

Chromite Ore Processing Residue in Hudson County, New Jersey

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Chromite ore processing residue occurs at over 130 sites in Hudson County, New Jersey. Many of these sites are in urban residential areas. This waste is a result of 70 years of chromate and bichromate chemical manufacturing. At least 15% of the sites contain total chromium concentrations greater than 10,000 mg/kg, with hexavalent content ranging from about 1 to 50%. Continuing leaching of this waste results in yellow-colored surface water runoff and yellow deposits on the soil surface and inside basement walls. The chemistry, environmental fate, health effects, and human exposure potentials for this waste are described.

Introduction

Hudson County is located in northeastern New Jersey on the western shore of the Hudson river opposite New York City. The county has a population of approximately 550,000 and is the most densely populated county in the state. Jersey City is the largest municipality in the county and second largest in the state. With 11 miles of waterfront, the city has a long history as a manufacturing and industrial hub. However, in recent decades changing economic conditions have led to the closing or departure of many industrial facilities, and there has been a steady decline in the city's population. The estimated 1987 per capita income was \$8,605, ranking the city among the poorest in the state.

From 1905 to 1976, Hudson County was a center for chromate and bichromate chemical manufacturing. Two facilities were located in Jersey City and a third in nearby Kearny. Chromite ore was shipped to the county from around the world. The ore, containing 45 to 50% chromium, was mixed with lime and soda ash and heated to convert insoluble trivalent compounds to the more soluble hexavalent form, which was then leached out

with water. The remaining mud was reprocessed a second time before being discarded as processing residue, which contained between 2 and 7% chromium. The chromate production process produced about 1.5 lbs of residue for every pound of chromium product. It is estimated that the total amount of processing residue produced by the three facilities may range between 2 and 3 million tons.

Despite the potential toxicity of the residue, it was disposed of in a wide variety of ways that now pose potential widespread public health and environmental hazards throughout Hudson County. The residue was sold and given away for use as fill material and was widely used in construction at residential, commercial, and industrial sites throughout the county. Other uses of the waste included backfilling of demolition sites, grading for road construction, preparation for building foundations, construction of berms for storage tanks, and filling of wetlands. To date, the New Jersey Department of Environmental Protection has identified over 130 chromium-contaminated sites predominantly in Jersey City.

The environmental impact of the uncontrolled disposal of chromite ore processing residues has been reported for sites in England, Japan, and Baltimore. At a 37-acre site near Bolton, England, it was found that runoff from a chromite ore process residue landfill had adversely affected the biota in the river Croal (1,2). It was also reported that the residue was phytotoxic and highly alkaline.

In Japan, chromate contamination of groundwater and the ground surfaces in populated areas were found, resulting in an investigation of the public health signifi-

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cance of the use of chromite ore processing residue as a construction fill material. Excess dermatitis was reported during the summer months in communities contaminated with the waste (3).

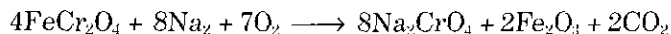
In Baltimore, Maryland, Allied Chemical had used chromite ore processing residue from its chromate production plant as fill in the Baltimore Harbor area. Leachate from the fill was drained to the harbor through storm sewers, disrupting aquatic life at the bottom of the harbor (4).

In November 1988, it was reported that the New Jersey state medical examiner listed chromium toxicity as a contributory cause of death in the case of a man who worked for several years at a truck loading facility built upon chromite ore processing waste (5). This report heightened concerns of health officials and the community about the chromium contamination.

The purpose of this paper is to summarize data showing the concentrations of total chromium at various Hudson County sites and describe the potential for human exposure and adverse effects due to the mobility and environmental fate of chromium.

Chemistry and Environmental Fate

Chromite ore processing residue is an industrial waste material generated by the manufacturing of chromates for chromite ore. Chromium is present in the trivalent state in the ore as chromium iron oxide (FeCr_2O_4). In this state, the chromium is inert and is not soluble in either acid or water. To produce the hexavalent, water-soluble chromate chemicals, the ore is pulverized in a ball mill to less than 100 mesh size, mixed with soda ash and lime, and roasted in rotary kilns at 1100 to 1150°C. The mix does not fuse, but the molten soda ash reacts with the chromite to form water-soluble sodium chromate. The reaction for this process can be generalized as follows:



The lime reacts with the aluminum, which is present in the ore at a concentration of about 13% and keeps it from dissolving when the roast is leached. A counter-current leach process is employed. The liquor released from the leach process is a deep yellow solution, saturated with sodium chromate. The sodium chromate is converted by acidification and crystallization into the desired product of the process, crystalline sodium dichromate. The solid material remaining following leaching is the chromate ore processing residue (6).

Chromite ore processing residue presents a serious environmental problem when improperly disposed of in that it continues to leach chromate salts for decades even though it has previously been subjected to efficient leaching methods. Slowly solubilizing chromate compounds are generally present in the residue at concentrations of between 0.7 to 5.0% (7). The fact that these residues continue to leach soluble chromium salts even

after efficient leaching and decades of weathering is attributed to the fact that the residue contains a variety of chromium salts that are very slowly soluble in water. Chief among these is calcium chromate (2,7). Other chromium compounds found in the ore include calcium aluminochromate ($3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCrO}_4$), tribasic calcium chromate [$\text{Ca}_3(\text{CrO}_4)_2$], and basic ferric chromate [$\text{Fe}(\text{OH})\text{CrO}_4$] (7).

The vertical distribution of concentrations of chromium at fill sites is in flux due to the presence of slowly solubilizing chromate salts. The upward mobility of these salts via capillary rise produces surface chromium concentrations that vary with changing meteorological conditions. Due to this phenomenon, concentrations in the uppermost centimeter of surface soil can vary over time from parts per million levels to percent levels that are many times greater than the concentration in the soil/fill column (New Jersey Department of Environmental Protection, personal communication). This surface enrichment is of great significance because it is surface concentrations that are used in computing exposure potential. Figure 1 shows a contaminated site with the typical "chromate bloom." Horizontal migration of the chromium results in similar blooms on the inside of basement walls. Scrappings from walls of a firehouse and hardware store were found to contain 37,000 (8) and 2,000 mg/kg chrome (9), respectively. Drainage ditches in areas of the contamination often contain bright yellow water, indicating surface water contamination. Groundwater has been found to contain 30 mg/L (10). The chromate salts tend to concentrate in the uppermost centimeter of surface soil, and this layer actually represents the interval subject to resuspension processes and direct contact. Thus, it is necessary to take great care when sampling soils for the purpose of exposure assessment.

Health Effects of Chromium

Chromium is an essential trace element with a role in glucose metabolism. In addition to dietary sources, chromium is also available in mineral supplements. Chromium deficiency has been reported only in rare cases during intravenous feeding (11).

Acute toxicity of chromium compounds from industrial accidents or deliberate ingestion can result in gastrointestinal symptoms and bleeding. A late toxic effect may be liver or kidney failure, the latter necessitating dialysis. Treatment for acute toxic exposures to chromium is mainly supportive (12).

Hexavalent chromium is corrosive, allergenic, and mutagenic, while the trivalent form has much less capacity for damaging effects. Occupational experience attributes adverse outcomes mainly to hexavalent compounds.

Adverse health effects resulting from chronic occupational exposure to chromium have been known since the nineteenth century. Chromium compounds were found to cause damage to skin and mucosal surfaces



FIGURE 1. Chromite ore processing residue waste site number 2, November 21, 1989. Yellow "chromate blooms" appear at the most heavily contaminated sites. They are most likely to be observed during the dry weather a few days after a rain.

with adverse outcomes including chrome ulcers, irritant and allergic dermatitis, and perforation of the nasal septum (13). Chrome ulcers and septum perforation appear to be specific for chromium exposure.

Epidemiological studies subsequently identified an increased risk for lung cancer among working cohorts with exposure to chromium. The risk, identified for industries such as chromate production, pigment manufacturing, and electroplating, was associated with exposure to hexavalent chromium. Early studies suggested relative risks as high as 80 for chromate workers, although improved industrial hygiene reduced this risk for later cohorts (14).

Exposure Potential

Figures 2 and 3 show the location of the chromite ore processing waste sites in Jersey City and Kearny. Many of these sites are located in densely populated residential areas, active industrial or commercial sites, and on pub-

lic lands. Table 1 shows a summary of data listing soil concentrations of total chromium for most sites. These data were collected as part of a New Jersey Department of Environmental Protection (NJDEP) investigation. Chromium levels in the soil at the sites have been reported as high as 53,000 ppm (15).

Chromium contamination has been found to be widespread in soil, surface water, sediments, and groundwater. It has also been found on paved and unpaved surfaces at the sites and on the floors and walls of buildings. In the case of one school near several uncontrolled sites, chromium was found to be detectable in the ventilation system and in carpets throughout the school. During dry periods, yellow crystals can be observed on the surface of some sites, and there is clearly a potential for airborne transport and tracking of the material indoors.

The large number and diversity of the Hudson County chromium waste sites presents a perhaps unprecedented complex web of exposure pathways that may challenge the limits of current exposure assessment technology.

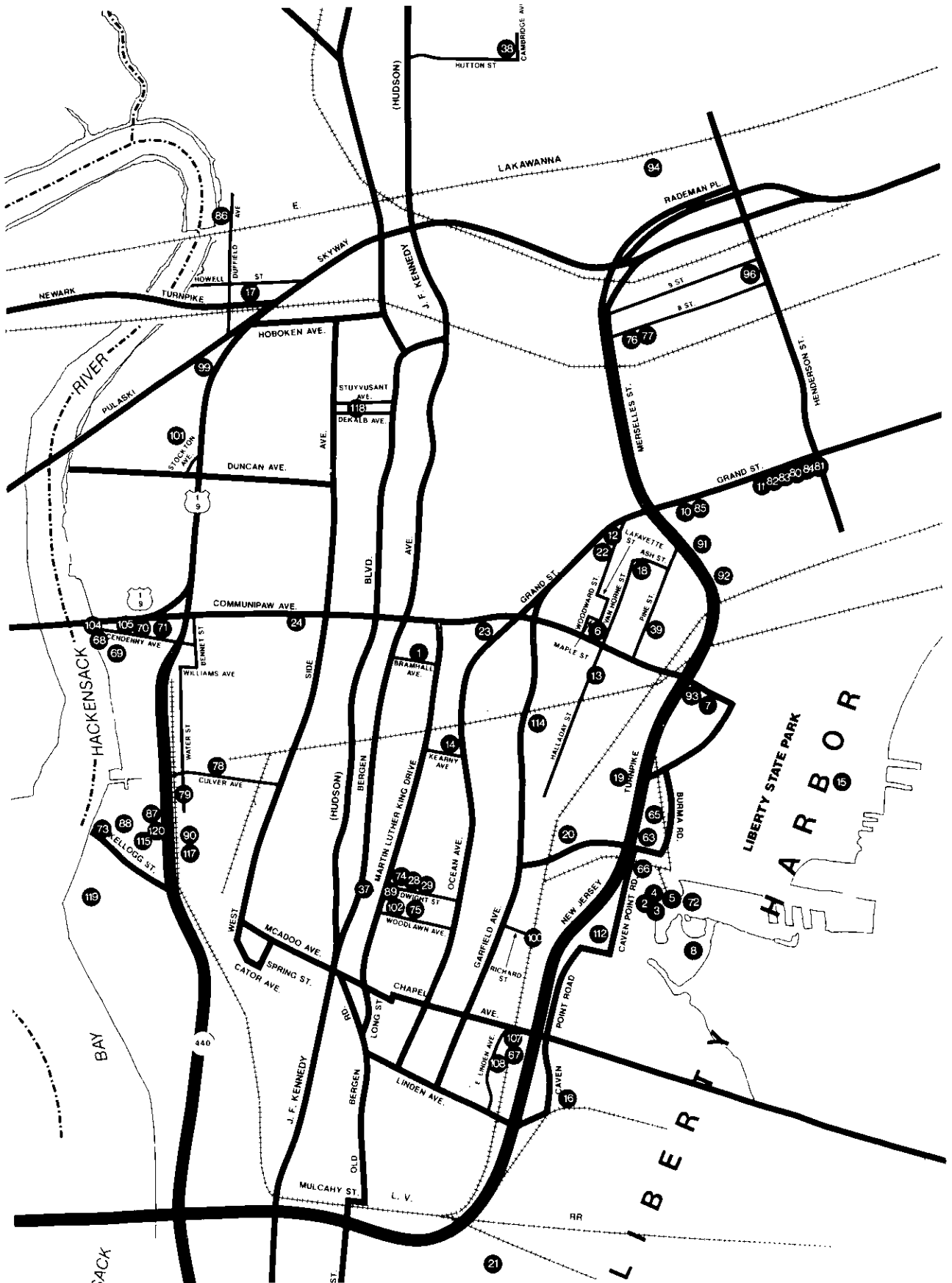


FIGURE 2. Chromite ore processing residue waste sites, Jersey City, New Jersey.

CHROMIUM SOIL CONTAMINATION

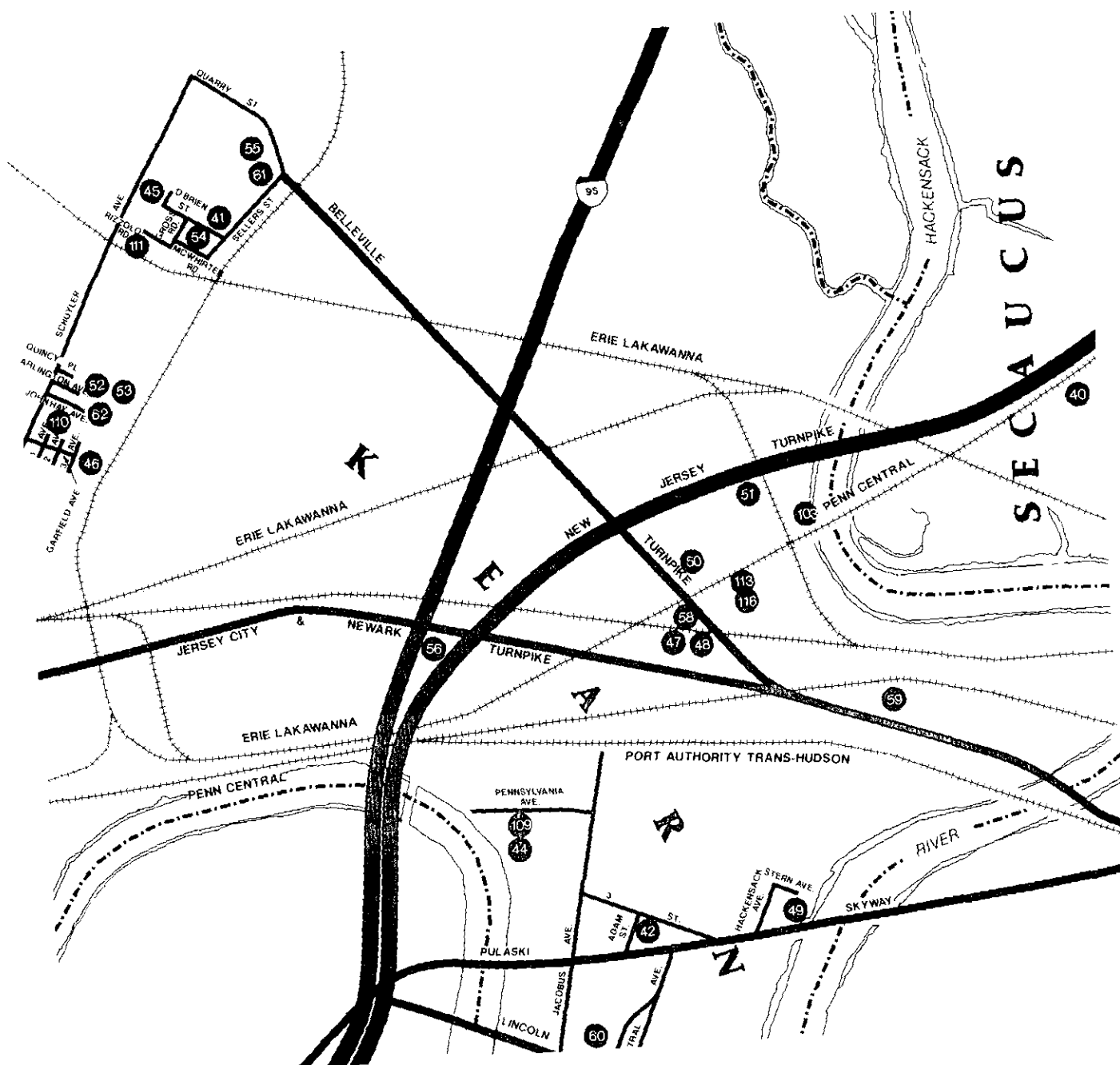


FIGURE 3. Chromite ore processing residue waste sites, Kearny and Secaucus, New Jersey.

Potential pathways of exposure include inhalation of suspended particles; direct contact with contaminated soil, water, or contaminated surfaces and consumption of contaminated food; and ingestion of inspirable particles. Drinking water, however, is supplied from uncontaminated sources. Behavioral variables would largely determine the relative importance of the various routes of exposure.

Potentially exposed populations include those living in or near contaminated residential sites; workers at contaminated industrial or commercial sites; residents

near industrial sites; and those living, working, or playing on contaminated public lands. Analytical methods for biological monitoring for exposure to chromium can be applied to blood and blood components, urine, body tissues, and hair; testing is done mainly on blood and urine.

The New Jersey Department of Health (NJDOH) conducted an evaluation of children and adults with possible exposure to chromium from contaminated fill dirt used in a residential area. School-age children living in zones closest to the known chromium-contami-

Table 1. Site numbers and range of total chromium in soil.^a

Chromium range, mg/kg	Site numbers
100–5,000	7, 8, 10, 12, 21, 22, 23, 24, 28, 29, 40, 46, 47, 48, 49, 53, 55, 56, 58, 61, 62, 63, 65, 67, 69, 70, 74, 83, 84, 85, 86, 89, 94, 103, 108
5,001–10,000	1, 2, 3, 5, 11, 14, 15, 16, 20, 37, 42, 45, 52, 54, 59, 60, 66, 73, 101, 104, 105, 107, 110
10,001–15,000	13, 18, 19, 38, 41, 50, 80, 81, 82, 90, 102
15,001–20,000	6, 17, 39, 51, 68
20,001–25,000	112, 119
25,001–30,000	96, 117
30,001–55,000	113, 115

^aThere are no soil data for sites 4, 44, 71, 72, 75, 76, 77, 78, 79, 87, 88, 91, 92, 93, 99, 100, 109, 111, 114, 116, 118, and 120. Hexavalent content ranges from about 1 to 50% of total chromium.

nated sites were more likely to have urine chromium levels above the selected detection limit than children living in zones more distant from known contamination. There were no significant age or gender differences, although girls were less likely than boys to have detectable urine chromium levels. Adults did not demonstrate this site-related pattern. An outdoor exposure to chromium through ingestion or inhalation was postulated (16).

In order to identify workplaces where chromium contamination is present and to evaluate the potential for exposure, the NJDOH has conducted preliminary workplace surveys to determine the presence of chromium contamination. The preliminary workplace surveys included a walkthrough of the facility and bulk sampling to identify total and hexavalent chromium. Table 2 shows data from some workplaces where the highest interior concentrations of hexavalent and total chromium were found. In most cases the interior chromium

appeared as yellow crystals at the base of walls and cracks in the floor. In some cases the extremely high ratio of hexavalent to total chromium may be the result of surface enrichment of the more soluble hexavalent form. To date, preliminary evaluations have been conducted at 79 workplaces. The workplaces with chromium contamination have been contacted to notify them of results and to take appropriate control measures. The survey will be used to prioritize the sites for remedial measures and further industrial hygiene investigations.

The clearly defined human health effects of chromium, combined with the extensive potential for population exposure, underscore the need for a thorough and systematic evaluation of health risks in Hudson County. This assessment must include ambient, residential, and workplace exposures in order to guide appropriate remedial actions.

The costs of clean up and containment of the waste have been estimated in the billion dollar range. This estimate does not include any long-term health surveillance for the community, nor does it address the potential need for remediation of contaminated residences and workplaces. The NJDEP has taken a two-phase approach to remediation. The first phase is to conduct interim remedial measures that involve covering, fencing, and otherwise restricting access to contaminated sites. This eliminates direct contact and substantially but temporarily reduces migration of chromium contamination. The next phase is permanent remediation, which for many of the smaller sites involves excavation and removal. Innovation treatment technologies are being studied for application at the larger sites.

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Table 2. Chromium concentrations in soil and inside buildings.

Site number	Total chromium in soil, mg/kg	Interior total chromium, mg/kg	Interior hexavalent chromium, mg/kg
2	8400	2730	3860 ^a
5	5800	49	7
16	7900	77	1
53		415	3
55	2340	2560	20
58	4747	9810	8670
107	5468	4666	4870
108	103	89	1
114		96	3

^a Although it is not plausible to have more hexavalent chromium than total chromium, this discrepancy is possibly due to the precision of the analysis.

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