air, 4.6 tonnes into water and 1330 tonnes onto land (Mukherjee 1998).

How can chromium affect ecosystem health?

Soil, sediment, water, air and living things can all become contaminated with chromium as a result of mining and other industrial activities. Because there has never been a major chromite mine in North America, most of the concerns about chromium toxicity in Canada and the US (including the film Erin Brokovich) are not about chromite mining but "downstream" industrial uses of chromium. Based on what we know about chromium and experiences in other parts of the world, we know that mining and processing chromite also poses significant risks of contamination if poorly managed.

Depending on environmental conditions, chromium can be converted from Cr-VI to Cr-III or vice versa and both types of conversions can occur in the same system. These natural processes are influenced by complex physical, biological and chemical factors such as soil type, mineral content, water characteristics, and biological interactions.

Soil and Plants

Relatively small amounts of Cr-VI (1-10 mg/kg) and Cr-III (25-100 mg/kg) can negatively impact the number, type, health and activity of soil organisms and so impact the health of the soil ecosystem. Soil organisms play crucial roles in developing o soil structure and the cycling of organic matter and nutrients.

Plants can accumulate Cr-III and Cr-VI from soil, sediment, water and from dust deposited onto leaves. It is normal for small amounts of Cr-III to be found in plants and many accumulate only a little chromium, most of which is stored in the roots. However, some species can store high amounts of chromium in roots and above-ground parts. These "hyperaccumulators" can be aquatic or land plants, and include duckweed (*Spirodela polyrhiza*), mustard greens (*Brassica juncea*) and ragweed (*Ambrosia artemisiifolia*).

Exposure to excess Cr-III or Cr-VI can negatively affect plant health and survival. Sensitivity and effects can be very different between plant species and soil types, which makes predicting toxicity difficult. Toxic effects shown on experimental exposure to plants include:

- reduced or delayed growth;
- yellow leaves caused by decreased chlorophyll;
- narrow leaves;
- small root systems;
- damage to root membranes and decreased ability to take up water;
- changes in uptake and storage of nutrients (nitrogen, calcium etc.);
- decreased or no seed germination;
- decreased seed yield;
- wilting;
- death

Some studies suggest that plants convert all Cr-VI into Cr-III, but other studies have found Cr-VI and its intermediate forms, Cr-V and Cr-IV, persist in plants and algae. As Cr-VI, Cr-V and Cr-IV are involved in chromium's most toxic effects in humans and some other animals, their presence in plants has the potential to threaten ecological health.

Terrestrial Life
Information on the doses of chromium in water or food that cause health problems in mammals come mostly from toxicology tests done in the lab on mice and rats. Effects observed on animals in experimental doses through food, water or injection include: cancers, reproductive harm, behavioral changes, reduced growth and reduced survival. Very few field studies have been conducted about the effects of environmental chromium pollution on wildlife and we did not find any information directly relevant to potential impacts of chromite mining and ferrochrome production on terrestrial wildlife.

Aquatic Life
Chromium in aquatic ecosystems can harm algae, aquatic plants, invertebrates and fish. The amount of chromium taken up and stored in living tissue and its effects depend on factors such as species, organism size, sex and developmental stage, water characteristics and presence of other contaminants. Toxic effects include:

- reduced growth (algae, plants, invertebrates and fish)
- decrease in successful reproduction (invertebrates and fish)
- DNA damage (fish)
- reduced weights (fish)
- decreased disease resistance (fish)
- reduced survival (plants, invertebrates and fish)

Units of Measurement:
1 million micrograms (ug) equals 1 gram.
1 thousand milligrams (mg) equals 1 gram.

Studies have observed Cr-VI toxicity on algae and aquatic plants exposed to as little as 1-10 ug/L and on invertebrates and fish exposed to as little as 10 ug/L. In fish, Cr-VI harms internal organs such as the liver and kidney. Chromium-III in water seems to be more toxic to fish than Cr-VI. It can decrease fertilization success, deposit onto gills which damages tissue and function and can cause death at relatively low doses. Chromium-III has caused toxic effects on fish at 5 ug/L, on invertebrates at 44 ug/L and on algae at 320 ug/L.

Chromium in mine and ferrochrome wastes can be much higher than the concentrations known to harm aquatic life. At an open pit chromite mine in India, Cr-VI in mine effluents ranged from 20 ug/L to 120 ug/L and in mine seepage from 50 ug/L to 1220 ug/L. In a study testing ferrochrome slag from Turkey, 610 ug/L of Cr-VI leached from crushed slag and 3800 ug/L of Cr-VI leached from ground slag.

Biomagnification
Biomagnification is an increase in the concentration of contaminants at higher levels of a food chain as predators eat contaminated food, retain the contaminants and then pass them on to higher level predators. Toxic compounds that biomagnfy can seriously threaten ecosystem health. Chromium however, is not considered likely to biomagnify in aquatic and terrestrial food chains. A number of studies have actually found lower chromium concentrations in aquatic creatures higher up the food chain and there is no documented evidence for biomagnification of chromium from soil to plant to animal. This conclusion, however, is based on very few studies of the risk of chromium in food chains, and evidence does exist for biomagnification of chromium from wetland invertebrates to their predators - birds.

What don't we know about the ecosystem risks of chromium?

The majority of toxicity studies about chromium and environmental effects have been conducted in labs, which don't fully account for complex field conditions. Scientists acknowledge there is a need for more research regarding chromium uptake, effects and risks in freshwater and terrestrial wildlife. Some key areas of uncertainty and lack of information include the following:

1. Without site specific studies, toxicity predictions are limited because responses to chromium vary widely among different soil types, water characteristics, plant and animal species.

2. It is unclear whether Cr-III or Cr-VI is more toxic to plants.

3. It is unclear what forms of chromium are present in plants after uptake and what risks these may pose to plant consumers.

4. Chromium exposure can change the nutrient uptake of plants, and the potential health effects of this for plant consumers have not been investigated.

5. Recent research suggests that standard tests may be underestimating Cr-III toxicity to algae.

6. Chromium is considered not likely to biomagnify up aquatic and terres trial food chains, but this is based on few studies.

Does the government regulate chromium in the environment?

Both the Canadian and Ontario governments have standards for allowable chromium levels in the environment (Table 1). In recent years governments have undertaken reviews to update some chromium regulations, many of which have resulted in stricter standards.

Ferrochrome arc furnace dust is categorized as toxic waste in Canada (waste K091) and must be treated before disposal in order to prevent leaching of toxins into the environment. Canadian and Ontarian hazardous waste guidelines require that wastes leach no more than 5 000 ugCr/L, a limit which is less stringent than a number of other countries and does not address allowable Cr-VI levels separately.

The Canadian Interim Sediment Quality Guideline for bioavailable total chromium is 37.3 mg/kg of dry sediment, while the Probable Effects Level (for aquatic creatures) for bioavailable total chromium is 90 mg/kg. Chromium-VI can be present in the top layer of sediment when the overlying water contains oxygen, but no guideline has been established for Cr-VI in sediment. The Ontario Contaminated Site Condition Standard for total chromium in sediment is set at the upper limit of typical sediment concentration in the province.

Canada has set Quality Criteria for agricultural irrigation water and livestock water. The Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life for Cr-VI is based on toxicity to a sensitive invertebrate (*Ceriodaphnia dubia*) and the interim guideline for Cr-III is based on toxicity to rainbow trout (*Oncorhynchus mykiss*). There are currently no tissue residue guidelines for the protection of animals and people who consume fish.

Based on plant contact with soil, the Canadian Provisional Guideline for the protection of environmental health is 0.4 mgCr-VI/kg for agricultural soils, and 1.4 mgCr-VI/kg for industrial and commercial soils. Canada's chromium soil guidelines for the protection of environmental and human health are generally stricter than soil standards in other countries. The upper range of typical Ontario chromium concentrations in uncontaminated soils are slightly higher than the Canadian guidelines, thus the Ontario Site Condition Soil Standards have set limits that allow more chromium than the Canadian guidelines.

The federal Metal Mine Effluent Regulations do not set a limit for chromium in effluent being discharged into the environment. The effluent is required to pass an acute lethality test for rainbow trout, which means that it cannot kill more than 50% of the fish tested within 96 hours.

There are no federal Air Quality Guidelines for the protection of human health and the environment. Ontario has environmental air regulations set for the protection of human health.

Table 1 Canadian and Ontarian Regulations and Guidelines for chromium in the environment.

CAN is Canada. ON is Ontario. ug = microgram = 1 000 000 grams. na is not applicable

Limit	Total Cr	Cr-III	Cr-VI
Freshwater (ug/L)1 2			
CAN & ON: Water Quality Guidelines for Protection of Aquatic Life	-	8.9	1
CAN: livestock Water Interim Quality Criteria	-	50	50
CAN: irrigation Water Interim Quality Criteria	-	4.9	8
ON: non-potable Groundwater Standard	810	-	140
ON: non-potable Groundwater Standard in shallow soil or within 30m of water body	640	-	110
Sediment (mg/g dry weight)1 2			
CAN: Interim Quality Guideline	37.3	-	-
CAN: Probable Effects Level	90		
ON: Contaminated Site Condition Standard	26		
Soils (mg/kg)1 **2**			
CAN: Guideline for protection of environmental and human health for agricultural, residential/parklands	64	-	0.4
CAN: Guideline for the protection of environmental and human health for industrial and commercial lands	87	-	1.4
ON: All land uses, Soil Standard for contaminated sites	160	-	-
ON: All land uses, medium – fine, coarse textured Soil Standard for contaminated sites	-	-	10, 8
ON: Residential/Parkland/Institutional/Industrial/Commercial/Community property use Soil Standard for contaminated sites within 30m of water body	70	-	0.66
ON: Agricultural or Other property use Soil Standard for contaminated sites within 30m of water body, potable groundwater condition	67	-	0.66
Environmental Air (ug/m^3)3	**Cr-0, II, III**	**Cr-VI PM_{10}**	**Cr-VI TSP**
ON: 24-hr average Ambient Air Quality Criterion set in 1982 (Cr-II, III)	1.5	-	-
ON: 0.5-hr average Standard based on Cr-III respiratory effects, effective 2016	1.5	na	na
ON: 24-hour average Air Standard and Ambient Air Quality Criterion based on Cr-III respiratory effects, effective 2016	0.5	na	na
ON: 24-hr average Ambient Air Quality Criterion, based on Cr-VI carcinogenicity, effective 2016	na	0.00035	0.0007
ON: annual Ambient Air Quality Criterion, based on Cr-VI carcinogenicity, effective 2016	na	0.00007	0.00014
ON: 0.5-hr average Air Standard, based on Cr-VI carcinogenicity, effective 2016	na	-	0.002
ON: annual Air Standard, based on Cr-VI)- carcinogenicity, effective 2016	na	-	0.00014
Waste (ug/L)4 5			
CAN: Hazardous Waste Transport Regulation ON: Hazardous Waste Quality Criteria	5 000	-	-

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[2] http://ceqg-rcqe.ccme.ca/

[3] http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_086518.pdf

[4] http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2011/010-6353.pdf

[5] http://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-149/page-19.html#h-34

[6] http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900347_e.htm#BK31