CHAPTER 2
INTRODUCTION

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New Jersey Chromium Workgroup Report

CHAPTER 2

Introduction

A. Background and Context

In response to a request by Commissioner Bradley M. Campbell, staff from The New Jersey Department of Environmental Protection (Department) convened an internal workgroup to review and discuss the applicability of current and proposed cleanup criteria for chromium as they apply to chromium ore processing residue (COPR) waste sites in New Jersey. The request emanated from concerns raised to the Commissioner by the Hudson County community where most of the chrome ore processing residue waste sites are located. The group worked intensively for six months outlining the details of the issues for examination and making recommendations to the Department for improving the cleanup criteria and/or the application of the cleanup criteria.

The overall charge to the workgroup, as identified by Commissioner Campbell:

The workgroup will review the application of the current chromium standards and any revised standards.

The workgroup was charged with specific questions (memos outlining the charges to the group are included as an appendix of this report). The questions were:

- Analytical: The Site Remediation and Waste Management Program currently accepts results of chromium analyses using a non-certified digestion method. It has been recommended that the NJDEP-certified digestion method for hexavalent chromium be used.

- Interconversion of trivalent chromium to hexavalent chromium and site-specific chemistry: Due to the differing toxicity of chromium depending on its valence state (tri- or hexa-valent), it is vital to understand the interconversions of these two species. Investigation of this chemistry is needed.

- Concentration due to capillary action: Hexavalent chromium may concentrate on surfaces due to its solubility and transport in groundwater. This phenomenon needs examination.

- Carcinogenicity of hexavalent chromium via ingestion: It has been suggested that this form of chromium, know to be carcinogenic via inhalation, may also induce cancers when ingested. This route of exposure needs further investigation.

This list of questions was developed into specific charges, which were assigned to each of the four subgroup components. The subgroups and their charges are:

Risk Assessment Subgroup

Carcinogenicity via ingestion: Do toxicological studies show that hexavalent chromium is carcinogenic when ingested? Should the exposure route be altered to address potential ingestion carcinogenicity?

Contact Dermatitis: The procedure for site specific allergic contact dermatitis criteria includes the assumption that exposure to hexavalent chromium occurs in solution because the approved threshold is solution-based. If this is not appropriate, suggest another mechanism, and a method for quantifying dose-response and exposure.

Exposure Pathways: Are the exposure pathways for chromium adequately addressed in the soil standards, particularly as they relate to alternative remediation standards?

Analytical Chemistry Subgroup

Certified Method: The Site Remediation and Waste Management Program has been accepting analytical results for hexavalent chromium using a non-NJDEP certified analytical method for Cr(VI) digestion. There is an USEPA-certified method available (Method 3060a). Should the Department mandate use of the USEPA method for hexavalent chromium determinations? What should the Department do about data obtained by the non-certified method the Site Remediation and Waste Management Program has been using for site decisions?

Data Review and Acceptance: What should the Department policy be on analytical data where the associated quality assurance protocols are outside method limits?

Additional Analytical Methods: USEPA Method 6800 "Elemental and Speciated Isotope Dilution Mass Spectrometry" is approved and included in SW846 for the analysis of speciated metals, including chromium. The Office of Quality Assurance (OQA) does not currently offer certification for USEPA Method 6800. Should the OQA offer certification for USEPA Method 6800? If so, what should be the extent of its potential applications?

Method Deficiencies: There is a question that the methods for the regulatory-approved methods of preparation and analysis of hexavelent chromium (USEPA Methods 3060a, 7196a and 7199) underestimate its in-situ concentration in certain types of soil. What are the circumstances where the low bias in hexavalent chromium measurements exist? Are there any conditions under which high bias (resulting from oxidation of Cr(III) to Cr(VI)) in sample preparation and/or measurement occurs?

Quality Assurance Tools: The Department has proposed a collaboration with USEPA, National Institute of Standards and Technology (NIST) and the Environmental and Occupational Health Sciences Institute (EOHSI) to develop a reference material of defined Cr(VI) concentration using a source material from Hudson County, New Jersey, that can be used to assess the efficacy of future Cr(VI) measurements. Should such a reference material be developed?

Other Measurement Options: Is it possible to develop a commercially available, NJDEP-certifiable method to replace the current method (Method 3060a)? If not, should speciation of hexavalent chromium continue to be performed should only total chromium be measured? Are there any known biases to the measurement of total chromium in soil that would prevent its use in establishing chromium remediation standards?

Air Transport Subgroup

Exposure Pathways: The protocol for the development of alternative remediation standards for chromium needs to include the physical mechanism by which dust gets into the air and reach humans via inhalation. Are the mechanisms for this transport adequately calculated?

Environmental Chemistry Subgroup

Nature of COPR: The interconversion question is imbedded in the larger problem of the nature of chromium ore processing residue (COPR). The physical (micropore) structure of the residue may be the rate-limiting factor in the release of hexavalent chromium. What is the nature of this waste material and how does it influence what we know about chromium chemistry?

Transport to Groundwater: What concentration of chromium in the soil at the COPR sites results in chromium levels above the drinking water standard in ground water? Do the NJDEP cleanup standards currently under development adequately protect groundwater?

Interconversion: What is the capacity of trivalent chromium to convert to hexavalent chromium in the soil of the COPR sites? Do the current remediation standards adequately account for this interconversion? If not, recommend some options the Department should pursue to address any discrepancy or inadequacy, including research.

Concentration Effect: Enrichment of concentrated hexavalent chromium has been observed on soils and in structures at the sites. Soluble hexavalent chromium dissolves in groundwater and can move throughout the soil column. The chromium becomes concentrated as the water evaporates. Rainfall events and movement of groundwater levels can change the location of these concentrated evaporative fronts. Can the concentration of chromium in the enrichment areas be anticipated and modeled? Is there a concentration in the soil that protects against elevated levels of hexavalent chromium from being deposited in this way?

This document summarizes the issues and recommendations discussed by the workgroup members and reflects the combined contribution of staff of the Department. It is intended to serve as an informational resource to the Department and as a foundation for future cleanup decisions at chromium ore processing residue (COPR) sites in the state to reduce the environmental and public health impacts of chromium contamination.

B. Properties of Chromium

Chromium is a naturally occurring metallic element found in the earth's crust. Chromium exists in several oxidation states, although only the trivalent, Cr(III), and the hexavalent, Cr(VI), forms are common in the natural environment. The predominant form of chromium in crustal rocks is chromite ore, which contains a mixture of Cr(III) oxides. It is the only commercial source of chromium. Very small releases of naturally occurring chromium to the aquatic environment can occur as a result of weathering and erosion. The predominant source of chromium contamination in environmental media is industrial uses and discharges. Raw metallic chromium is used mainly for making steel and other alloys. Chromium compounds, in either the Cr(III) or Cr(VI) forms, are used for chrome plating, the manufacture of dyes and pigments, leather and wood preservation, and treatment of cooling tower water. Smaller amounts are used in drilling mud, textiles, and toner for copying machines.

Occupational exposure to chromium occurs from chromate production, stainless-steel production, chrome plating, and leather tanning. Occupational exposure can be two orders of magnitude higher than exposure to the general population (ATSDR 1998, OSHA 1998). People who live in the vicinity of chromium waste disposal sites or chromium manufacturing and processing plants have a greater probability of elevated chromium exposure than the general population. These exposures are generally to both Cr(VI) and Cr(III).

Trivalent

Trivalent chromium occurs naturally in the environment and is the most stable of the forms of chromium both in nature and in biological systems. Cr(III) is an essential micro-nutrient in humans, necessary to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Without Cr(III) in the diet, the body loses its ability to use sugars, proteins, and fat properly, which may result in weight loss or decreased growth, improper function of the nervous system, and a diabetic-like condition. Therefore, Cr(III) compounds have been used as dietary supplements and are beneficial if taken in recommended dosages. The dietary daily recommendation is 50 to 200 µg/d for adults. The general population is exposed to Cr(III) by eating food, drinking water, and inhaling air that contains the chemical. The average daily intake from air, water, and food is estimated to be approximately 0.2 to 0.4 micrograms (µg), 2.0 µg, and 60 µg, respectively (ATSDR 1998, USEPA 1998a, WHO 1998).

Hexavalent

Exposure to the hexavalent form of chromium has been shown to cause both cancer and noncancer health effects. The respiratory tract is the major target for Cr(VI) following inhalation exposure in humans. Other effects noted from acute inhalation exposure to very high concentrations of Cr(VI) include gastrointestinal and neurological effects, while dermal exposure causes skin burns in humans (USEPA 1998b, 1999b). Epidemiological studies of workers have clearly established that inhaled chromium is a human carcinogen, resulting in an increased risk of lung cancer. Although chromium-exposed workers were exposed to both Cr(III) and Cr(VI) compounds, only Cr(VI) has been found to be carcinogenic in animal studies, causing lung

tumors via inhalation, so USEPA has concluded that only Cr(VI) should be classified as a Group A carcinogen (known human carcinogen) by the inhalation route of exposure (ATSDR 1998, USEPA 1999b). Hexavalent chromium, when inhaled over a period of many years, can also cause a variety of noncancer health effects including damage to the nose, blood disorders, lung disease including asthma, and kidney damage. Noncancer health effects can also result from the ingestion of Cr(VI), although the health effects would not be likely to occur unless the ingested soil contained a considerable amount of hexavalent chromium. These health effects are liver damage and relatively minor changes in blood cells.

USEPA used a mathematical model, based on data from an occupational study of chromate production workers, to estimate the probability of a person developing cancer from continuously breathing air containing a specified concentration of chromium. The "acceptable" risk used by USEPA is calculated to be that level of Cr(VI) which causes no more than one-in-a-million cancer in the population of exposed individuals exposed to it. More details on the development of Cr(VI) risk levels are presented in Chapter 3 (Risk Assessment Subgroup) of this report.

C. Development of Cleanup Standards

- Generic

The Legislature directed the Department to develop human health based soil remediation standards that protect human health for constituents present at contaminated sites. Specifically, the standards are to be developed according to the way the land is or will be developed - residential and nonresidential (N.J.S.A. 58:10-1 et seq.). Within these scenarios, the standards are further refined by exposure route – ingestion, inhalation, impact to groundwater (drinking water), and skin contact. To prevent the unacceptable risk to human health exposure due to contaminated sites, the Department has developed generic soil remediation standards for a number of contaminants, including trivalent and hexavalent chromium. Considered in the development of these generic standards are human health effects for both carcinogenic and noncarcinogenic endpoints. The Legislature determined that standards would be set at one additional cancer risk in one million ($1x10^{-6}$) for carcinogens and a hazard quotient not to exceed one (1) for noncarcinogens. The generic Soil Remediation Standards are to be used at any site regardless of site conditions. However, the Department recognizes that the inclusion of site-specific conditions may be appropriate in determining alternative remediation standards. The central principle employed in developing the generic standards was to establish viable methodologies for calculating values and to apply these to the full range of exposure scenarios and contaminants that need to be assessed. Conservative estimates (though not worst case estimates) were used when establishing parameters to include in the models used to generate the generic standards.

Generic numbers are used as defaults; that is, in instances where conditions at a site are unknown, generic (or very general), assumptions are made about the site. These assumptions are used in determining conservative conditions under which exposure to contamination may occur.

- Alternative Remediation Standards (ARS)

Site-specific characteristics may be substituted for default inputs in the algorithm in order to calculate alternative remediation standards for the site. The site-specific factors that may be substituted are discussed further in the Basis and Background documents developed by the Department for each exposure route. The Basis and Background documents are detailed descriptions of the methodologies used to develop the generic standards. Throughout the documents are sections describing instances where site-specific parameters may be substituted in the development of the alternative remediation standards.

In instances where data on a particular site is available, that site-specific information is used in lieu of the more conservative generic default values. Alternative Remediation Standards (ARS) are specific to the site and the pathway for which they are developed. The procedures to develop ARS's are based on site specific conditions and are contained in each exposure or transport pathway basis and background document. ARS's may be developed so that they are appropriate for nonresidential or residential uses. After an ARS is developed for a given pathway, it must be compared to the generic standards for the remaining exposure pathways. The lower of the generic standards or ARS becomes the remediation standard.

D. The Site Cleanup Process

Whenever a contaminated site is investigated or remediated, there are two options available with respect to soil cleanup criteria. One option is to use the already available generic numbers that apply to all sites in New Jersey. The other option is to develop an alternative remediation standard that incorporates site-specific conditions and information.

There are a number of factors that will determine how the soil remediation standards (either generic or ARS) will be applied for a contaminant at a site. How they are applied is intimately related to the phase of remediation. The phases of remediation are:

- **Memorandum of Agreement (MOA):** A written voluntary agreement between NJDEP and one or more persons concerning remedial activities planned for a contaminated site.

- **Preliminary Assessment (PA):** Identifies all contaminated and potentially contaminated areas of concern (including historic) that will require a formal site investigation.

- **Site Investigation (SI):** Determines if any contaminants are present above applicable remediation standards/criteria through sampling and analysis. During this step, the site is assessed for general use information (e.g., residential or nonresidential use). When analytical results of sampling become available, they are compared to the generic soil standards for each pathway (standards may vary based on the exposure route, i.e., inhalation, and by the use of the site, i.e., residential):
  - Ingestion-dermal exposure pathway (residential/nonresidential use)
  - Inhalation exposure pathway (residential/nonresidential use)
  - Impact to ground water exposure pathway

If the site investigation sample results of all suspected contaminants are **lower** than the soil remediation standards for all exposure pathways, a No Further Action (NFA) letter may be

issued for the site. If the site investigation sample results show levels of contaminant(s) **higher** than the lowest soil remediation standards then a remedial investigation must be conducted.

- **Remedial Investigation (RI):** Entails gathering data necessary to determine the nature and extent of contamination at the site, establishing the remedial response criteria and identifying remedial action alternatives, which are described in the statutes (described in the following section). Remedial options include treatment, removal, or control via institutional and/or engineering controls.

- **Remedial Action (RA):** The physical action consistent with the selected remedy to correct a release or threatened release of a hazardous substance into the environment. The term, often referred to as a cleanup action or construction project, includes but is not limited to: engineering controls, confinement, dredging, neutralization, recycling, removal, reuse and storage or treatment of hazardous substances. Sampling is conducted during this phase to document the completion of the treatment or removal remedial action.

- **No Further Action (NFA)/Covenant Not to Sue:** A No Further Action (NFA) designation is given when all remedial activities that were necessary to address an environmental concern have been completed. This designation is given when it is determined that regulatory requirements have been satisfied at a site, including instances when no contamination is found above applicable criteria or when it is determined that no additional remedial work is required at the site. A **conditional NFA** is obtained when all remedial work has been completed at a site, but a Deed Notice, Classification Exception Area or engineering control is required because some contamination above appropriate standards or criteria remains. Also, a **conditional NFA** is obtained when only a portion of an entire site has been addressed in an unrestricted, limited restricted or restricted manner. The Department designates an NFA-A for a partial area of a site and an NFA-E for an entire site. An NFA-A or NFA-E can have restrictions or institutional controls such as a Deed Notice or Classification Exception Area if soil or groundwater contamination remains above applicable standards.

There are several types of no further actions that the Department can issue.

- **Full Site No Further Action:** A determination by the Department that, based upon evaluation of the historical uses and/or investigation of a site or subsite, there are no contaminants present, or that any discharged contaminants that were present at the site or subsite have been remediated.

- **Limited Restricted:** This remedial action type includes a deed notice that provides notice of the residual soil contamination and limits human activities. Properties must be restricted when contamination will remain above the residential soil cleanup criteria. A notice requires a property owner's concurrence and documents the location and concentration of all contaminants and how they must be controlled or maintained and monitored, if applicable.

- **Restricted:** This remedial action type includes both engineering controls and a deed notice at sites with soil contamination remaining.

- **Classification Exception Area (CEA):** Serves to provide notice that groundwater contamination in exceedance of the Department's GroundWater Quality Standard exists in a particular location.

A **Deed Notice** (formerly called a Declaration of Environmental Restriction) is imposed for sites having a limited restricted or a restricted use designation. This notice ensures the disclosure of site conditions to future owners and the maintenance of required engineering controls. Certain exceptions for affected ground water also can be obtained depending upon its use. A **Classification Exception Area** is established at sites when groundwater contaminant levels exceed state groundwater quality criteria, but there is an expectation that over time, standards will be met. This designation must be established as part of an approved remedy to protect groundwater resources. The intent of a CEA is to ensure the uses of a designated aquifer in a specific area are restricted until contaminant levels are measured below appropriate standards.

E. Statutory Authority for Site Cleanups

The Brownfield and Contaminated Site Remediation Act ("Act") is detailed regarding remedy selection.

- The Act at NJSA 58:10B-12g(1) states "Unrestricted use remedial actions, limited restricted use remedial actions and restricted use remedial actions shall be allowed except that unrestricted use remedial actions and limited restricted use remedial actions shall be preferred over restricted use remedial actions. The department, however, may not disapprove the use of a restricted use remedial action or a limited restricted use remedial action so long as the selected remedial action meets the health risk standard established in subsection d. of this section, and where, as applicable, is protective of the environment. The choice of the remedial action to be implemented shall be made by the person performing the remediation in accordance with regulations adopted by the department and that choice of the remedial action shall be approved by the department if all the criteria for remedial action selection enumerated in this section, as applicable, are met. The department may not require a person to compare or investigate any alternative remedial action as part of its review of the selected remedial action."

- The Act at NJSA 58:10B-12g(2) states "Contamination may, upon the department's approval, be left onsite at levels or concentrations that exceed the minimum soil remediation standards for residential use if the implementation of institutional or engineering controls at that site will result in the protection of public health, safety and the environment at the health risk standard established in subsection d. of this section and if the requirements established in subsections a., b., c. and d. of section 36 of P.L.1993, c.139 (C.58:10B-13) are met. "

- The Act at NJSA 58:10B-13f states "Whenever the department approves or has approved the use of engineering controls for the remediation of soil, groundwater, or surface water, to protect public health, safety or the environment, the department may require additional remediation of that site only if the engineering controls no longer are protective of public health, safety, or the environment."

In accordance with the Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B-12, the draft soil remediation standards are developed for the protection of human health and therefore, are not specifically developed to be protective of ecological resources. However, high levels of contamination must be evaluated, on a site by site basis, for potential ecological impacts as well as for the presence of free and residual product pursuant to the Technical Requirements for Site Remediation, N.J.A.C. 7:26E.

F. History of the Development of Cleanup Criteria for Chromium and Status of Chromium Sites in New Jersey

Soil cleanup criteria have been developed for two valence states of chromium: trivalent chromium and hexavalent chromium. Different criteria have been established due to the differences in toxicity and solubility between the two valence states.

The Department has refined its guidance for chromium soil cleanup levels based upon changes and developments in the applicable science over the years. Table 2.1 shows the cleanup levels from 1989 through the present. Table 1.1 shows the 1998 proposed cleanup levels. A discussion about how the Department derived the cleanup criteria described in the table is available at the Departments Chromate Project website (http://www.state.nj.us/dep/srp/siteinfo/chrome/cr_criteria.htm). A brief synopsis is presented here.

Table 2.1. History of Chromium Soil Cleanup Levels in New Jersey

Year	Chromium Cleanup Level, mg/kg dry weight (ppm)
1989	75 ppm total Cr
1993	10 ppm soil Cr(VI) 500 ppm soil Cr(III)
1998	Multiple exposure pathway proposal for Cr(VI) and Cr(III) announced by Department. See Table 1.1.

Prior to 1989, the Department used a 100 mg/kg[1] action level for total chromium. This action level was based on New Jersey background total chromium soil concentrations derived from Rutgers University data and also took into account qualitative toxicological information available at the time.

The Department established subsequent guidance on a total chromium cleanup level in 1989 with a value of 75 mg/kg to account for allergic contact dermatitis (ACD). USEPA does not use the ACD endpoint in its standard-setting process. The guidance was developed in New Jersey for total chromium to protect exposure to the hexavalent form, which is the toxic form. A suitable digestion method did not exist at the time specific for hexavalent chromium in soil, so a total chromium level was established.

[1] mg/kg: milligram total chromium per kilogram of dry weight soil (equivalent to parts per million or ppm)

From 1993 until September 3, 1998, the soil cleanup criterion for Cr(III) was 500 mg/kg, based on an allergic contact dermatitis health endpoint. As this health condition results from short-term or acute exposures to chromium, the same criterion was applicable to both residential and nonresidential land use scenarios. On September 3, 1998, the Department proposed to delete this criterion and establish a soil cleanup criterion based on a soil ingestion exposure pathway using USEPA exposure pathway models, exposure assumptions, and toxicology data. This resulted in a new residential soil cleanup criterion of 78,000 ppm for Cr(III). Using USEPA models and assumptions, there is no unacceptable risk from Cr(III) exposure under the nonresidential land use scenario. As such, the Department chose not to regulate Cr(III) under a nonresidential land use scenario. From 1993 until 1998, the soil cleanup criterion for Cr(VI) was 10 mg/kg.

In addition, the Department proposed to establish separate Cr(VI) soil cleanup criteria for the following exposure pathways:

Soil ingestion
Inhalation of soil particles
Impact of soil contamination on ground water quality

Soil Ingestion

For the ingestion and inhalation soil exposure pathways, the Department again proposed to establish soil cleanup criteria using USEPA exposure pathway models, toxicology data, and exposure assumptions (substituting New Jersey specific data where applicable). As the existing toxicology data for the ingestion and inhalation exposure pathways were based on long-term or chronic exposures to Cr(VI), different criteria could be developed for residential and nonresidential land use scenarios. The Department had proposed on September 18, 1998, to use 240 ppm and 6,100 ppm Cr(VI) for the soil ingestion pathway under the residential and nonresidential land use scenarios, respectively.

Inhalation of Soil Particles

Based on data in the IRIS (Integrated Risk Information System) database, a value of 20 ppm Cr(VI) was proposed for the cancer inhalation endpoint for a nonresidential setting and 270 ppm Cr(VI) for a residential setting.

Impact of Soil Contamination on GroundWater Quality

For the impact to ground water exposure pathway, the Department proposed on September 18, 1998, the use of USEPA exposure pathway models and the Department groundwater quality standard for Cr(VI) to develop a site-specific cleanup criterion. Due to highly variable soil conditions throughout the State, it is not possible at this time to develop a generic soil impact to groundwater cleanup criterion for Cr(VI). As the groundwater quality standard for Cr(VI) is the same throughout the state, different soil cleanup criteria cannot be developed for residential and nonresidential land use scenarios.

Current Sites

A site status report for the COPR sites in New Jersey is presented in Table 2.2.

Table 2.2 Chromite Ore Processing Residue Sites Status (September 17, 2004)

Organization	Active Sites RI or RA Phase	NFA*	Total Sites
Honeywell	20	2	22
Occidental Chemical	22	18	40
PPG Industries	23	38	61
Exxon	2	0	2
Developer/Owner	1	3	4
Sub-Total Responsible Party	**68**	**61**	**129**
Allied Directive	24	0	24
NJDEP	0	1	1
NJDEP Orphan Site #1	13	1	14
NJDEP Orphan Site #2	15	0	15
Sub-Total Publicly Funded	**52**	**2**	**54**
Sites Investigated and Not Contaminated	0	0	27
SUBTOTAL	**120**	**63**	**183**
TOTAL	**120**	**63****	**210**

* Sites Cleaned-Up with "**Entire Site - No Further Action (NFA-E) Determinations**" (37 Residential and 26 Non Residential). Approximately 34% of all confirmed Hudson County Chromium Sites have been investigated and cleaned up.

**Remedy Selection Summary:

- 48 - Excavation
- 6 – Alternative Remediation Standard developed & No remedial action necessary
- 4 - Cap and Deed Notice
- 2 – Iron Sulfate & Portland Cement Treatment
- 2 - No remedial action necessary
- 1 - Deed Notice only

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