

**SUMMARY OF THE BASIS AND BACKGROUND OF THE  
SOIL CLEANUP CRITERIA FOR  
TRIVALENT AND HEXAVALENT CHROMIUM**

**NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION  
SITE REMEDIATION PROGRAM  
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## I. Executive Summary

In response to requests by the regulated community as well as interested citizens in Hudson County, The New Jersey Department of Environmental Protection (Department) prepared several draft documents concerning suggested soil cleanup criteria for trivalent and hexavalent chromium. These documents were made available to the regulated community as well as other stakeholders as part of an informal interested party review in September 1995. In addition, a several of informal public meetings were held in Hudson County along with informal meetings with interested environmental groups and Hudson County chromium responsible parties. As a result of this process, the Department received approximately 1,000 pages of written comments from twelve (12) interested parties.

The Department has reviewed the comments from the interested party review, conducted additional research and reviewed additional scientific literature in an effort to develop reasonable, clear and predictable soil cleanup criteria for the remediation of chromium contaminated sites in New Jersey. This effort has culminated in a series of soil cleanup criteria for trivalent and hexavalent chromium. This document summarizes the basis and background of the development of these criteria. The Department will begin a formal rulemaking effort for the development of soil cleanup standards in 1999. The soil cleanup criteria for chromium discussed in this document will be part of the rulemaking effort. The Department will use the new chromium soil cleanup criteria as guidance in the interim.

Because of the technical nature of the text, a glossary of terms has been provided as Attachment 1 to facilitate the reading of this document.

Whenever a 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 within New Jersey. The other option is to develop an alternative number that incorporates site-specific conditions and information or recent scientific developments. Such a number is more formally known as an Alternative Remediation Standard and is in accordance with Public Law 1997, Chapter 278 (Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B). These two options existed for the current chromium soil cleanup criteria and will exist for the new chromium soil cleanup criteria.

Soil cleanup criteria have been developed for two (2) valence states of chromium: trivalent chromium ( $\text{Cr}^{+3}$ ) and hexavalent chromium ( $\text{Cr}^{+6}$ ). Different criteria have been established due to the differing toxicity and solubility between the two valence states.

From 1993 until September 3, 1998 the soil cleanup criterion for  $\text{Cr}^{+3}$  had been 500 parts per million (ppm or mg/kg) and had been 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 United States Environmental Protection Agency (USEPA) exposure pathway models, exposure assumptions, and toxicology data. This resulted in a new residential soil cleanup criterion of 78,000 ppm for  $\text{Cr}^{+3}$ . Using USEPA models and assumptions, there is no unacceptable risk from  $\text{Cr}^{+3}$  exposure under the nonresidential land use scenario. As such, the Department chose not to regulate  $\text{Cr}^{+3}$  under a nonresidential land use scenario.

Simultaneously with the Department's proposal of this soil cleanup criterion, the USEPA toxicology database known as the Integrated Risk Information System (IRIS) was modified with respect to  $\text{Cr}^{+3}$ . Recalculation of the Department's proposed 78,000 ppm  $\text{Cr}^{+3}$  criterion using the new USEPA toxicology data yields a value of 120,000 ppm  $\text{Cr}^{+3}$ . The Department now proposes to use this value as the  $\text{Cr}^{+3}$  soil cleanup criterion.

Currently, only toxicological information for  $\text{Cr}^{+3}$  via the ingestion pathway is found IRIS. Therefore, the Department is only proposing a soil cleanup criterion for  $\text{Cr}^{+3}$  based on the soil ingestion exposure pathway. It is important to note that the 120,000 ppm  $\text{Cr}^{+3}$  criterion for the residential land use scenario and the finding of no unacceptable risk from  $\text{Cr}^{+3}$  exposure under a nonresidential land use scenario are only applicable to insoluble forms of  $\text{Cr}^{+3}$ .

The soil cleanup criterion for  $\text{Cr}^{+6}$  of 10 ppm was also established in 1993 and was also based on an allergic contact dermatitis health endpoint. As this health condition results from short-term or acute exposures to chromium, the same criterion would be applicable to both residential and nonresidential land use scenarios. On September 3, 1998, the Department proposed to retain soil cleanup criteria based on this exposure pathway; however, the new generic soil cleanup criterion was expected to increase. In addition, the Department also proposed to establish  $\text{Cr}^{+6}$  soil cleanup criteria for the following exposure pathways:

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

For the soil 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  $\text{Cr}^{+6}$ , different criteria could be developed for residential and nonresidential land use scenarios.

Again concurrent with the Department's proposal of the above, the USEPA modified the IRIS database which affected inputs potentially used in developing soil cleanup criteria for both the soil ingestion and soil inhalation pathways. The Department had proposed on September 3, 1998 to use as  $\text{Cr}^{+6}$  criteria 390 ppm and 10,000 ppm for the soil ingestion pathway under the residential and nonresidential land use scenarios, respectively. The Department has recalculated the affected criteria and determined that the  $\text{Cr}^{+6}$  criteria for the soil ingestion pathway should be

240 ppm and 6,100 ppm for the residential and nonresidential land use scenarios, respectively. Comparison of the derived values using the new IRIS data led to the conclusion that the preliminary value of 20 ppm Cr<sup>+6</sup> originally proposed for the inhalation pathway leading to a cancer health endpoint on September 3, 1998 would still be the most protective for a nonresidential setting. Regarding the residential land use scenario, the Department still proposes to use the Cr<sup>+6</sup> USEPA soil screening level (USEPA 1996) for the inhalation pathway. Consequently, the Department is not altering its September 3, 1998 proposal for establishing criteria with respect to the Cr<sup>+6</sup> inhalation pathway.

For the impact to ground water exposure pathway, the Department proposed on September 3, 1998 and will continue to propose the use of USEPA exposure pathway models and the Department ground water quality standard for Cr<sup>+6</sup> 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 ground water cleanup criterion for Cr<sup>+6</sup>. As the ground water quality standard for Cr<sup>+6</sup> is the same throughout the state, different soil cleanup criteria cannot be developed for residential and nonresidential land use scenarios.

The proposed soil cleanup criteria for Cr<sup>+6</sup> for the various exposure pathways follow. Please note that the numbers provided below are either derived by the USEPA or calculated using standard USEPA equations and assumptions.

<u>Exposure Pathway</u>	<u>Residential Scenario</u>	<u>Nonresidential Scenario</u>	<u>Comments</u>
Ingestion	240 ppm	6,100 ppm	
Inhalation	270 ppm	20 ppm Preliminary	1,2
Impact to Ground Water		Site Specific	3,4
Allergic Contact Dermatitis		Under Development	1,3

<sup>1</sup> Exposure models and assumptions have been established or are being finalized; development of a generic soil cleanup criterion is currently being conducted.

<sup>2</sup> Due to the effects of vehicular traffic, the nonresidential land use scenario cleanup criterion will be lower than the residential land use scenario cleanup criterion. The nonresidential land use cleanup criterion is preliminary and presumes a site size of 2 acres.

<sup>3</sup> Soil cleanup criterion will be the same for both residential and nonresidential land use scenarios.

<sup>4</sup> Due to highly variable soil conditions throughout the State, it is not possible at this time to develop a generic soil impact to ground water cleanup criterion for Cr<sup>+6</sup>.

The Department is recommending the release of these cleanup levels in the form of Soil Cleanup Criteria guidance prior to a rule making proposal as soil cleanup standards. Please note that all the soil cleanup numbers presently being used in site remediation are “guidance” and are awaiting formal adoption via the rulemaking process. The Department will begin a formal rulemaking effort for the development of soil cleanup standards in 1999. In addition, the Department will release these new criteria in response to the large number of written requests to both the Department and the Governor’s Office to finalize soil cleanup numbers for chromium.

## II. Background

The Department of Environmental Protection (Department) has continually refined its guidance for chromium soil cleanup levels based upon changes and developments in the applicable science (Table 1).

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**Table 1.** History of Chromium Soil Cleanup Levels in New Jersey

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Pre-1989	100 mg total Cr/kg DW soil action level was established
1989	75 mg total Cr/kg DW soil guidance established
1993	10 mg Cr <sup>+6</sup> /kg DW soil and 500 mg Cr <sup>+3</sup> /kg DW soil guidance established
1994	Action levels of 10 mg Cr <sup>+6</sup> /kg DW soil and 500 mg Cr <sup>+3</sup> /kg DW soil presented in Hudson County Chromate Waste Cleanup Update #20 prepared by the Department.
Sept. 3, 1998	Multiple exposure pathway proposal for Cr <sup>+6</sup> and Cr <sup>+3</sup> announced by the Department
Sept. 18, 1998	Multiple exposure pathway proposal modified to reflect September 3, 1998 changes by the United States Environmental Protection Agency (USEPA) in the Integrated Risk Information System (IRIS) database

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Initially the Department used a 100 milligram total chromium per kilogram of dry weight soil (mg total Cr/kg DW soil, equivalent to parts per million or ppm) action level prior to 1989. This action level was based on a multiple of the maximum New Jersey background total chromium soil concentrations derived from Rutgers University data and also took into account qualitative toxicological information.

The Department established subsequent guidance on a chromium cleanup level in 1989 with a value of 75 mg total Cr/kg DW soil to preclude allergic contact dermatitis (ACD) in more than 10 percent of a sensitized population. This number was based on the work of Bagdon (1989) and a risk assessment conducted for the Department by Environmental Science and Engineering, Inc.

(NJDEP, 1989). Its initial application was site-specific for the chromate production waste contaminated sites in Hudson County. It is important to note that the USEPA does not use the ACD endpoint as a basis for determining the need to remediate a site.

The Department developed this guidance on the basis of a 10 milligrams of hexavalent chromium per kilogram of dry weight soil ( $\text{mg Cr}^{+6}/\text{kg DW soil}$ ) cleanup level. However, the lack in confidence of a hexavalent chromium ( $\text{Cr}^{+6}$ ) analytical method for soil caused the Department to rely on the use of total chromium data. Based on an analysis of the available data (NJDEP, 1989), the Department estimated that the 95 percentile of the sample distribution of the ratio between  $\text{Cr}^{+6}$  and total chromium in chromate ore waste residue was 0.14. Consequently, the target level of 75 mg total Cr/kg DW soil was not expected to result in a  $\text{Cr}^{+6}$  level greater than 10 mg  $\text{Cr}^{+6}/\text{kg DW soil}$  in soil samples. Eventually this action level supplanted the earlier 100 mg total Cr/kg DW soil value for use statewide.

In 1993 the Department further refined the earlier guidance and began using the values of 10 mg  $\text{Cr}^{+6}/\text{kg DW soil}$  and 500 milligrams of trivalent chromium per kilogram of dry weight soil ( $\text{mg Cr}^{+3}/\text{kg DW soil}$ ). The endpoint was ACD and based on the work of Bagdon and Hazen (1991). The Department's Division of Science and Research indicated that a 10 milligram  $\text{Cr}^{+6}$  per liter solution ( $\text{mg Cr}^{+6}/\text{l}$ ) would cause ACD in 10 percent of a sensitized population. Making a conservative assumption that all the  $\text{Cr}^{+6}$  was extractable, the Division of Science and Research determined that this was equivalent to 10 mg  $\text{Cr}^{+6}/\text{kg DW soil}$ . The 500 mg  $\text{Cr}^{+3}/\text{kg DW soil}$  number was based on information in Bagdon and Hazen (1991) that trivalent chromium ( $\text{Cr}^{+3}$ ) was less potent than  $\text{Cr}^{+6}$  by a factor of 50 relative to ACD. This guidance was in place until September 3, 1998.

Concurrent with this change was a shift in the Department's position on measuring hexavalent chromium directly. As a result of Department investigations, modifications in the analytical methodology were made. This along with greater experience in using the methodology increased the Department's confidence in measuring  $\text{Cr}^{+6}$  concentrations in soil directly. Consequently, the Department determined that the use of total chromium as a surrogate was no longer necessary.

Subsequent research, discussions with the responsible parties and other stakeholders, and the impact of recent legislation (Hazardous Discharge Site Remediation Act, N.J.S.A. 58:10B) have led the Department to consider changing the minimum elicitation threshold (MET) for ACD from 10 to 25 mg  $\text{Cr}^{+6}/\text{l}$ . The Department has now completed its evaluation of the human health study conducted by ChemRisk – McLaren/Hart and James Nethercott, M.D. (1995), and the Department formally proposes to use 25 mg  $\text{Cr}^{+6}/\text{l}$  as the MET.

Another development is that the Department no longer considers the conservative assumption of 100% extractability as necessarily appropriate based on its experience with chromium contamination and in particular the solid chromate production waste found in Hudson County. The Department intends to institute a protocol that will assess the extractability and therefore availability of  $\text{Cr}^{+6}$  in a fluid media. The specifics of the protocol are described below.

In response to information requests from the regulated community, the Department developed several draft basis and background documents to communicate the Department's current thinking on the chromium issues. The Department held an informal interested party review (IIPR) of these same documents in September 1995. As part of this outreach effort, a series of public meetings were held. These included meetings held at St. Aedan's School and St. Michael's Methodist Church in Jersey City. A meeting with interested environmental groups was also held as well as a meeting with the Hudson County chromium responsible parties (AlliedSignal, Inc.; PPG Industries, Inc.; and representatives of Occidental Chemical Corporation). The large response (from 12 separate entities totaling approximately 1,000 pages of written comments) generated by this IIPR caused the Department to further investigate many of the aspects of the chromium issues and in many cases revise the Department's original position. This document constitutes in part the Department's response to those comments.

In the past, much of the Department's attention has appeared to focus on the ACD endpoint. This is because the Department believed that the ACD related cleanup criterion would dictate where it was necessary to remediate. However, with the adjustment for extractability, it is likely that other human health endpoints such as cancer (air inhalation pathway) may determine the remediation goal. Of course ecological, ground water, and surface water impacts must also be evaluated when determining if remediation is required.

### **III. Soil Cleanup Criteria for Trivalent and Hexavalent Chromium**

The Department currently issues guidance on trivalent and hexavalent remediation goals or the methodologies to determine them on a site-specific basis. Because there are no existing soil cleanup standards for chromium, Public Law 1997, Chapter 278 allows the development of an Alternative Remediation Standard (ARS) to be used as a substitute. It is the intention of the Department to first issue this guidance as soil cleanup criteria (SCC) on an interim basis, and subsequently, formalize these protocols and derived values as soil cleanup standards via rule making procedures.

#### **III.A. Trivalent Chromium**

##### **III.A.1. Cancer Endpoint**

There is none as there is no carcinogenicity assessment available for Cr<sup>+3</sup> on IRIS.

##### **III.A.2. Noncancer Endpoint**

The Department's Site Remediation Program prepared a draft basis and background document which established a residential land use SCC for Cr<sup>+3</sup> of 78,000 mg Cr<sup>+3</sup>/ kg DW soil and a position that Cr<sup>+3</sup> should not be regulated in a nonresidential land use situation (NJDEP, 1995a). The Department employed standard USEPA risk assessment methodology in the derivation of the Cr<sup>+3</sup>



SCC. The exposure pathway examined was incidental soil ingestion with a noncancer endpoint. It is important to note that these SCC are only applicable to insoluble forms of  $\text{Cr}^{+3}$ .

The Department determined that ACD is not a relevant endpoint for  $\text{Cr}^{+3}$  due to the insolubility of  $\text{Cr}^{+3}$  compounds typically found in the environment. The toxicity information used to develop the  $\text{Cr}^{+3}$  SCC is based on an animal study where rats were fed  $\text{Cr}^{+3}$  (Ivankovic and Preussman, 1975). This study indicated that no real adverse health effects were detected even at the highest levels tested. The Department supported the use of NJDEP 1995a as the basis for justifying the 78,000 mg  $\text{Cr}^{+3}$ /kg DW soil as a residential land use SCC for  $\text{Cr}^{+3}$ . It is important to note that this position was entirely consistent with that of the USEPA.

On September 3, 1998 the Department proposed the use of a 78,000 mg  $\text{Cr}^{+6}$ /kg DW soil  $\text{Cr}^{+3}$  SCC. However, incorporation of the USEPA changes to the IRIS database, which came out simultaneously on September 3, 1998, result in a recalculated  $\text{Cr}^{+3}$  SCC of 120,000 mg  $\text{Cr}^{+3}$ /kg DW soil for an ingestion pathway in a residential setting. The Department now proposes to use this 120,000 mg  $\text{Cr}^{+3}$ /kg DW soil value as the  $\text{Cr}^{+3}$  SCC. The Department still chooses to not regulate  $\text{Cr}^{+3}$  under a nonresidential land use scenario. All the constraints of the previous numbers still apply.

### **III.A.3. Ecological Endpoints**

The information available on the potential ecological effects of  $\text{Cr}^{+3}$  is limited. The central issue is whether or not the  $\text{Cr}^{+3}$  is in a form available to ecological receptors. In the Department's opinion,  $\text{Cr}^{+3}$  generally is found in the environment predominantly in an insoluble or complexed form. Therefore, the potential for severe ecological effects is minimized provided the  $\text{Cr}^{+3}$  did not originate specifically from a recent discharge of a soluble  $\text{Cr}^{+3}$  compound. The Department has determined that it will assess the ecological hazard on a case-by-case basis. This has been mandated by Hazardous Discharge Site Remediation Act, N.J.S.A. 58:10B which precludes the development of formal ecological standards until after the Environment Advisory Task Force is constituted and has determined the appropriate way to resolve the ecological concerns.

### **III.A.4. Impact to Ground Water**

The Department intends to assess the potential impact of  $\text{Cr}^{+3}$  on ground water and surface water on a case by case basis. However, to date the Department has not encountered cases involving significant amounts of soluble  $\text{Cr}^{+3}$ . This is partial confirmation of the Department's position that  $\text{Cr}^{+3}$  is found in the environment predominantly in an insoluble or complexed form provided the source isn't a recent discharge of a soluble  $\text{Cr}^{+3}$  compound. Chromium contamination of ground water and surface water is mainly associated with  $\text{Cr}^{+6}$ , which is far more water soluble than  $\text{Cr}^{+3}$ .

## **III.B. Hexavalent Chromium**

### **III.B.1. Cancer Endpoint**

For Cr<sup>+6</sup> relative to a cancer human health endpoint, the critical exposure route is the inhalation pathway. To calculate a cleanup criterion for Cr<sup>+6</sup>, it is necessary to assess the Cr<sup>+6</sup> soil concentrations present. Calculation of a particulate emission rate and a dispersion pattern are next. Finally, the Cr<sup>+6</sup> soil concentration that would be associated with a given risk using standard USEPA cancer dose-response relationships and equations would need to be determined. Currently this is done on a site by site basis as an ARS.

The Department currently provides the guidance that USEPA sanctioned models can be used to predict particulate emissions as well as particulate dispersion. This is as per Public Law 1997, Chapter 278. The selection of given emission and dispersion models is preferably based on a comparison of predicted model results and actual field data as a means of verifying the appropriateness of the selections. The Department has already used this mechanism to approve the use of AP-42 (Cowherd et al. 1989; USEPA 1995a) in combination with the Fugitive Dust Model (USEPA 1991) to generate ARS data at several chromate processing waste sites in Hudson County.

The Department is allowing site-specific information to be used in the models. The considered inputs include particle size distribution, local weather parameters, traffic patterns, lot size, and configuration as well as other factors.

Residential and nonresidential exposure scenarios are being employed where appropriate. These situations are being differentiated via the inputs to the standard USEPA risk assessment equations. Based on analysis by the Department of model outputs, the major difference between these two scenarios is not the human lifetime exposure assumptions, but rather the impact of vehicular traffic. Vehicular traffic when present dominates the emission levels. Consequently, the calculated remediation goals for nonresidential sites are lower than comparable residential sites. Note that the risk level employed in both scenarios is an excess cancer risk of  $1 \times 10^{-6}$  specified by Public Law 1997, Chapter 278.

Once a site-specific number is generated, compliance is determined by comparing the calculated value to the 95<sup>th</sup> % upper confidence limit of the mean of the observations. With respect to the inhalation pathway, the Department is considering moving away from a “bright line” approach. This is in recognition that a single exceedance at a single location should not necessarily require a remedial action for the entire site, particularly when the phenomenon being evaluated is likely derived from an area source and not a point source.

For a nonresidential exposure scenario, the Department proposes to use the logic employed in the above-described ARS to develop a Cr<sup>+6</sup> SCC for a cancer endpoint. The intention is to comply with the requirements of N.J.A.C. 1:30 by employing USEPA approved air models in combination with USEPA exposure assessment equations and USEPA standard assumptions. The Department is currently proposing to use AP-42 as the particulate emissions model and the Industrial Source

Complex – Short Term, Version 3 (ISCST3) as the particulate air dispersion model. The Department's selection of ISCST3 over FDM was influenced by the fact that the defaults for the ISCST3 are already known. In addition, FDM requires much more site-specific data input than ISCST3. Consequently, an ARS can be much more readily determined at much less expense if ISCST3 is used instead of FDM. Furthermore, initial evaluation indicates that this pairing of models produced more protective results than the AP-42/FDM pairing.

To generate a generic nonresidential land use  $\text{Cr}^{+6}$  SCC for a cancer endpoint, the Department intends to input protective assumptions into the models (AP-42 and ISCST3) and calculate a value. Preliminary calculations indicate that such a SCC is 20 mg  $\text{Cr}^{+6}$ /kg DW soil if a site size of 2 acres is presumed. Site size is a major factor impacting the dispersion model. The Department is currently in the process of determining what a reasonable nonresidential site size should be for New Jersey. The Department projects that the site size default value will be 2 acres. Be advised that the larger the site, the less stringent the SCC. The 20 mg  $\text{Cr}^{+6}$ /kg DW soil value also incorporates default values for other parameters, which are specific for New Jersey, as well as USEPA defaults. The fraction of the total amount of particles present represented by respirable particles (particles 10 microns in diameter or less) and the percent silt present are the major factors impacting the emissions model. The USEPA defaults employed for these parameters were taken from AP-42 Compilation of Air Pollution Emission Factors.

For a residential land use scenario, the Department proposes to use the USEPA soil screening value of 270 mg  $\text{Cr}^{+6}$ /kg DW soil. However, the USEPA value was determined using loam soil as a default in the USEPA Soil Screening Level (SSL) equations. The Department is currently evaluating the feasibility of substituting values for a New Jersey soil type for the loam default into the USEPA SSL equations to generate a more New Jersey oriented residential air value. Doing so would still be consistent with USEPA guidance and the requirements of N.J.A.C. 1:30. However, until such time that it is decided to use New Jersey soil data, USEPA defaults will remain in place. It is notable that USEPA personnel have indicated that the USEPA SSL equations are not designed to generate a nonresidential land use value.

While the USEPA on September 3, 1998 modified the IRIS database regarding the toxicity of  $\text{Cr}^{+6}$ , an evaluation by the Department of the new data indicates the September 3, 1998 proposed value of 20 mg  $\text{Cr}^{+6}$ /kg DW soil would still be the most protective for a nonresidential land use scenario. Consequently, the Department is not altering its September 3, 1998 position.

### **III.B.2. Noncancer Endpoint**

#### **III.B.2.A. Ingestion Pathway**

The Department proposes to use the USEPA SSL value for the residential ingestion pathway. This value is 390 mg  $\text{Cr}^{+6}$ /kg DW soil in the May 1996 technical background document (USEPA 1996). However, with the September 3, 1998 change in the IRIS database, this number becomes 240 mg  $\text{Cr}^{+6}$ /kg DW soil. For the nonresidential ingestion pathway, the use of the standard USEPA risk

assessment equations and defaults previously yielded a value of 10,000 mg Cr<sup>+6</sup> /kg DW soil. Using the new IRIS information in combination with these same standard USEPA equations and assumptions yields a Cr<sup>+6</sup> SCC of 6,100 mg Cr<sup>+6</sup>/kg DW soil.

### **III.B.2.B. Dermal Pathway**

The Department recognized the need to develop a procedure that would relate the ACD endpoint to Cr<sup>+6</sup> soil concentrations. This is because soil concentration data are traditionally the type of data generated during remedial investigations and is how all the other soil cleanup criteria are expressed. Consequently, an ARS procedure was developed which allows for the use of site-specific conditions in the development of a site-specific ACD-based Cr<sup>+6</sup> cleanup level. This procedure is considered applicable to all types of Cr<sup>+6</sup> contaminated sites within the State.

The Department intends to utilize an agitated extraction test to reflect, but not duplicate, the assumed exposure scenario. The Department readily admits that ephemeral phenomena such as a puddle or a wet soil are dynamic and complex. Variable in configuration and duration of existence, these systems are complicated by other factors. Disturbance, turbulent flow, diffusion, adsorption, ion exchange, percolation, and evapotranspiration are some of the factors influencing the concentration of dissolved ions present. Certainly, there are no standardized analytical methods currently available that are designed to simulate these events. However, the use of a standard method is desirable in order to assure the availability of the test procedure in commercial laboratories. Therefore, the Department determined that the only viable approach was to obtain a protective measure of the extractability of the hexavalent chromium contaminated material using an approach that employed a standardized method and also reflected, but made no claim to duplicate, the assumed exposure scenario. This would then be used to estimate the hexavalent chromium concentration in soil that would produce the MET.

The Department in consultation with Larry P. Jackson, Ph.D. of Environmental Quality Management developed such an approach based on the concept of soil-water partition coefficients (Kd) which utilizes experimentally derived data from American Society for Testing and Materials Method D3987-85 (Method 3987). Jackson (1998) is the result of this collaboration. Jackson has extensive experience with the validation of Method 3987 and has won numerous awards from the American Society for Testing and Materials for his work with hazardous waste characterization and management including leaching methods and chemistry. He is currently the liaison between American Society for Testing and Materials Committee D34 and the USEPA on this topic and also serves as a consultant to USEPA in this area as well. Jackson believes Method 3987 is suitable for such a use.

The Department proposes to use the results of Method 3987 to generate a Kd relationship; select a specific Kd; and use it to derive a hexavalent chromium cleanup criterion that corresponds to the 25 mg Cr<sup>+6</sup>/l MET. This is of course envisioned initially as a site-specific protocol. Duplicate samples of the highest hexavalent chromium concentration representative of the type of contamination found on a given site would be extracted at 4 different extraction solution to

soil sample ratios. The samples to be extracted will be homogenized, but otherwise unmodified (not screened). This is to directly reflect the particle size structure and soil characteristics present at the site. The proposed ratios would be 4:1, 10:1, 20:1, and 40:1. Replication at each ratio is recommended, but not required. Extraction ratio (LSR) is defined as the ratio of the volume (liters) of extraction liquid or solution to the weight (kilograms) of solid sample to be extracted. The calculated  $K_d$  for each point would be plotted against its corresponding extraction ratio. A best-fit determination would be conducted and the actual type of relationship established. This relationship would then be used to derive the  $K_d$  at an LSR of 2:1 to be used in combination with the 25 mg  $\text{Cr}^{+6}$ /l MET to calculate the ACD criterion. The intent of the Department is to follow the principles utilized by the EPA in developing their SSLs that are also based on soil-water partition concepts.

The question arises whether or not the methodology is protective or not. One aspect of Method 3987 that is conservative is the 18 hour agitation period. Clearly, the 30 rotations per minute for this time period produce more mixing than would normally occur at a site. However, Method 3987 also traditionally calls for the use of a 20:1 LSR. The Department is taking the position that while this ratio maximizes the absolute amount of hexavalent chromium extracted and better reflects equilibrium conditions, the concentration of the extracted ions is artificially decreased to an inappropriate level. Therefore the Department will require the use of a 2:1 LSR. The Department recognizes that in doing so, the assessed situation may not be at equilibrium. The Department is comfortable with this position because the conditions of the assumed exposure scenario are also likely to be non-equilibrium in nature. Again this decision is protective in nature.

Uncertainty regarding the methodology is an issue that needs to be discussed. Jackson (1998) indicates that Method 3987 can be employed in this manner; but that there are increasing concerns about reproducibility as lower LSRs such as 1:1 are used. The use of a range of LSRs (including higher LSRs) to determine the relationship between  $K_d$  and extracted soil concentrations is an effort to minimize this effect. Previously the Department would select the experimental LSR; employ extensive replication to estimate the relationship between the concentration of the extraction solution and the extracted soil concentration; and then back-calculate the soil concentration that would produce the assumed MET. The problem was that the selected LSR was on a portion of the regression subject to potentially the largest variability. By incorporating a range of LSRs, the derived  $K_d$  relationship is much more robust than the relationship (between extraction solution concentration and extracted soil concentration) produced by the Department's previous approach.

Various parties have questioned the selection of the 2:1 LSR by the Department. The initial selection of a 2:1 LSR was in part an evaluation of the results achievable using Method 3987; the theoretical conditions at which free water is available in a soil type; and a risk management decision. The EPA uses values of 2.65 grams per cubic centimeter ( $\text{g}/\text{cm}^3$ ) and 1.5  $\text{g}/\text{cm}^3$  for the typical soil density and bulk density, respectively. Inserting these values into the EPA equation for soil porosity yields a value of 434 milliliters (ml) of pore space per liter of soil.

$$\text{Soil porosity} = 1 - \frac{(\text{bulk density})}{(\text{soil density})}$$

Alternatively if 1,000 cubic centimeters (cm<sup>3</sup>), the equivalent of 1 liter, of this soil were totally saturated, there would be 0.434 liters (l) of water present. Conversely, this would mean that there are typically 566 cubic centimeters (cm<sup>3</sup>) of actual soil present for this specific case. Therefore every 0.434 l of excess water at saturation corresponds to approximately 1.5 kilograms (kg) of soil. This represents an LSR of 2:7, which is much lower than 2:1. Consequently, the 2:1 LSR is a nonconservative assumption, but far less so than 20:1. The 2:1 ratio also represents in the Department's opinion the practical lower limit at which Method 3987 can be conducted for generalized use. Previously, the Department was considering using a 1:1 LSR because laboratory testing of a selection of New Jersey soil types indicated this was the point at which free water would become available. However, to use an LSR of 2:7 or 1:1 would require the utilization of an extrapolated portion of the Kd/LSR relationship prone to very high variability. The Department determined the use of a 2:7 or 1:1 LSR to be inappropriate and "redundantly conservative."

Recognizing there would be continuing objections to the Department's selection of a 2:1 LSR, the Department then sought the opinion of an outside reviewer, who could act as an objective third party, to determine the appropriateness of the selection of a 2:1 LSR. The chosen outside reviewer was Jon Chorover, Ph.D., Assistant Professor of Environmental Soil Chemistry at Penn State University. Chorover (1998) is the result of this effort. Chorover has published in the area of metals behavior and has served as a workshop organizer for the Soil Science Society of America on the topic of transport modeling.

Chorover used Fick's Law to evaluate the assumed exposure scenario. The main parameters examined were water column depth, time, soil porosity, and soil bulk density. After making a number of simplifying assumptions, he established a mechanism for calculating the depth of soil contributing to the diffusive flux. The ratio of water column depth to depth of soil contributing to the diffusion is directly relatable to the LSR issue. Certainly, there are additional factors that are involved and were not considered, such as evapotranspiration, turbulence, configuration, adsorption behavior, multi-directional movement, etc. However, to include all factors would make the analysis too complex. The Department opted to define the situation to a reasonable extent and then establish the equivalent of a protective Tier I screening level. The use of Method 3987 provides this measure of conservatism because of the long duration and nature of the mixing involved with the extraction. Chorover (1998) provides support that it is appropriate for the Department to require Method 3987 be run at an LSR of 2:1. In fact, the use of 2:1 LSR is now considered by the Department to be actually somewhat nonconservative in nature.

If the Department wished to develop a specific statewide ACD-based SCC for Cr<sup>+6</sup>, this could be accomplished through the analysis of laboratory data from a study which simulated a recent spill (having occurred approximately 24 hours prior) of a soluble Cr<sup>+6</sup> solution (sodium dichromate).

Using a native New Jersey sandy soil containing a relatively small amount of organic matter would serve the purpose of making the value more pertinent to the locality as well as being protective. Such a soil would be treated with a  $\text{Cr}^{+6}$  solution and extracted at multiple LSRs using Method 3987. The relationship between  $K_d$  and LSR would then be calculated and used to generate the  $K_d$  at a LSR of 2:1. This  $K_d$  value would then be used to back-calculate the  $\text{Cr}^{+6}$  soil concentration that would generate a 25 mg  $\text{Cr}^{+6}/\text{l}$  solution. By determining the  $\text{Cr}^{+6}$  soil concentration which would produce the equivalent of a 25 mg  $\text{Cr}^{+6}/\text{l}$  solution under fully saturated soil conditions, a SCC could be established. While this has not been formally done, such a calculated ACD-based SCC would be applicable for both residential and nonresidential land use conditions. The initial phases of developing such a criterion have been initiated by the Department with a current scheduled project duration of 6 months barring unforeseen developments.

### **III.B.3. Ecological Endpoints**

The assessment of the ecological impacts of  $\text{Cr}^{+6}$  will be handled on a case by case basis. Again the development of ecological criteria is precluded by Hazardous Discharge Site Remediation Act, N.J.S.A. 58:10B.

### **III.B.4. Impact to Ground Water**

Impact to ground water (and potentially surface water) by  $\text{Cr}^{+6}$  is being assessed by employing one of two options. Both use 100 micrograms of  $\text{Cr}^{+6}$  per liter (ug  $\text{Cr}^{+6}/\text{l}$ ) as a compliance value. This value is derived from the maximum contaminant level allowed in drinking water which is 100 ug Total Cr/l.

The first option is the use of USEPA Method 1312 (Synthetic Precipitation Leaching Procedure) to assess the  $\text{Cr}^{+6}$  availability. This is an agitated extraction method that utilizes unbuffered water at a pH of 4.2 as the extraction solution. The 100 grams of the sample to be evaluated is placed in a container with 2 liters of the extraction solution. The contents of the container are mixed for 18 hours at room temperature. The distribution of the  $\text{Cr}^{+6}$  between the extraction solution and the extracted sample are determined. A site-specific  $K_d$  is then calculated using a soil partitioning equation. This  $K_d$  is then used to back calculate the  $\text{Cr}^{+6}$  concentration in soil that would produce a level of 100 ug  $\text{Cr}^{+6}/\text{l}$ .

The second option is the direct assessment of the ground water through laboratory analysis. Ground water is sampled and analyzed for  $\text{Cr}^{+6}$ . This value is then compare to the appropriate compliance value, which in this case is 100 ug  $\text{Cr}^{+6}/\text{l}$ . Under this second option, there are additional requirements that must be met. First, area of the highest concentration of  $\text{Cr}^{+6}$  contamination must be evaluated. Secondly, the  $\text{Cr}^{+6}$  contamination must be in contact with the ground water.

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## **ATTACHMENT 1: Glossary of Terms and Acronyms**

ACD: Allergic contact dermatitis

AP-42: air model that generates particulate emissions data

ARS: Alternative remediation standard

ASTM Method D3987-85: This is a water extraction procedure that the Department is recommending to determine the solubility of  $\text{Cr}^{+6}$  in a given soil or waste and therefore assess its potential to elicit ACD.

$\text{Cr}^{+3}$ : Trivalent chromium

$\text{Cr}^{+6}$ : Hexavalent chromium

Fick's Law: a law of chemistry and physics: the rate of diffusion of one substance in another is proportional to the negative gradient of the concentration of the first substance

Hexavalent Chromium Analysis: The Department strongly recommends the use of the NJDEP Modified SW846 Methods 3060A and 7196A for the analysis of soil for hexavalent chromium. Where background interference is a problem, the Department uses USEPA Method 218.6 (Ion Chromatography) in place of NJDEP Modified SW846 Method 7196A.

IIPR: Informal interested party review

IRIS: Integrated Risk Information System

ISCST3: Industrial Source Complex – Short Term, Version 3 is an air model that generates particle dispersion data

Kd: solid-liquid partitioning coefficient

LSR: The ratio of the volume of extraction liquid expressed in liters to the weight in kilograms of soil sample being extracted utilizing American Society of Testing and Materials Method D3987-85.

MET: Minimum elicitation threshold

Nonresidential land use scenario: This represents a typical adult worker exposure at an industrial site and involves a 8 hour working day, 250 working days per year over a 25 year period. This scenario is equivalent to the Restricted Use scenario in Public Law 1997, Chapter 278.

Residential land use scenario: This represents a typical child through adult exposure at a single

home location and involves a 24 hour exposure time, 350 days per year over a 30 year period. This scenario is equivalent to the Unrestricted Use scenario in Public Law 1997, Chapter 278.

RP: Responsible party

Site specific risk assessment: Risk assessment as set forth in N.J.S.A. 58:10B-12f(1) pursuant to the USEPA Risk Assessment Guidelines for Superfund, Part B.

SCC: Soil cleanup criteria or criterion

SSL: Soil screening level

Total Cr: Total chromium is the sum of the hexavalent and trivalent chromium forms. Analytically, it is determined by SW846 Methods 3050B and 6010B or the USEPA equivalent Method 200.8

USEPA: United States Environmental Protection Agency

USEPA 1312: An extraction procedure simulating the effects of acid rainfall that is being recommended by the Department to evaluate the potential impact of Cr<sup>+6</sup> on ground water.